Indo – German Energy Program
Energy Transition with Discoms

Model IT & OT Implementation Roadmap for Indian Discoms

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Consulting Partners

Accenture Solutions Private Limited

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List of Abbreviations

Abbreviation	Full Form
AMI	Advance Metering Infrastructure
ANSI	American National Standards Institute
AI/ML	Artificial Intelligence & Machine Learning
API	Application Programming Interface
AT&C	Aggregate Transmission and Commercial
BPL	Broadband Over Power Line
BRPL	BSES Rajdhani Power Limited
CAST	Clean, Augment, Shape, Transform
CEA	Central Electricity Authority
CIM	Common Information Model
CIS	Centre for Internet Security
CIS	Customer Information System
CRM	Customer Relationship Management
CSC	Critical Security Controls
CSF	Cyber Security Framework
DA	Distribution Automation
DCU	Data Concentrator Unit
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DISCOM	Distribution Company
DMS	Distribution Management System
DR	Demand Response
DSS	Decision Support System
DT	Distribution Transformer
EAS	Extended Analytical services
ETL	Extract Transform & Load
EU	European Union
EHV	Extra High Voltage
EISA	European and Information Security Agency
EMS	Energy Management System
ERP	Enterprise Resource Planning
EV	Electric Vehicle
GEP	Gateway Access Protocol
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GOI	Government of India
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
GUI	Graphical User Interface
HAN	Home Area Network
HES	Head End System

Abbreviation	Full Form
HQ	Headquarter
HV	High Voltage
HVDS	High Voltage Distribution System
ICS	Industrial Control System
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Devices
IEEE	Institute of Electrical and Electronics Engineers
IIoT	Industrial Internet of Things
IOT	Internet Of Things
IT	Internet Protocol
IPDS	Integrated Power Development Scheme
IR sensors	Infrared Sensors
IS	Indian Standard
ISA	International Society of Automation
ISO	International Organization of Standardization
IT	Information Technology
JDBC	Java Database Connectivity
LBS	Load Breaker Switch
LDAP	Light Weight Directory Access Protocol
LT	Low Tension
MBP	Model Businesses Practices
MDAS	Meter Data Acquisition System
MDMS	Meter Data Management System
MFA	Multifactor Authenticator
MIS	Management Information System
MNRE	Ministry of New & Renewable Energy
NAESB	North American Energy Standard Bord
NIC	Network Interface Card
NIST	National Institute of Standards and Technology
NSGM	National Smart Grid Mission
ODBC	Oracle Database Connectivity
O&M	Operation & Maintenance
OEM	Original Equipment Manufacturer
OLEDB	Object Linked Embedded Database
OMS	Outage Management System
OPC	Open Platform Communication
OT	Operational Technology
PERA	Purdue Enterprise Reference Architecture
PLC	Programmable Logic Controller
PLC	Power Line Communication
PV	Photovoltaic

Abbreviation	Full Form
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RDSS	Revamped Distribution Sector Scheme
RE	Renewable Energy
RFID	Radio Frequency Identification
RMU	Ring Main Unit
RT-DAS	Real Time Data Acquisition System
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
TCP	Transport Layer Protocol
UAT	User Acceptance Testing
UHBVNL	Uttar Haryana Bijli Vitran Nigam Limited

Executive summary

While power distribution systems have been adopting automation, control and IT services since a few decades, the solutions were limited to substation and mainlines. In more recent years, the pace and scope of the digitalization of the power systems have grown due to the confluence of favourable market developments and technology advancements. Increased focus on digital solutions provides a large opportunity for the Indian distribution sector to adopt various technologies, systems, and applications to approach current business problems including their financial and operational effectiveness. While IT solutions can help to automate business functions such as billing, accounting and customer service, OT solutions can help in making operations more efficient through distribution management and outage management.

To leverage these benefits provided by different IT and OT systems, Indian DISCOMs are implementing various digital solutions that have been enabled by strong policy thrust including multiple power sector schemes and reforms. However, there is still significant ground to cover in terms of adoption of these IT and OT systems.

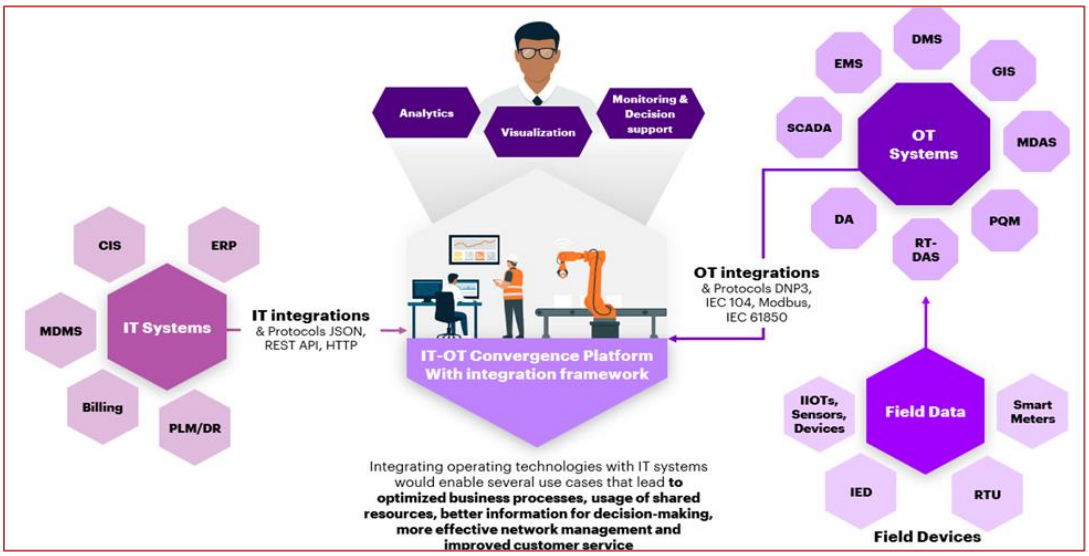
Moreover, the limited solutions implemented till date have been implemented in silos, without considering the possibility of their integration with other existing or near future system additions. Given the IT and OT systems are deployed by different vendors, the systems are often incompatible and additional interventions are required to integrate the same. Other challenges include integration challenges with the existing legacy systems, consideration of cybersecurity issues and lack of availability of standards for IT-OT integration regarding data exchange, interoperability, security, communication & networking, etc.

To accelerate a DISCOM's digital transformation journey, deployment of IT-OT solutions and their subsequent integration will be a key enabler. Thus, there is a need to understand the possible solutions and potential roadmap for undertaking a DISCOM's digitalization journey and the incremental value that IT & OT convergence can add.

Several digital solution platforms, including IT-OT integration solution platforms, be it vendor specific or open-source solutions, are available throughout the world to help distribution utilities to accelerate the convergence of IT and OT systems. However, India's distribution utilities are still behind the curve in this area for the following reasons – (i) inadequate field infrastructure, such as sensors and smart meters, (ii) implementation and operation of IT and OT systems in silos, (iii) lack of specific regulatory standards & guidelines for digitalization, system integration & cybersecurity, (iv) lack of awareness on the potential benefits among Indian DISCOMs, and (v) cost intensive.

Recognizing the value that deployment of IT-OT solutions can add in accelerating their digitalization journey, Indian DISCOMs are emphasizing the adoption of IT-OT integration solutions/ platforms to deliver excellence and gain better margins. Therefore, an implementation roadmap, emphasizing the methodology to identify use cases, select a suite of appropriate IT and OT systems, defining the integration strategy and operationalize the use cases is the need of the hour.

Figure 1 : IT-OT landscape



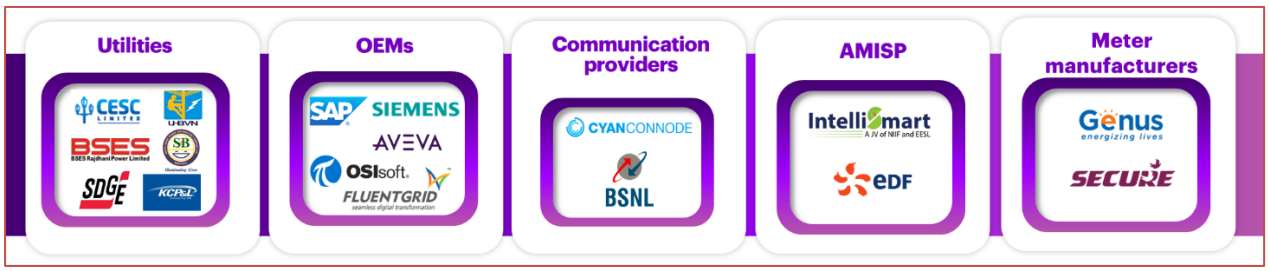
With this background, this report aims to understand the following:

1. Digitalization in the Indian power distribution sector
2. Key learnings from Indian DISCOMs and international DSOs on their digitalization journey
3. Impact of IT OT convergence and the available integration solutions
4. Roadmap for DISCOM digitalization journey through IT-OT implementation

The following approach was followed to gain insights into the above-mentioned areas:

- Primary interactions with the relevant stakeholders[1]:
  - Accenture experts with on-ground experience with Indian and global utilities
  - IT-OT ecosystem (under digitalization programs) players such as Indian and international utilities, OEMs and communication providers

Figure 2 : Stakeholder interactions



- Secondary research through publicly available documents and websites
  - Standard documents released by renowned Indian and global standard bodies
  - Official websites of Indian Discoms/ International DSOs
  - Whitepapers, brochures and publicly available documents from OEMs

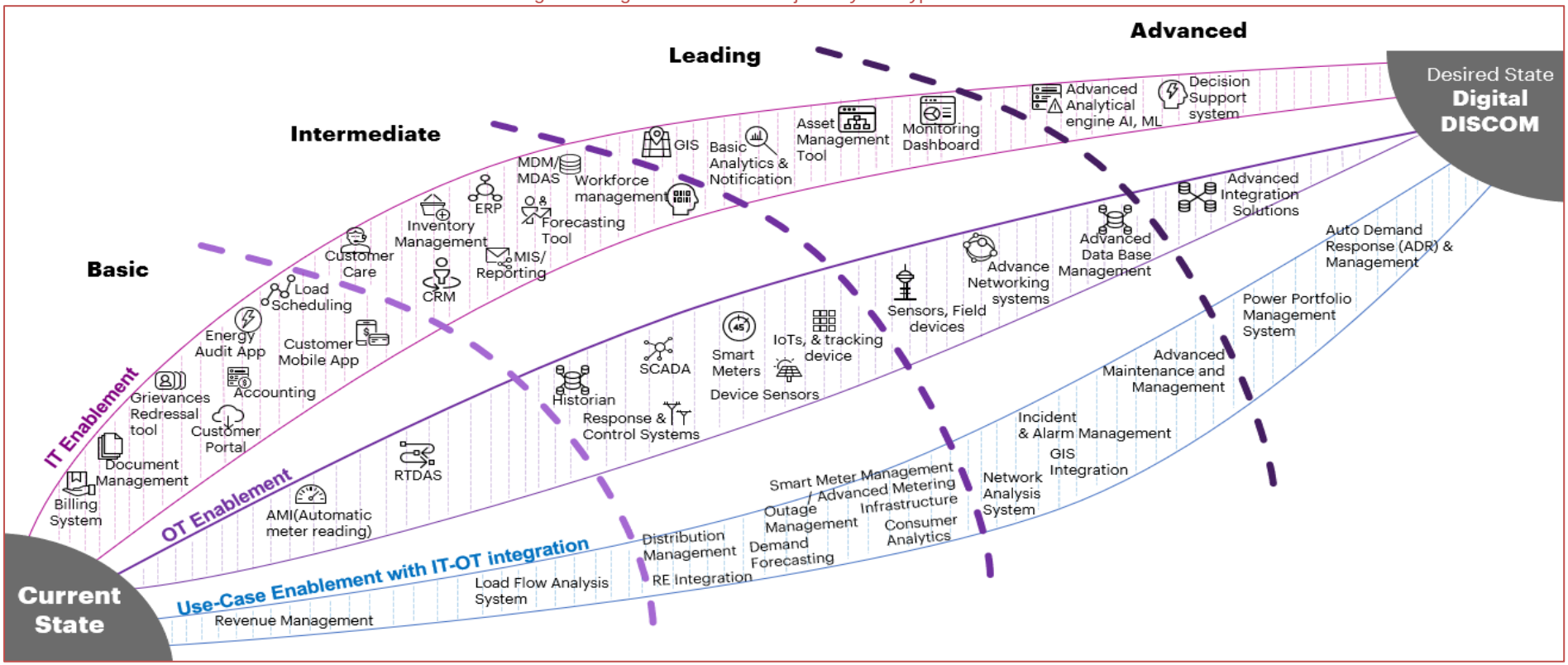
Through this study, it was inferred that parametric analysis of the integration solutions is critical and various parameters need to be analysed before selection of any solution. Apart from the technical and functional parameters,

[1] A broad questionnaire (*Annexure 1*) was developed, which was used to guide the discussion with the OEMs & various DISCOMs. Extensive discussions were carried out to understand different aspects of DISCOMs' digitalization programs and IT-OT solutions including their benefits and limitations.

the utility needs to consider specific use cases or sub-solutions that are to be enabled or strengthened on priority for mitigating specific business challenges, be it vendor specific or open-source solutions.

Even though significant vendor specific solutions and open standard solutions are accessible internationally, it is important for the DISCOMs to analyse their own techno-functional maturity, based on the existing level of digitalization, IT-OT applications and enabled use-cases. Additionally, it is critical that the DISCOM defines the desired objectives before selecting a solution or product suite and beginning. Based on this, each DISCOM must embark on a customized journey to become an advanced, digitally enabled and data driven DISCOM. The below figure provides a snapshot of the different stages of the digital transformation journey of a DISCOM.

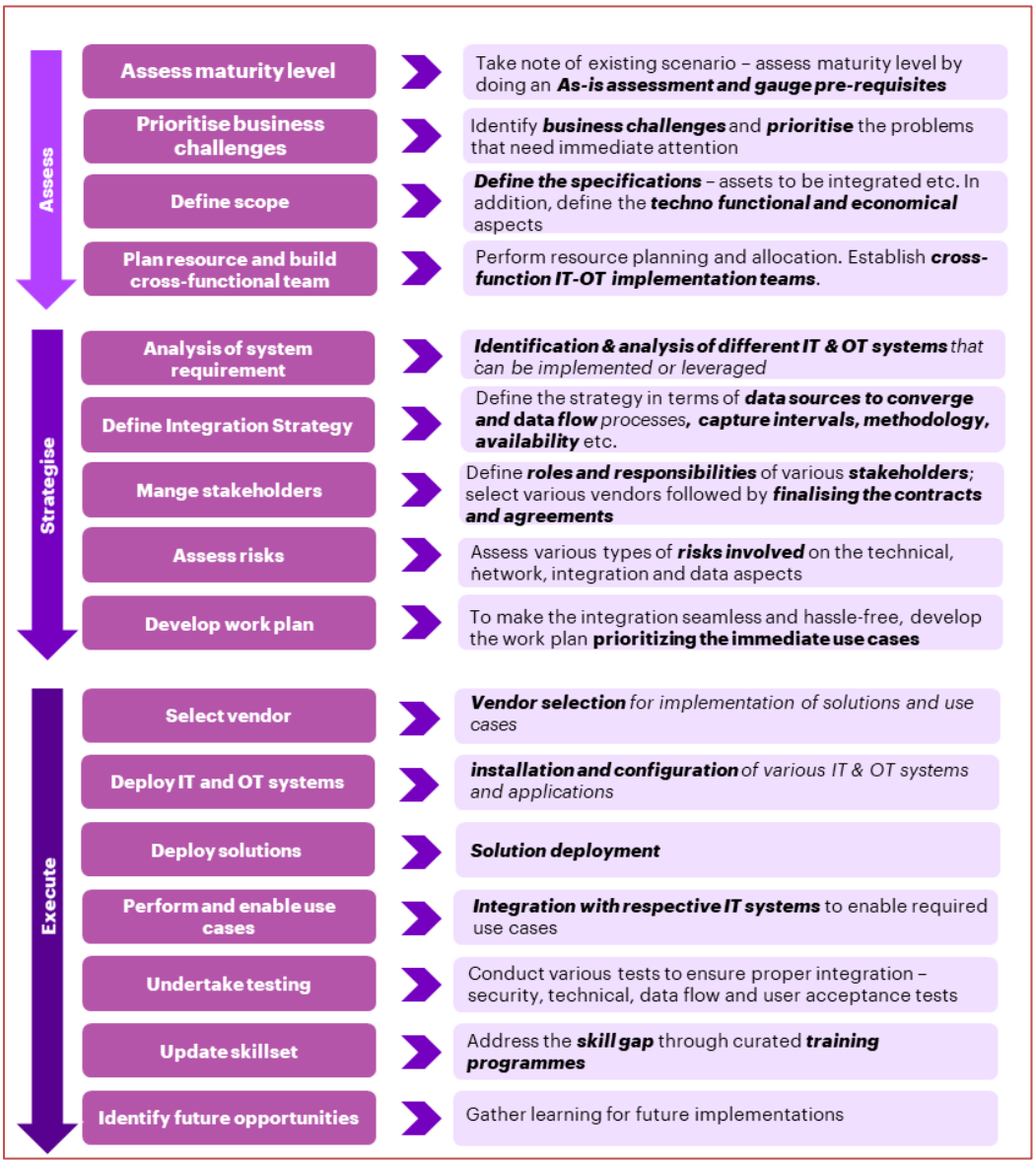
Figure 3: Digital transformation journey of a typical DISCOM



The implementation approach recommended for the DISCOMs to embark on their digitalization journey can be divided into three broad phases as illustrated below:

i. **Assess**: This phase deals with the identification of the maturity level and business challenges based on which the scope is defined, and the resources are planned.
ii. **Strategize**: This phase entails defining the integration strategy. The DISCOM defines role and responsibilities of different stakeholders, undertakes a risk assessment, and develops the work plan.
iii. **Execute:** This phase involves vendor selection, solution deployment, use case enablement and testing. The DISCOM will also need to continuously undertake training programmes to bridge skill gaps. Documenting key learnings from each of the activities and identification of upgradations will be required for enabling future use cases.

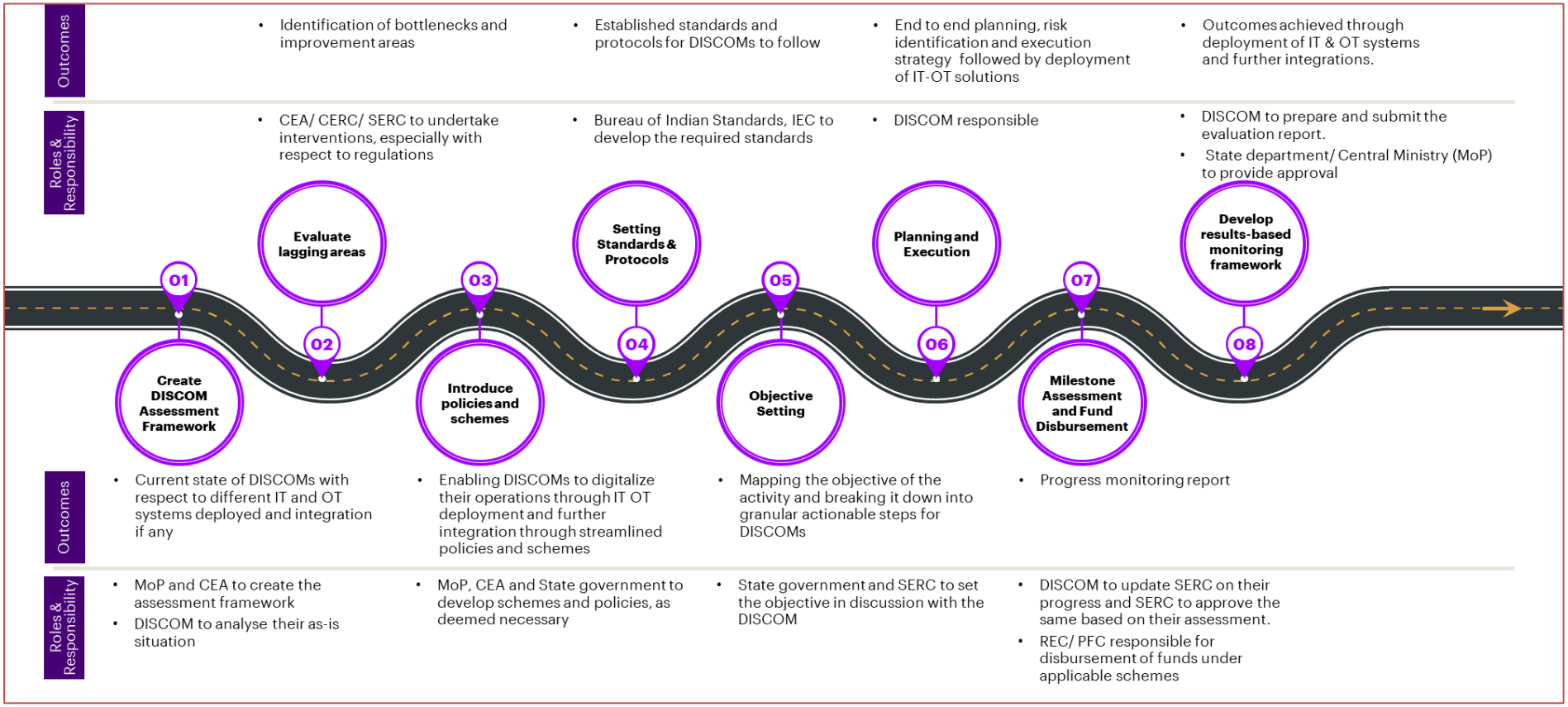
Figure 4: Implementation approach of digitalization journey on IT & OT landscape



Deploying various digital solutions is a complex process where the relevant stakeholders across the organization need to come forward, recognize the need for transformation and collectively address the business needs by learning new behaviours, skills, and ways of working. Thus, a structured change management approach becomes very critical for all

DISCOMs, to ensure a smooth transition while mitigating disruption in the systems and processes. This includes preparing the necessary steps for change, monitoring pre- and post-change activities, anticipating challenges, and supporting employees to ensure successful implementation.
As important it is for the DISCOMs to strategize their own IT & OT system implementation & integration journey as part of digitalization program, it is also imperative that the policymakers drive the programme at a sectoral level. This is important for creating an urgency and make the necessary tools available for the DISCOMs to embark on the journey. We recommend the following phases as part of the national roadmap for enabling digitalization, with focus on IT-OT integration, for Indian DISCOMs:

Figure 5 : Implementation roadmap for Indian distribution sector to undertake digital transformation journey

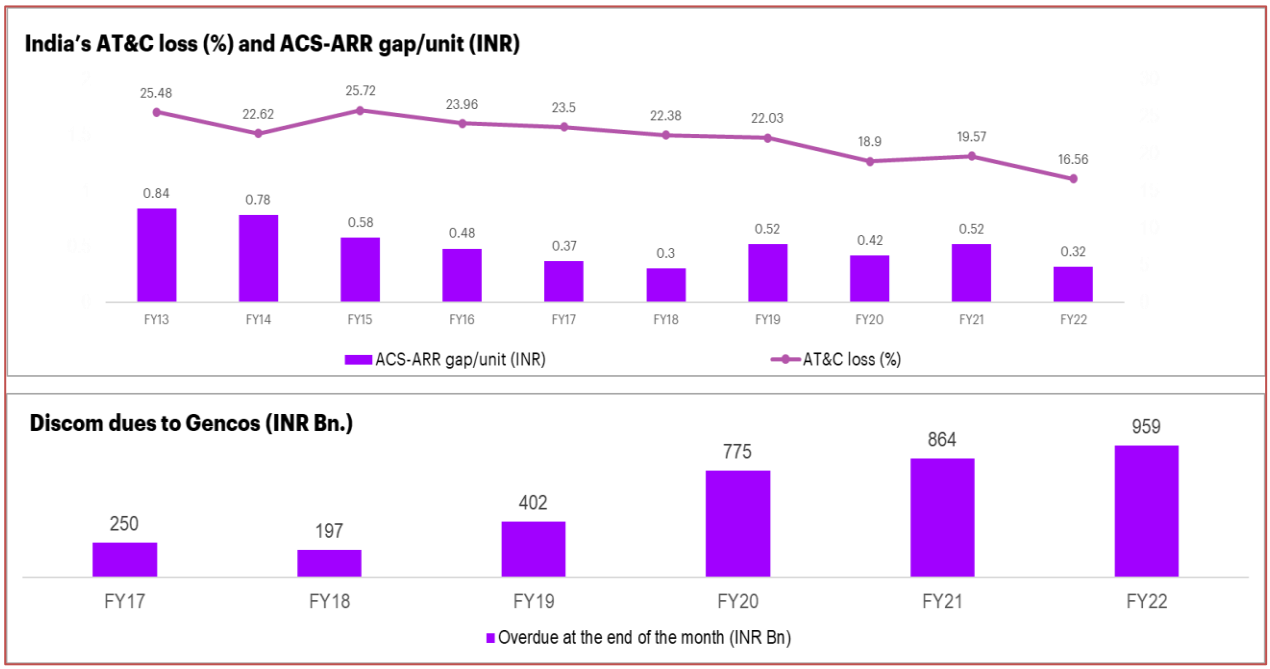


1. Context setting

The power distribution sector is one of the most important links in the entire Indian power sector value chain. It acts as an interface between the generation companies and the consumers. Comprising of 78 distribution companies (DISCOMs), presently the distribution sector in India is dominated by mostly state-owned utilities.

Over the past few years, the power distribution sector has witnessed major developments (including provision of universal access to electricity) but continues to face some major challenges. DISCOMs are in a turmoil in terms of financial and operational sustainability as they face high AT&C losses, high ACS-ARR gap and poor peak demand management along with an increased pressure to be profitable while complying with GoI's schemes and programmes. Based on the statistics, the AT&C losses stood at 16.56% and the gap between ACS-ARR was at INR 0.32 per unit at the end of FY 22. Additionally, the total outstanding dues of DISCOMs payable to generators crossed INR 959 billion (end of April 2022). Some recent trends are depicted in the graph below:

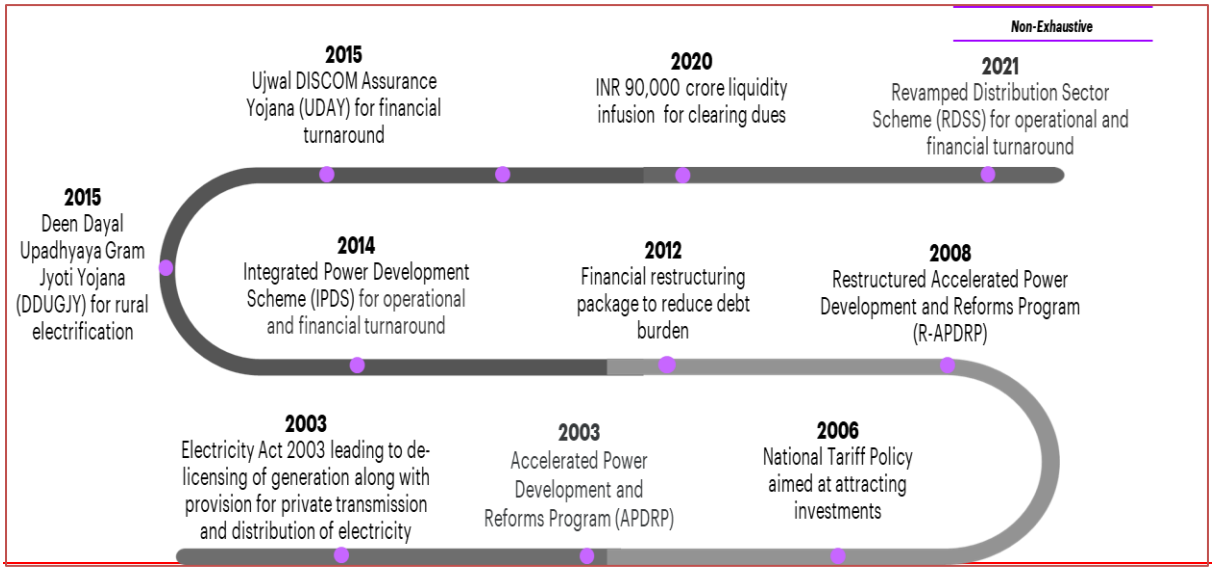
Figure 6: Trends in the Indian Distribution Sector



Source: Praapti portal, PFC Report

Looking at the distressed state, the Government of India has been aiding states through various Central Sector/ centrally sponsored schemes for improving the condition of the distribution sector. The primary goal of these schemes is to restructure and reform distribution sector to improve operational efficiency, reduce AT&C loss and reduce the ACS & ARR gap. The key reforms introduced by the Government over the years have been summarised in the below figure:

Figure 7: Summary of Government schemes and reform measures



Objectives of few selected key schemes are defined below:

- **Restructured Accelerated Power Development and Reforms Programme (R-APDRP)**: Launched in 2008 with aim to establish baseline data, strengthen IT applications for energy accounting/auditing, IT based consumer service centres along with regular distribution strengthening projects
- **Integrated Power Development Scheme (IPDS):** Launched in 2014 to strengthen sub-transmission, distribution network and metering in the urban areas. The component of IT enablement and strengthening of distribution network of R-APDRP was subsumed in this scheme
- **Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY):** Launched in 2014 as a flagship program to achieve complete rural electrification
- **Ujwal DISCOM Assurance Yojana (UDAY):** Launched in 2015 envisaging financial turnaround, operational improvement, reduction of cost of generation of power, development of renewable energy and improved energy efficiency and conservation
- **Revamped Distribution Sector Scheme (RDSS):** Launched in 2021 with an aim to improve the operational efficiencies and financial sustainability of all DISCOMs/ Power Departments by providing conditional financial assistance to DISCOMs for strengthening of supply infrastructure. IPDS and DDUGJY were subsumed under this scheme. The RDSS scheme, with an outlay of INR 3,03,758 Crore over 5 years (FY 2021-22 to FY 2025-26) aims to achieve the following objectives:
  - Reduction of AT&C losses to pan-India levels of 12-15% by 2024-25
  - Reduction of ACS-ARR gap to zero by 2024-25
  - Improvement in the quality, reliability, and affordability of power supply to consumers through a financially sustainable and operationally efficient distribution sector

  These objectives are set to be met through the following two components of the scheme:
  - Part A – Financial support for prepaid smart metering & system metering and up-gradation of the distribution infrastructure
  - Part B – Training & capacity building and other enabling & supporting activities

  A key focus of this scheme will be wide adoption of smart meters across the country and help meet the ambitious target of 250 million smart meter installation by 2025.

It is evident that the Government is dedicated to improving the financial and operational efficiency of DISCOMs through multiple schemes. While improving financial status includes reducing transmission and distribution losses and elimination of cost-revenue gap, the operational side focuses on improving infrastructure & digitalization via initiatives like installation of smart meters and feeder metering to enhance collection efficiency and transparency. In an effort to recognise and promote digitization in DISCOMs, the RDSS scheme aims at scaling up smart meter implementation and targets to install 250 million smart meters by 2025. Most recently in April 2022, the Government cleared proposals worth INR 1.62 lakh crore from 13 states under RDSS for smart metering and for infrastructure upgradation toward loss reduction efforts.

As more ground devices are installed in the system, more quantum of data is generated, thereby presenting a larger opportunity to use this data to make more informed decisions. This data can help in delivering many smart solutions such as customer segmentation, energy accounting and management, better load forecasting, power procurement planning, predictive maintenance of critical assets, etc. Thus, digitalization, through adoption of the right technologies, can play a pivotal role in addressing most of the current woes by improving productivity and efficiency and thereby transforming them from debt-ridden entities to financially stable and consumer serving entities. Given this potential, GoI is undertaking major initiatives to digitalize the Indian power distribution sector.

Currently different Indian DISCOMs are at different levels of technological maturity, as they implement only select IT and OT systems based on their requirements and available resources. Deployment and integration of these systems has the potential to mitigate most of the operational challenges faced by the DISCOMs via diverse use case enablement.

With this background, this report aims to provide an overview of the digitalization journey for Indian DISCOMs with a focus on various IT & OT system implementation & further integrations. The report classifies the Indian DISCOMs based on their techno-functional maturity level and aims to help them prioritize the digitalization initiatives based on their current maturity level, business challenges & desired objectives. Finally, based on the analysis of the as-is Indian IT-OT landscape and learnings from other international DSOs, the report presents a strategic roadmap for the overall digital transformation of Indian DISCOMs through IT & OT system enablement and integration along with the various components of change management that each DISCOM should undertake.

2. Digitalization of Indian power distribution sector

Power distribution systems have been adopting automation, control and IT services since the beginning of the digital era in the late eighties. However, the scope of work was mostly limited to substations and mainlines because of the focus on engineering economics and reliability considerations.

In more recent years, the pace and scope of the digitalization of the power systems have grown due to the confluence of favourable market developments and technology advancements. On one hand, demand and supply characteristics are changing, becoming more dynamic and uncertain, which in turn necessitates faster and better situational awareness, analytics, and controls. On the other hand, technology advancements on both sides of the electric meter are making it possible to add new digital technologies and integrate them into the ever-evolving utility automation systems.

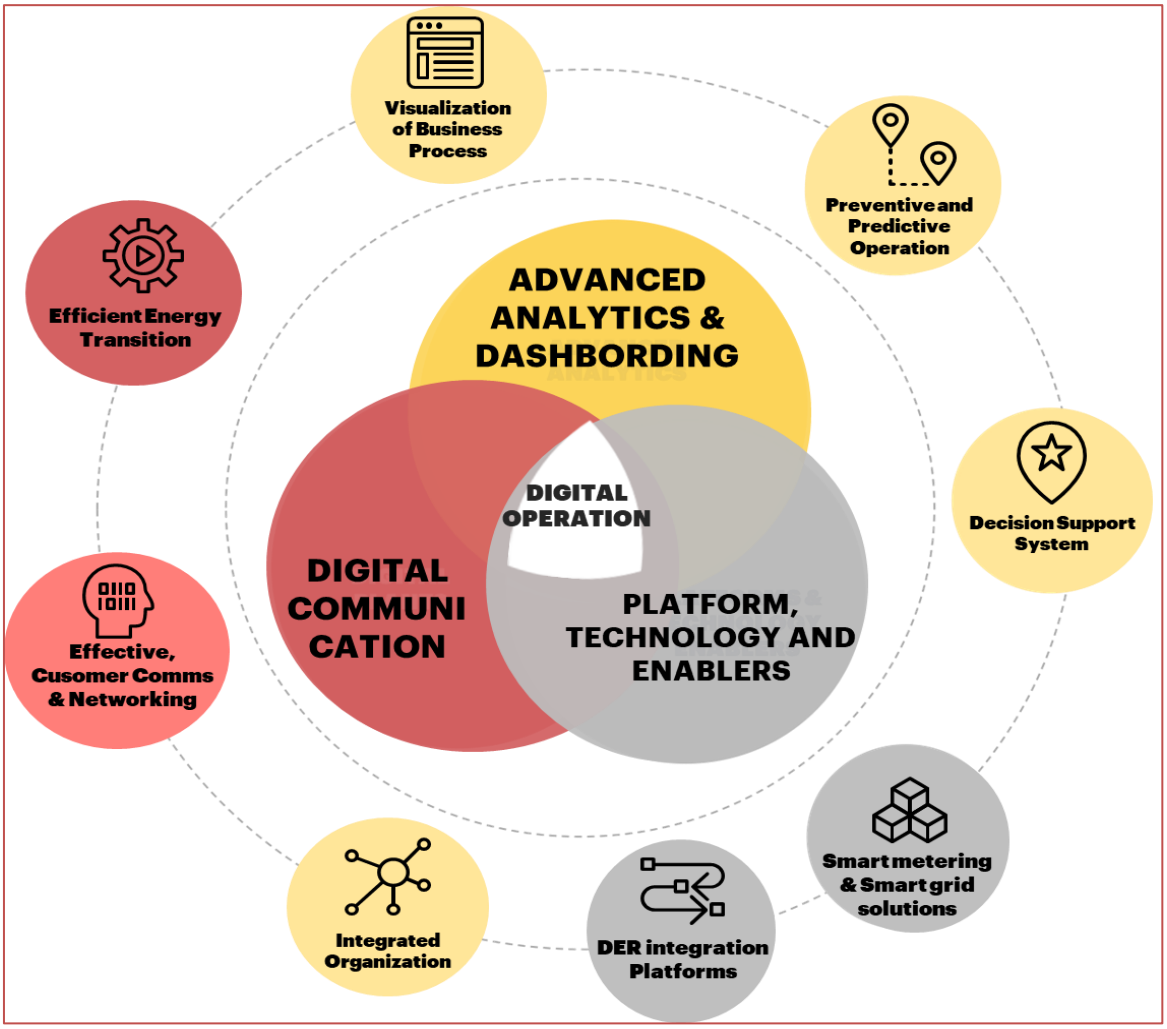
2.1 Benefits of digitalization

Digitalization for utilities can be described as utilizing digital technology to add value to the core functionality of the utility that can improve the monetization strategies and create new value-generating possibilities while enhancing the utility's techno-functional capabilities and operational effectiveness.

Digitalization, which involves various IT-OT systems & solutions, broadly offers three main functionalities to a distribution utility: digital communication & networking, platforms & technology enablers and advanced analytics & dashboarding. Adoption of these can help a DISCOM in achieving the following:

- Various smart metering and smart grid solutioning platforms which can effectively reduce the risk of revenue cycle, ACS & ARR gap & AT&C loss
- Preventive and predictive operation & maintenance, which can cut down the operation cost and gain operational efficiency
- Pro-active decision support system, which can reduce the outage time and gain reliability of power supply. Effective decision support can also enable various use cases like load forecasting & scheduling, distribution management system, demand side management etc
- DER integration platforms which can further help the DISCOM to achieve efficient energy transition
- Various visualization and monitoring use cases, enabled with the help of GIS, SCADA, customer management and IoT systems, to achieve efficient incident management and proactive network & asset monitoring

Figure 8 : DISCOMs' digital operation



2.2 Key elements of digitalization

Digitalization of DISCOMs for managing their electrical network, revenue cycle management, consumer services, internal stakeholder management (employees, vendors, etc.) and for the robust decision support system (like analytics, management information system, etc.) are majorly dependent on deployment and usage of various information technology (IT) and operational technology (OT) systems.

At macro level, there are 12-15 different IT & OT solutions, which DISCOMs may adopt, each having lot of options in terms of solutions availability in the market. Hence, to select the right solution stack, DISCOMs based on their consumer size, geographical area spread, existing IT systems, manpower, skills, and scalability requirements, needs to chalk out an organisation-level technology roadmap for the next 7-10 years in a holistic and integrated manner to achieve the desired objective.

- **OT systems adopted in power distribution companies** broadly include the systems and technologies (not limited to) as follows:
    - Smart Metering / Advanced Metering Infrastructure
    - Sensors & other field devices to capture field data

- Communication networking to capture and transmit field data
- SCADA (Supervisory Control & Data Acquisition System)
- OMS (Outage Management System)
- DMS (Distribution Management System)
- ADMS (Advanced Distribution Management System)
- Network Analysis System
- Auto Demand Response (ADR) System
- Work Force Management System

- **IT systems adopted in power distribution companies** broadly include systems & applications (not limited to) listed as follows:
  - Revenue Management System
  - Enterprise Resource Planning (Finance, HR, Logistics, Operation, Purchase & Procurement etc.)
  - Inventory Management system
  - Financial Accounting Software
  - Consumer Mobile APPs/ Consumer Care /CRM system
  - Document Management System
  - Billing Application
  - Energy Audit tool
  - MIS and Data Analytics System
  - Interactive Voice Response System (IVRS)
  - Dashboard and Analytical Engines.
  - Geographical Information System

Some of the major IT & OT systems and applications are described below in details. Many national and international DISCOMs have already leveraged many of the IT and OT applications and enabled different digital solutions with IT-OT enablement (some case studies are provided in Annexure 2).

Major OT systems deployed in power distribution sector:

1. Smart Metering /Advanced Metering Infrastructure

(i) About Smart Metering/ Advanced Metering Infrastructure

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers. AMI applies smart control and communication technologies to automate metering functions that have earlier been done through manually intensive operations, including electricity meter readings, service connection and disconnection, tamper and theft detection, fault and outage identification, and voltage monitoring. Combined with advanced customer-based technologies, AMI also enables utilities to offer new rate options that incentivize customers to reduce peak demand and energy consumption.[2]

[2] Source: Smartgrid.gov

Figure 9: AMI infrastructure

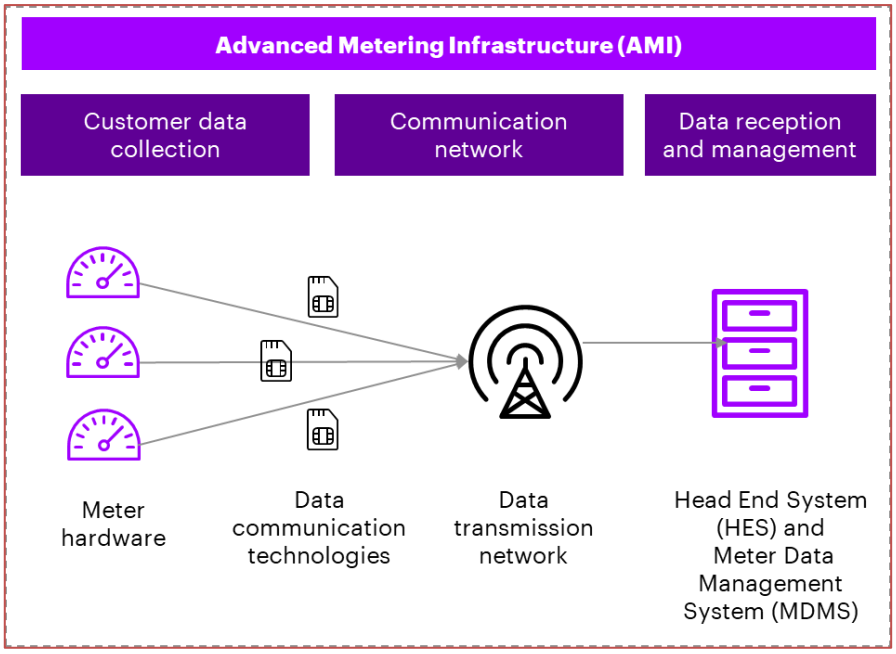


Table 1: Components of AMI infrastructure

Meter hardware	Advanced meter devices with capacity to collect information, transmit the data and receive information between utility and consumer.
Data communication technologies	Cellular technologies for smart meter connectivity
Data transmission network	Advanced networks which support two-way communication from smart meters to utility companies and vice-versa
HES and MDMS	Host system which receives, stores and analyses the metering information

(ii) Benefits of an AMI system

- **System Reliability:** AMI technology improves the distribution and overall reliability of electricity by enabling electricity distributors to identify and automatically respond to electric demand, which in turn minimizes power outages.

- **Energy Costs**: Increased reliability and functionality and reduced power outages and streamlined billing operations will dramatically cut costs associated with providing and maintaining the grid, thereby significantly lowering electricity rates.

- **Electricity Theft:** Power theft is a common problem in India. AMI systems that track energy usage will help monitor power almost in real time thus leading to increased system transparency.

(iii) Communication Technologies for AMI/ Smart Metering[3]

At present, the following communication technologies are typically used for AMI systems:

[3] Source: Report by CEA on *'Guidelines for Distribution Utilities for Development of Distribution Infrastructure'*

- **Power Line Communication (PLC)**: Smart Meters use the power line itself for data communication between the meter and a DCU placed at appropriate location connecting 100 to 200 meters at customer premises. The DCUs are connected to the Utility's systems through GPRS or fibre-optic networks.
- **Radio Frequency (RF) Mesh**: Smart Meters use RF for data communication between the meter and a DCU which is connected to the (HES/MDM) systems through GPRS or fibre-optic networks. In a mesh network, number of smart meters communicating to any DCU/access point/router is dynamic in nature as the self-configuring mesh will find the most optimal route for communicating the meter data to the HES/MDAS through nearest available DCU/access point/router. The failure of any DCU/access point/router leads to re-designing of the network automatically to use another nearby DCU so that data communication is uninterrupted between the meter and the control centre.
- **Cellular Technology (GSM/GPRS/3G/4G/NBIoT)**: Smart Meters directly communicate the data to the control centre by utilising the Telecom cellular data network (GPRS/3G/4G/NBIoT) and this system typically does not require any DCUs.
- **Optical fibre:** The communication takes place through optical wave propagation within fibre line which is based on total internal reflection principle. Meter data pushed towards DCU (Data Consolidation Unit, also known as Fat Box Unit) through optical fibre line, then consolidated data carried forward through consolidated fibre line to the data layer for further processing of meter data.

Recently, the use of devices based on 'Internet of Things' (IoT), or simply 'Machine to Machine' (M2M) communication for wide ranging sensory devices have increased on a great pace.
The following table captures the details of most commonly used communication technologies for Smart Metering / AMI across the world.

Table 2: Comparison of communication technologies

Metric	Optical Fibre (OFC)	PLC	RF Mesh	GSM / GPRS
General Usage	Advantageous over electrical transmissions, OF have largely replaced copper wire networks	Broadband overpower Lines, Systems for carrying data on a power conductor for WAN Applications	Point-to-point wireless transport for voice, data, video etc.	Very wide network reach and can be used easily on remote locations
Frequency Range	180 THz to 330 THz	1.7-80 MHz Most providers rely on the 1-30 MHz spectrum bandwidth for BPL transmission	Licence Free bands: 865-867[4] MHz; 2.4 GHz Licensed bands: 433	900 to 1990 MHz

[4] Presently only 2 MHz (865 to 867) license free spectrum is allotted in India for machine- to-machine (M2M) communication. In 2018, TRAI approved allotment of 7 MHz of spectrum for M2M communications which them went to Wireless Planning Committee (WPC) for allotment. WPC approved 6 MHz, but actual allotment is still pending. The additional 6 MHz with the existing 2 MHz will significantly help M2M on RF Mesh for variety of applications. DoT and WPC may expedite the allotment by WPC.

Metric	Optical Fibre (OFC)	PLC	RF Mesh	GSM / GPRS
Peak Single user Data rate	15 to 101 Tbit/s	Low frequency (100-200 kHz) carriers: Few hundred bps; Speeds up to 10 Mbps have been achieved.	Typical 4-16 Mbps	Upto 2 Mbps
Coverage capabilities	Up to 100 km on a single network	Distances of more than 15 km can be achieved over a medium voltage network	Up to 1 km; longer distances capable with lower bit rates	Several kilometres (In low traffic conditions)
Cost	High initial investment and depends upon the distance and other conditions	High cost of implementation and lack of vendors	Moderate	Moderate
Technology maturity	Latest with the scope of future developments	More popular in Europe where quality of existing infrastructure is good	Mature; 500+ deployments worldwide	Fairly mature (4G LTE / NBioT is the latest technology)
Type of Signal	Optical Signal	Electrical signal	RF signal	Digital, Circuit switched network signal

For implementation in the Indian context, wherein the cost of implementation plays a key role in ensuring that the solution is affordable, Optical Fibre Cable for communication between each smart meter may not be a feasible alternative.

Accordingly, the advantages and disadvantages of three more common and mature technologies have been compared below.

Table 3: Pros and cons of mature communication technologies

Technology	Pros	Cons
Power Line Communication (PLC)	• *Infrastructure:* Leveraging use of existing infrastructure. • *Cost-effective:* Use of existing infrastructure and can transmit over long distances; advantage for utilities serving rural areas • *Useful grid analytics:* Enables preventive maintenance; Use of the distribution network to send signals, which enables analytics to isolate and troubleshoot problems with insulators, transformers and other grid devices	• *Network interference:* Large industrial customers may introduce noise and harmonics on the power line that may affect performance and distort communications • *Less bandwidth:* Narrower available bandwidth can impact data capacity and the speed or rate at which data can be accessed in some applications • *Poor network conditions:* The existing network conditions in India may cause data loss

Technology	Pros	Cons
Radio Frequency Mesh (RF)	• *Distributed regionally:* Can target specific areas for deployment • *Self-healing:* In case of network failure in any particular link, the network automatically finds another path to communicate with the HES • *Self-forming:* The network's intelligence enables the signal to find the optimal route back to the HES; Important in areas with obstructions, like mountains or high-rise buildings	• *Infrastructure*: May require more infrastructure deployment /DCU than other options, especially in rural areas, where meters are more spread out across the service territory • *Proprietary technology:* The communication technology is proprietary to each vendor and therefore inter-operability becomes a challenge.
Cellular Network – 3G/4G/NBIoT Technology	• *Faster deployment:* Enables long-range communication and can be rolled out quickly using the existing cellular data infrastructure • *Optimal for targeted applications:* Can be deployed cost-effectively to support even marginal consumer groups • *Proven technology:* In use for more than a decade, well established and fairly reliable • *Secure:* Serving billions of customers worldwide, cellular networks are already secure, advantage of which can be reaped by Utilities • *Common protocol:* Standardised protocol compliant which is vendor agnostic, making inter-operability seamless	• *Obsolescence issues:* Cellular networks tend to roll over prior to the useful life of the metering technology, raising concerns about how long a deployed technology will remain viable • *Network availability issue*: Sharing public cellular networks, often completely dependent on the carrier's (TSP's) priorities in the event of an outage

A suitable communication technology for various smart grid operations may be selected by the utilities as per the actual site conditions.

2. Sensors & other field devices to capture field data

This physical field devices collectively create the physical layer of OT solutions from where the OT data originates. The field devices may be any type of sensing, tracking or reading equipment to capture physical conditions or positioning of any assets, resource or process. The field devices consist of intelligent electronic devices (IEDs) including sensors, PLC, IIoT devices etc.

The data generated at this level is in the rawest form and is collected at a high frequency by these field devices. At this physical data capture level, the attributes of the distribution assets are sensed & communicated to respective remote terminals/ communication system.

Table 4 : Data generated by utility infrastructure

Type of Data	Devices
Operational Data	Intelligent Electronic Devices (IEDs) and Remote Terminal Units (RTUs)
Billing, Usage & Load Profile Data	Smart Meters
Health Data	IoT Devices & Sensors
Generation Data	Rooftop Solar Units & Windmills
Protection Data	IEDs

An example of devices and the data generated by them for a distribution utility is provided below:

Table 5 : Example of Level 0 & 1 devices and the data generated

S. No.	Distribution Asset	OT Data Source	OT Data
1	**Transformer (DT)**	Bluetooth Enabled Voltmeter	1. Input & Output Voltage
		Bluetooth Enabled Ammeter	2. Input & Output Current
		DT smart meter (GSM)	3. Input & Output Power Factor 4. Primary & Secondary loss
		Remote Pressure Sensors (IOTs)	5. Chamber Pressure
		Programmable communicating thermostats (PCTs)	6. Winding Temperature 7. Cooling oil temperature 8. Cooling air temperature
		Surge Sensors (IOTs)	9. Surge Detector value
		PLC IoT gateway/Ethernet	10. PLCs
2	**Wire / Distribution Line**	Programmable Communicating Thermostats (PCTs)	11. Shell Temperature (PTCs)
		DL smart meter (GSM)	12. Ohmic Loss (IR Sensors) 13. Load (in Kw)
		Wireless Power line Sensors (IoTs)	14. Connectivity
		Load Cell device (IoTs)	15. Tensile Strength
3	**Feeder Line**	DL smart meter (GSM) / PLC IoT gateway / Ethernet	16. Peak Loading (Amps) 17. Energy Loss (MU) 18. Minimum Voltage (KV) 19. Voltage Drop (%) 20. High Current Flow (Amps)
		Load Cell device (IoTs)	21. Tensile Strength
		Programmable Communicating Thermostats (PCTs)	22. Shell Temperature (PTCs)

S. No.	Distribution Asset	OT Data Source	OT Data	
4	**DG Set**	Bluetooth Enabled Voltmeter	23.	Battery Voltage(V)
		IoT enabled (LMS)	24. 25. 26.	Coolant levels (Lit) Fuel levels (Lit) Fuel Consumptions (Lit)
		Programmable Communicating Thermostats (PCTs)	27.	Engine Temperature(F)
		Sensor Tachometer (IoT device)	28.	RPM (rad/sec)
		Remote Vibration Sensor (IoT device)	29.	Noise Leve l(Hz)
		RFID / Bluetooth	30.	Control Panel Outputs
5	**Smart Meter**	Consumer smart meter (GSM/IoT Device/RFID)	31. 32. 33. 34. 35.	Current Level Voltage Level Maximum Demand Peak Current Level Run Time

3. SCADA & Mini SCADA - Real Time Data Acquisition System (RTDAS)

(i) About SCADA

SCADA, which stands for Supervisory Control and Data Acquisition, is a system of different software & hardware components, that allows a utility to supervise & control processes. The SCADA system collects information from various Intelligent Electronic Devices (IEDs) in an electrical system via different methods of communication and helps the utility in monitoring and controlling them. SCADA acquires the data on real time basis from each connected network equipment and sends this data to the control centre for facilitating decision making for switching operation of network elements remotely for faster action. The SCADA uses various visualization technologies and also automates the supervisory task based on predefined parameters and algorithms to benefit the operator in supervision & decision making. It is pertinent to emphasize that motorization of switchgears is a critical success factor for enablement of SCADA.

Substation Automation is the first step towards implementation of SCADA system and may be implemented on an open platform to allow use of IEDs from different vendors. Under sub-station automation, the replacement of all old, dilapidated panels, protection and control devices etc. at grids substation with state-of-the-art SCADA compatible switchgear have to be taken up for feeding data to the SCADA system. Further, based on the available data, the utilities have to adopt the “condition-based” maintenance practices. Condition based practices enable the utility to increase routine inspection intervals (i.e., perform fewer inspections) and perform major teardown inspections only when the equipment exhibits symptoms of incipient failures.

(ii) **SCADA Inputs**

Analog Inputs like Temperature, Pressure, Flow rate, Humidity, Level etc.

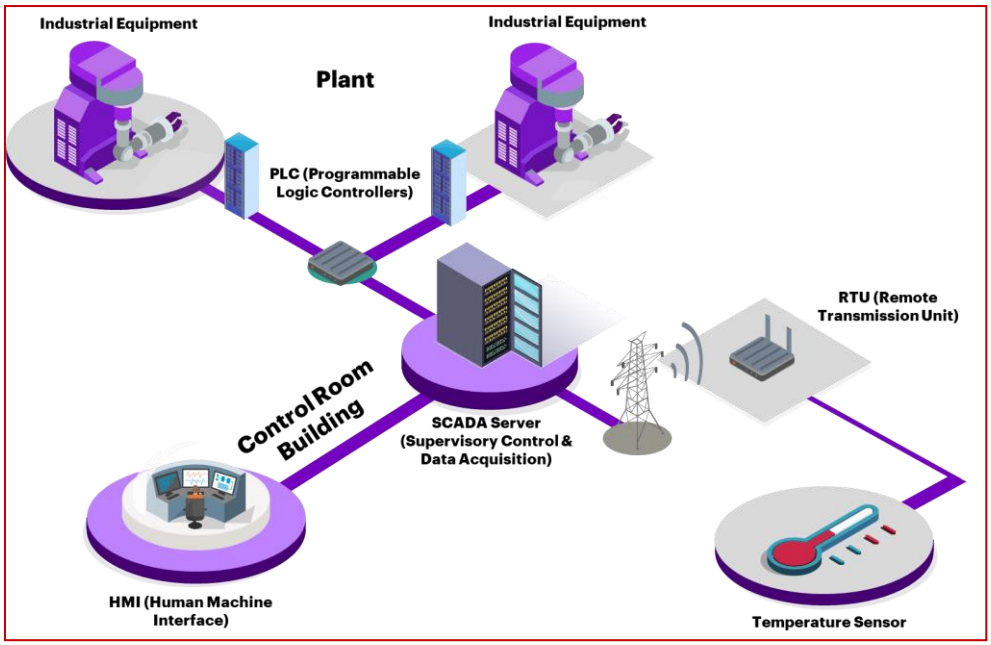
Digital Inputs - Inputs from Flow switches, level switches, Pressure switches, Proximity switches, Limit switches, auxiliary contact of contactor etc.

(iii) **SCADA Outputs:**

Analog signals like 4-20 mA or 0 to 10V DC

Digital signals like pulse output, relay output etc.

Figure 10: Overview of SCADA system



(iv) **Benefits of SCADA**

The benefits of using a SCADA system are as follows -

- Enables the understanding of real time health of equipment and assets & readily available information to enable faster restoration of supply
- Improved reliability indices like SAIDI, SAIFI, CAIDI etc.
- Helps in unmanned operations of grid stations - increased safety in work environment
- Provided readily available information within seconds to enable quick actions and faster restoration of supply while ensuring data security
- Provides alerts for significant events, thus facilitate elimination of the risk of equipment damage
- Better handling of the reactive power support equipment.
- Replaces erstwhile ad-hoc maintenance practices with a more scientific and reasoned maintenance practices.
- Facilitates reduced manpower matrix, enabled with defined and focused targets to reduce the maintenance cost

(v) **About mini-SCADA/ RTDAS**

As the implementation of full SCADA require major expenditure and time, the utilities may use Mini SCADA i.e., RT-DAS in the smaller towns / urban areas for data acquisition purposes. As the major areas of concern in the power distribution sector are high AT&C loss and poor power

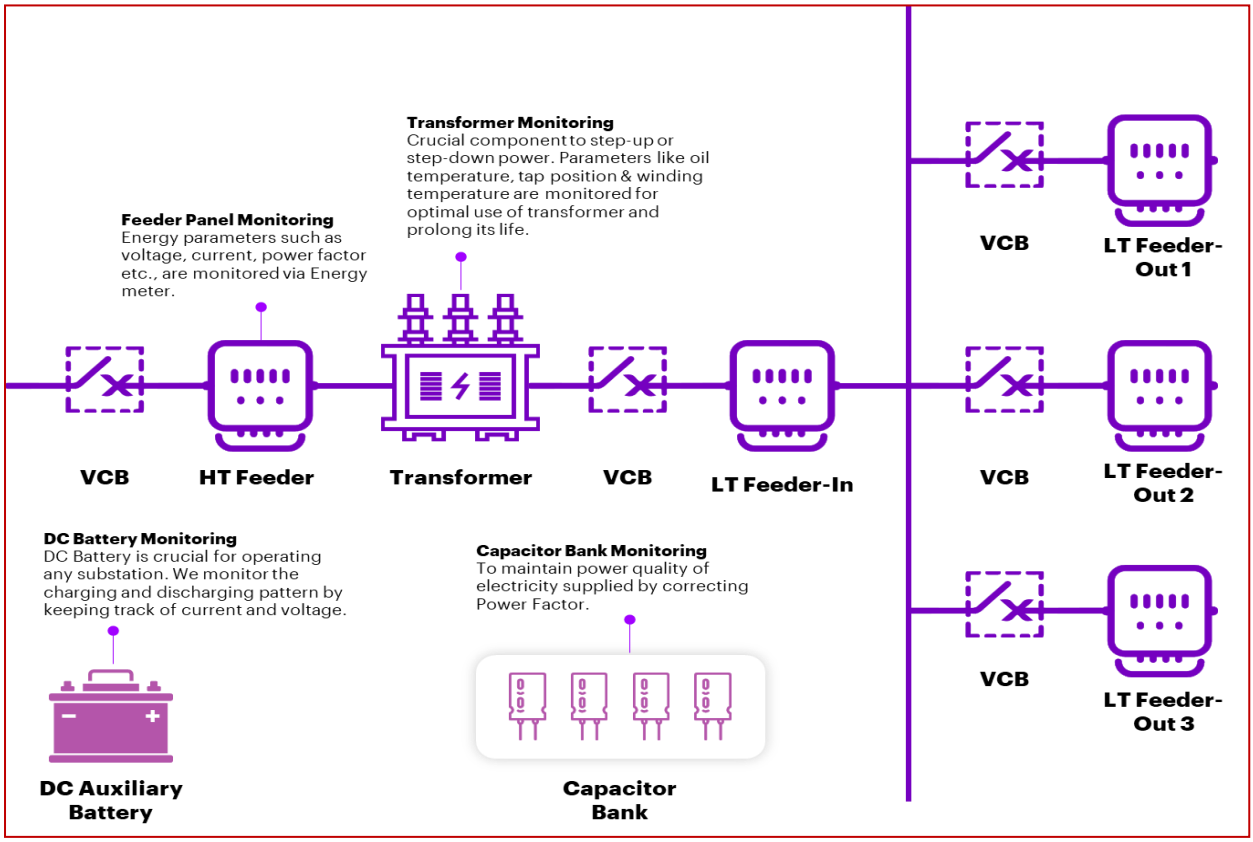
distribution reliability, real time accurate measurement & diagnosis of the system data is required which may be possible with the RT-DAS system in place of full SCADA. The objective of the RT-DAS is to accurately measure reliability of power distribution network and facilitate utility to take suitable administrative action for enhancement of power reliability.

Feeder Remote Terminal Unit (FRTU) based SAIFI/ SAIDI[5] measurement system in non-SCADA towns may be taken up with the use of RT-DAS to accurately measure the reliability of the power distribution network and facilitate the utility to take suitable administrative action for enhancement of power reliability. It shall also facilitate the utility to take appropriate measures for improvement of SAIDI/ SAIFI by knowing the reason of poor values of indices.

(vi) **Broad Scope of RT-DAS**

- RT-DAS at Data Centre
- FRTUs at S/S
- Essential compliance to IEC101/104 protocols for communication with FRTU and Modbus with Multi-Function Transducers (MFT)
- Cyber security/security compliance
- GPS Time synchronization
- SLD and mimics for monitoring at S/S and Data center

Figure 11: Real Time Data Acquisition System (RT – DAS)



[5] SAIFI - The **System Average Interruption Frequency Index** is the average number of interruptions that a customer would experience. SAIDI - The **System Average Interruption Duration Index** is the average outage duration for each customer served. Both these indices are commonly used as a reliability indicator by electric power utilities.

(vii) Benefits of RT-DAS

The benefits of using a RT-DAS are as follows -

- Accurate real time system of measurement
- Rugged and robust to withstand in S/S HV environment
- Notifying S/S about outage (can be extended to consumers using IT system SMS gateway)
- Generation of Reports (SAIFI /SAIDI reports as per regulator defined criteria)
- Operation monitors for switching devices to have preventive maintenance
- Historical data, MIS and analytics
- Future compatibility with SCADA / AMI etc.

(viii) Barriers to implement for SCADA and RT-DAS

Owing to the cost and requirement of dedicated trained staff for SCADA systems, smaller utilities often find it expensive to deploy. Another barrier cited for SCADA deployment is absence of reliable and cost-effective communication technologies from field level to the control room.

However, RT-DAS systems are relatively less capex intensive than SCADA and is easier to deploy & utilize. However, most utilities are dependent on GOI schemes like IPDS (earlier R-APDRP scheme) for financing its deployment.

4. Outage Management System

(i) About OMS

Outage Management System (OMS) provides the capability to efficiently identify and resolve outages and generate and report valuable information. OMS typically works in conjunction with Geographic Information System (GIS) and Customer Information System (CIS) to give proactive response to the consumer regarding supply restoration status by predicting the location of faulty network component which has contributed to outage to the consumer. It also helps in prioritizing the restoration efforts and managing resources based upon the criteria such as locations of emergency facilities, size and duration of outage. It also helps in analysing repetitive nature of faults and help maintenance crew in prioritizing their maintenance schedule.

It is prerequisite for OMS system to have complete network hierarchy from customer to LT network followed by distributions transformer, 11 KV feeder and emanating 66 kV or 33 KV substations. The requirement of complete hierarchy can be obtained through GIS platform by maintaining and sustaining of up-to-date network, assets and consumer mapping into GIS. Based on the either numbers of calls from customers or outage information from SCADA/DMS trigger the system application to predict the numbers of affected consumers. The list of affected consumers is sent to CIS for providing proactive intimation to consumers experiencing outages and assigning of field crew for early restoration of outages.

- In distribution feeder side, deployment of Ring Main Unit (RMU), Feeder automation using FRTU, Fault passage Indicators (FPIs) further help utilities to facilitate an efficient outage management process -

- RTU / Feeder RTU (FRTU): These devices communicate switch status & electrical parameters like voltage, current etc. from different feeder points / DT/ RMU at field locations to control centre. These RTUs / FRTUs receive command from control centre for operation of switches at site to achieve faster restoration / isolation.
- Distribution Transformer Monitoring Units (TMUs): The DTMUs monitor oil levels, oil temperatures, loading conditions and internal fault in distribution transformers. It also helps in taking proactive actions for maintenance of Distribution Transformer.
- Fault Passage Indicators (FPI): Fault Passage Indicators identifies location / type of faults through visual indications at control centre. The Identification of section under fault is used to direct maintenance crew for quick recovery of faulty section for subsequent restoration of faulty part.

(ii) Benefits

The benefits of using an OMS system are as follows -

- Enables recording of end-to-end outage data creating invaluable interruption data
- Predicts the consumer spectrum affected by outages and enables consumer information to be available on a real-time basis
- Improves quality of service to customers
- Reduction in Outage duration, restoration time and non-outage complaints
- Reduction in O&M costs and better regulatory relations with consumers
- Enables the customer care centre to prioritize the complaint handling sequences for business purposes
- Enables crew management and optimization for maintenance and restoration activities
- Improves performance assurance standards

(iii) Barriers to implement

For Outage Management System to be really effective in improving customer experience, its integration with Customer Information system and GIS is important. However, only few utilities across India have integrated OMS, GIS & CIS as of now.

5. Distribution Management System (DMS)

(i) About DMS

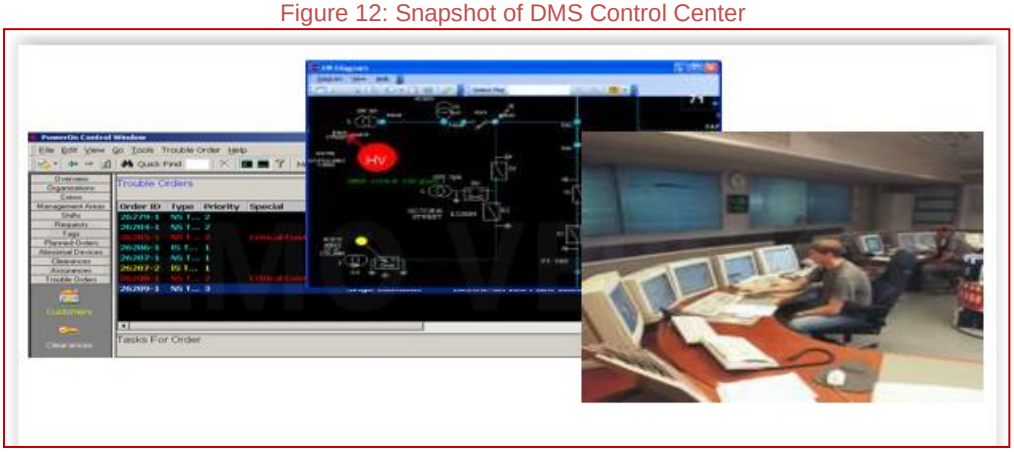
A Distribution Management System (DMS) is a collection of applications designed to monitor & control the entire distribution network efficiently and reliably. It acts as a decision support system to assist the control room and field operating personnel with the monitoring and control of the electric distribution system. It accesses real time data and provides all required information on a single console at the control centre in an integrated manner. This helps to detect, report and correct outages which includes the estimation of fault location and service restoration system. Application is also used for optimizing the network conditions including the Network Reconfiguration and the Volt-Var Control functions.

The main function performed by DMS are as follows.

- Network Connectivity Analysis (NCA)
- Load Flow Application (LFA)

- Voltage/VAR Control (VVC)
- Fault Management and System Restoration (FMSR)
- Loss Minimization via Feeder Reconfiguration (LMFR)
- Load Balancing via Feeder Reconfiguration (LBFR)
- Operations Monitor
- Short Term Load Forecasting
- Interface to customer information system (CISs)
- Interface to Geographical Information System (GISs)
- Trouble calls management and interface to outage management system (OMSs)
- Asset Management systems

Figure 12: Snapshot of DMS Control Center



(ii) **Benefits**

The main benefits of deploying a DMS are -

- Improved monitoring and control of distribution network
- Better control of power quality and enhanced use of reactive power sources
- Chances of manual error can be eliminated, as all grid stations are unmanned and centrally controlled
- Improved customer service on load shedding feeders through load forecasting and scheduling applications
- Faster fault isolation and restoration to reduce the interruption time
- Improved reliability indices at the distribution network level
- Provide for maximum use of the installed equipment in terms of best configuration and/or best settings of controls to reach specific objectives such as minimum losses
- Provides real time analysis of the system and provides means to analyse the present and hypothetical operating conditions of the distribution network for scenario analysis

(i) Barriers to implement

- Employee skilling is important for the utility to take complete advantage of the solution
- This is a costly solution and hence both hard and soft savings should be considered while undertaking cost-benefit analysis

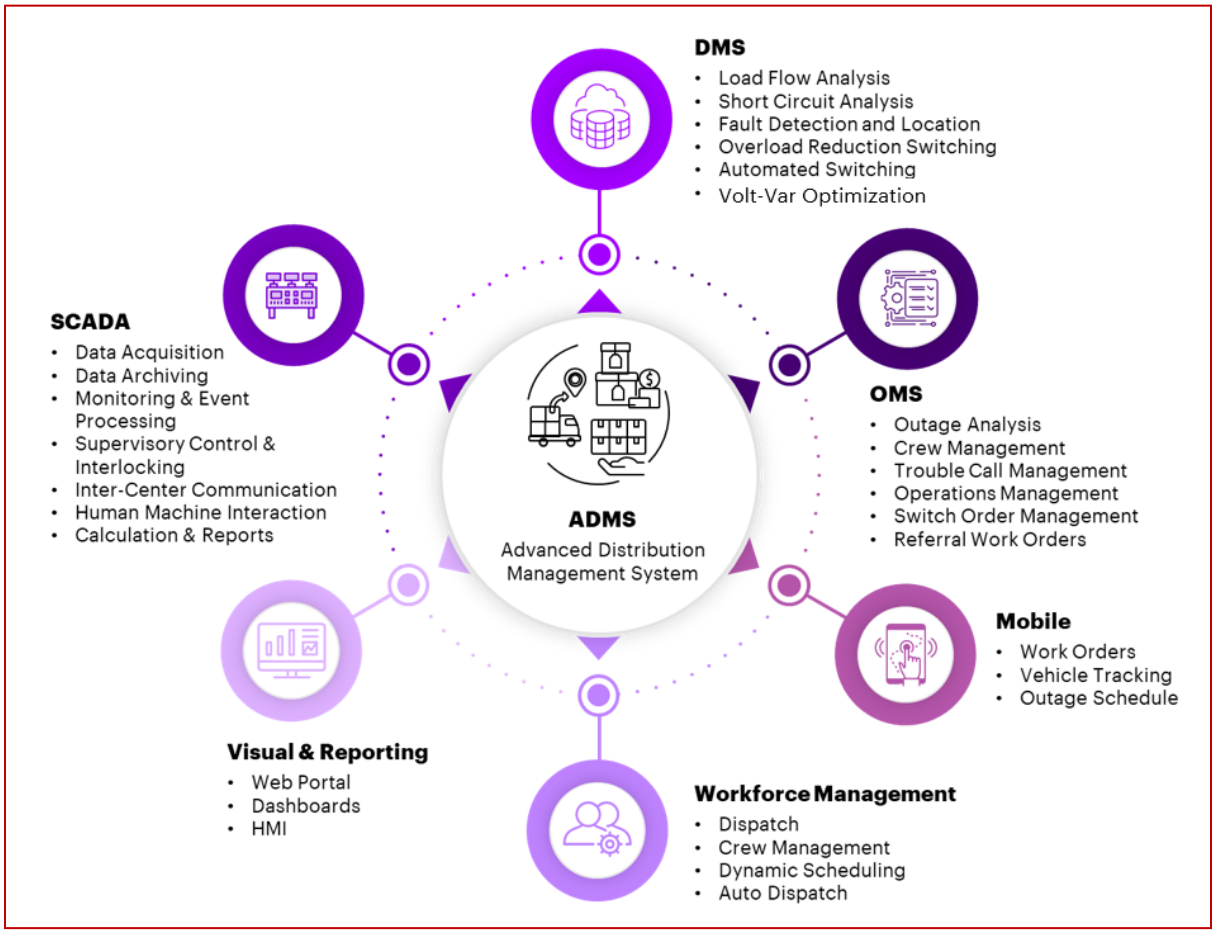
6. Advanced Distribution Management System

(i) About ADMS

The latest trend in the distribution utilities is to implement the unified SCADA, DMS and OMS which is solution of the same box. An Advanced Distribution Management System (ADMS) is the software platform that supports the full suite of distribution management and optimization including SCADA, GIS, DMS, OMS and provides advanced control capabilities. An ADMS includes functions that automate outage restoration and optimize the performance of the distribution grid. ADMS functions being developed for electric utilities include fault location, isolation and restoration; volt/var optimization; conservation through voltage reduction; peak demand management; and support for micro grids and electric vehicles.

Applications of ADMS looks for certain data which can be fed to this system through GIS which contains the asset, network, and consumer modelling of utility. Based on this data, all applications can be run successfully provided the data in GIS is maintained and updated judiciously and always in live condition as available in field.

Figure 13: ADMS system



(ii) Benefits

The benefits of ADMS are as follows-

- Reduction in the duration of outages
- Improvement in speed and accuracy of outage predictions
- Reduction in crew patrol and drive times through improved outage location identification

- Determine the crew resources necessary to achieve restoration objectives
- Effectively utilize resources between operating regions
- Determine when best to schedule mutual aid crews
- Provide customers with more accurate estimated restoration times
- Improve service reliability by tracking all customers affected by an outage, determining electrical configurations of every device on every feeder, and compiling details about each restoration process
- Quick tracing of crews through Auto Vehicle Location System (AVLS)
- Increased customer satisfaction

(iii) **Barriers to implement**

Deployment of ADMS solution will require the utility to have implemented other smart grid solutions like SCADA, OMS, DMS, etc. The major barriers to implement ADMS are -

- It is cost intensive and involves high performing algorithms and applications based on AI, ML, statistical modelling configured on top of DMS system to establish a data driven decision support system
- ADMS implementation requires organization changes including upskilling of existing manpower, re-defining process flows for the utility
- Requirement of a dedicated, cross-function team to ensure its smooth deployment
- Integration is difficult, since utility systems have traditionally been developed in silos. Thus, IT systems which can connect each of the different components needs to be developed and deployed. Thus, there is an integration challenge between the component operational systems and other legacy systems which poses a barrier for implementing the full suite of ADMS solution
- Since, there are limited experiences of ADMS implementation in India and across the globe, thus, vendor ecosystem & the solutions may not be mature. Thus, it is important to collaborate with the vendors as strategic partners for its implementation.
- Deployment of ADMS solution will require the utility to have implemented other smart grid solutions like SCADA, OMS, DMS, etc.

7. Automatic Demand Response (ADR)

The demand-side management can be implemented in distribution sector through TOU/TOD tariff or by switching off some of the non- essential loads at the time of peak.

(i) About ADR

Automatic Demand response system uses automation systems to communicate signals from utilities to energy-using devices that causes them to turn off during periods of high demand.

Under Automatic Demand Response System, based on the agreement with the consumer, the system sends control signals to smart devices installed at the home/business/ industries of interested consumers to cut off some of the non-essential load for a short period to prevent system overload. Under this system, consumers have to be awarded some benefits to allow the utility system to cut off their loads from control centre.

Figure 14: Typical Demand Response (DR) Event

(ii) Benefits

The benefits of deploying Automatic Demand Response are -

- **Peak Shaving** - Automatic Demand Response system allows interaction between availability of power and loads to interact in an automated fashion in real time, coordinating demand to flatten spikes. Eliminating the peak spikes in demand that may occur for a short time would eliminate the cost of adding reserve generators and allows users to cut their energy bills by managing low priority devices to use energy only when it is cheapest.
- **Intermittent Resource Management and Reducing System Ramps -** Automatic Demand response system is responsive and flexible, making it a valuable resource for integrating intermittent energy sources (like solar, wind) into the grid.
- **Relieving Network Congestion Stress –** ADR not only helps reduce stress at the generation level, but it also helps reduce transmission and distribution (T&D) congestion.
- **Frequency Regulation -** Utilities could leverage some demand response capabilities for frequency regulation. While not all technologies are suitable for frequency regulation (e.g., smart thermostats) due to response time requirements, these Demand response systems can be operated for a short duration to return the system to the required frequency.

As Smart Metering system with GIS Mapping / Consumer Indexing is expected to be made available for all consumers by March 2025, some pilots on Demand Response may be taken up by utilities with interested consumers by 2025-26 to gain some experience. Subsequently, with the approval of regulators, the utilities may implement demand response at a full scale as per the existing rules & regulation. However, notification of TOU tariff will be a critical enabler to change the power consumption behaviour of consumers to help in flattening the load curve.

Major IT systems/ applications:

1. Enterprise Resource Planning (ERP)

ERP refers to a type of software that organizations use to automate business processes & provide insights & internal controls. It used to manage day-to-day business activities such as accounting, procurement, project management, risk management and compliance, and supply chain operations. ERP systems tie together several business processes and enables the flow of data between them. Thus, by collating data from multiple sources & removing data duplication, the ERP system acts as a single source of truth.

(i) ERP for DISCOM:

The ERP solution helps enhance asset dependability and reduces further losses, increases billing efficiency, reduce outage timing, and thereby increases speed of execution. It also takes care of customer billing cycles in a timely and effective manner.

Objective of ERP implementation in Indian DISCOM:

The primary objective of a DISCOM adopting ERP is to improve business processes & efficiency, reduce costs, ensure better customer satisfaction along with compliance to applicable policy and regulatory norms.

There are multiple ERP modules which cater to different business needs of a DISCOM. Some of the key modules have been discussed below.

a. *Project Management:* DISCOM ERP system need to provide
   - Effective resource planning as per project needs
   - Timely delivery of services and proper project management
   - Accurate and fast invoice generation with swifter payment cycles
   - Performance betterment, effective human resource management with time and cost saving

b. *Customer Relationship Management:* Achieving effective & flexible customer communication and the integration of ERP with CRM system to communicate and notify end customers is one of the critical digitalization move to achieve ultimate customer satisfaction.

c. *Inventory Management*: Optimum inventory management can be achieved through ERP system implementation with interactive resource and material planning & monitoring. Effective ERP systems provide integration of inventory management modules with asset management & work management modules.

d. *Finance Management:* Right from meter to cash, the entire utility billing & financial process needs to be taken care of. Certain financial/contractual agreements with different types of customers need to be catered. A variety rate of tariffs must be managed and monitored prior to run the billing cycle.

e. *Workforce/work management:* With assets, geographical spread, mobile workforce being the primary areas of working for an Indian DISCOM, managing work is given high importance. The work orders & work force management must be interconnected through the ERP systems in such a way that it binds all necessary modules together.

f. *Asset Management:* As with many industries, energy and utility sector is quite concentrated with asset management. And hence, the ERP solution must be

heavily strong in terms of managing and monitoring assets instantly within a few clicks.

Additionally, DISCOM should review ERP security perspectives too while implementing an ERP solution, so that there is no scope of security breach during /after the process which may ultimately turn into financial losses for the DISCOMs.

(ii) Benefits of ERP:

- Robust project management
- Effective resource planning enabling time and cost savings
- Efficient management of work orders
- Better inventory control and management
- Faster payment cycles through enhanced invoice management systems

2. Customer Relationship Management

(i) About CRM

CRM system is implemented in the utilities for better consumer interaction and for facilitating in day-to-day decision making by the management of the company. The information/option available in CRM can be broadly categorized into following major categories

- **Search Options** – In CRM, multiple options are available for searching the consumer data
- **Fact Sheet** – Information w.r.t Business Master Data and Technical Master Data of a consumer is available
- **Notification** – In CRM, user can perform action like new connection, attribute change, billing, metering complaint, no supply and street lighting service requests w.r.t notification
- **Report** – User can also view different reports developed for different departments. These reports are used by user for analysing consumer account in detail.

Figure 15: Snapshot of CRM

(ii) Benefits

The key benefits of CRM are -

- Call Centre Executive may use this application for answering the consumer query or registering the consumer complaint resulting in increased productivity of call centre executive by about 25 %. The increase in productivity ensures that utility can answer more calls without increasing the number of operators in the commercial call centre.
- Unified call centre can attend to all type of complaints (commercial or operational)
- During outages, Call Centre operator will be able to identify the consumer and answer the consumer query in very less time due to which the average talk time (ATT) is reduced, improving consumer experience.

  It is recommended that integrated CRM centres should be adopted by all the utilities along with the implementation of AMI, SCADA, DMS, GIS mapping etc. to help the consumer more efficiently.

3. Billing System & Revenue Management System

(i) About Billing System:

Billing system helps the DISCOMs in managing the customer billing by automating the repetitive processes in the bill generation process. The Revenue Management System automates the business-critical processes, operations, back-office functions, and applications that helps utilities track customer billing, payment, queries, and complaints.

This application is integrated with the MDM system to capture the periodic metering data which further processed under this application and generates bills to various consumers.

For upstream data processing this application may have integration with document management system and the CRM system for automatic generation of bills & notifications to separate consumers.

The integration may be established through standard IT middleware system with proper data trafficking monitoring.

(ii) Benefits of Billing system:

- Reduction in time and cost for bill generation
- Improvement in billing accuracy
- Data availability for analysis and decision making

4. Energy Audit & Energy Management System

Energy audit & management is one of the important and critical operation, a DISCOM should take care of. Bureau of Energy Efficiency (BEE) through Ministry of Power, Government of India issued regulations for Conduct of Mandatory Annual Energy Audit and Periodic Energy Accounting in DISCOMs. As per the regulation, all Electricity Distribution Companies are mandated to conduct annual energy audit and periodic energy accounting on quarterly basis.

Computerized energy audit systems have been in use for a long time now in Indian distribution sector. Modern cloud-based energy analysis and audit software can run large simulations and equipment design programs. This software requires the input of weather data, operating times, and other energy-consuming parameters such as number and type of consumers with their

consumption patterns and their equipment ranges of consumptions, the efficiency of various devices, etc. The software comes with combination of financial analysis features.

Typically, an Energy Audit Tool has four different modules such as:

Audit module – This module shows energy consumption patterns. This module's aim is to identify the anomalies, analyse the utility bills, consumption, asset, and energy drivers. Functionalities are:

- A large number of pre-compiled graphs and charts
- CO2 & other emission charts

Modelling module – This module creates energy models for energy management and control of energy consumption. Functionalities are:

- Forecast and control of energy consumption, identify anomalous & deviations
- Economic benefits in the maintenance field

Benchmarking module – This module is for comparing various utilities and prioritizing one over another. Functionalities are:

- Evaluate the priorities of action
- Efficiency index calculation

Budgeting module – A module tool for creation and comparison of different budgets for each energy source type. Functionalities are:

- Create different scenarios to help develop energy efficiency plans

This applications have integration with financial software and reporting tool of a DISCOM.

(i) Benefits of using Energy Audit Tool:

- Propper segregation of line losses, gives a clear view of performance improvement zones.
- Continuous monitoring with accurate data inputs gives wholistic system visualization.
- Digital authentication and verification of benchmarking with controlled system outputs.
- Streamlines the Energy audit system with other system integrations such as financial tool or reporting tools etc.

5. Geographical Information System (GIS)

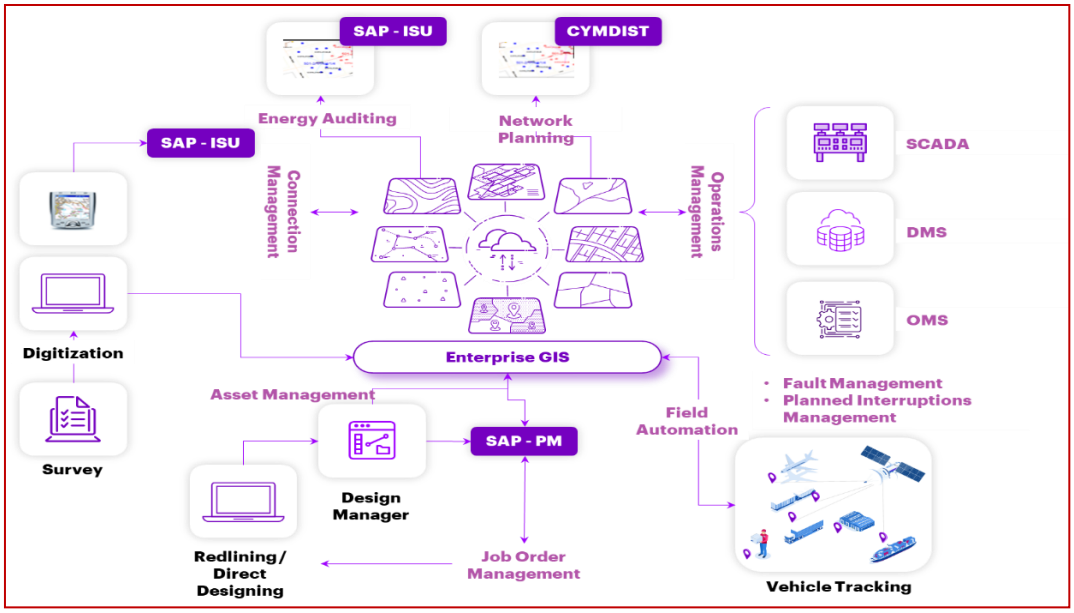
(ii) About GIS

Utilities need accurate information of their assets for efficient services. One of the biggest problems faced by utilities is storing historical data which can be paper based and updating to include real time changes at the field level. GIS is the system which leverages the actual information of lay out of power system on the geographical map digitally and helps utilities to manage relevant information about customers and distribution network with an overview of the entire system visualized on a map. GIS helps in addressing the challenges of utilities whose assets and network are spread across the geography for providing services to their consumers.

Generally, GIS is required to be updated regularly as per changes in the actual field conditions, but some time GIS loses its shine due to lack of timely data updation in GIS. With lack of latest

data, the integration of GIS with other business systems gets impacted and the overall objective of GIS gets completely derailed.

Figure 16: GIS system



(iii) Benefits

This is a very helpful application for utilities like electric distribution utilities, gas & water utilities, telecom utilities etc. GIS mapping is the optimal platform and forms the foundation technology for utilities which contains the following information:

- Geo coordinates-controlled asset record management
- Network topology for operation service management
- Consumer's location and indexing with network and asset for service delivery
- Field crew movement and tracking for ease of services to the customers
- Geo-fencing of the consumers for both commercial and maintenance operations, alongside vigilance activities
- Commercial operations and O&M staff tagged to the assets and consumers with each geo-location

The use of GIS can help various other processes like SCADA, Distribution Management System, Outage Management System, Network Planning, Energy Auditing, Field Force Automation, Asset Management, Customer Relationship Management, etc. to derive various business benefits. Some of the benefits rare as follows –

- **Operation Management** - Network hierarchy along with consumer mapping from GIS can help the network operator using DMS and OMS for further taking decision on operation management
- **Asset Management**: All new assets can be mapped and managed in an integrated environment where information can be flow from GIS to SAP and vice versa to have a robust asset management

- **Commercial management for new connection**: Consumer mapping is being utilized for verification of dues and technical feasibility before release of new connection. This would result in reduction of new connection cycle time.
- **Energy Audit:** Consumer mapping with Pole No. is being utilized for further indexing with supply points and its linkage with source points for carrying out energy audit at various service level.
- **Network Planning:** Network and consumer mapping can be utilized for carrying out the planning of new network and optimization of investments.
- **Vehicle Tracking:** Tracking of vehicle devices on GIS result in enhancing the productivity and adoption of shortest route

(iv) Barriers to implement

The barriers to implement GIS are -

- Data standardization, data acquisition, and system deployment
- Establishing Enterprise GIS requires complex technologies to be adopted
- Lack of appropriate skillsets
- Defining all the potential categories of users, their processes, the different kinds of data, functional requirements, software products, along with the system architecture

Being an asset intensive sector, distribution utilities across the country implement various IT & OT systems to optimize their operation and business processes. Current scenario shows unintegrated siloed solutions that has been implemented over the period of time. Digitalization with focus on IT-OT integration implementation has huge opportunity to generate immense value. It would enable the organization to leverage predictive and prescriptive analytics across processes & business functions. As the deployment of renewable energy increases through penetration of Distributed Energy Resources (DER) such as solar rooftop, energy storage systems & electric vehicles (EV) in India, the importance of IT-OT integration would increase multi-fold. Changing demand and supply trend over the period of time, with introduction of penalties and incentives based on power supply and reliability, IT-OT integration for better consumer experience will further be necessitated. Further proactive and predictive O&M system can gain ultimate operational efficiency through IT -OT enabled analytical solutions.

The combination of solutions (like SCADA, HES, MDM, Historian, GIS, Analytical or Visualization tools) will provide the complete IT - OT platform to meet the current objective of distribution utilities.

3. Importance of IT-OT convergence

Over the past few years, there has been a significant increase in the use of information technology (IT) and new operational technologies (OT) in the power sector in India. The increase in the use of IT in public sector DISCOMs has been driven primarily by the Restructured Accelerated Power Development and Reforms Programme (R-APDRP). The greater use of OT has also been made possible by funding from various government programmes. The private DISCOMs too have been implementing these technologies driven by the need to reduce their technical and commercial losses and improve performance levels.

Historically, IT and OT have occupied separate realms in the power sector. However, in order to realise their full potential, utilities need to integrate operating technologies with IT systems to achieve desired objectives of optimised business processes, better information for decision-making, more effective network management and improved customer service. While IT-OT convergence is not entirely new, there are more business and technology reasons now than in the past, which are driving the integration of the two technologies.

3.1 Key drivers for IT-OT integration in Indian DISCOMs

The following are the key drivers which encourage Indian DISCOMs to move towards IT – OT integration:

- **Focus on 24*7 reliable power supply** – Government of India (GoI) is focusing on enhancing consumer experience in public utility services. GoI has formulated Electricity (Rights of Consumers) Rules, 2020 which direct DISCOMs to provide a reliable power supply. These rules mandate that the DISCOMs immediately intimate consumers in case of an unplanned outage with estimated time of restoration. Integration of GIS, OMS & CRM systems can help DISCOMs in efficient identification of the location of the outage & affected consumers. Further, by integrating IT & OT systems the DISCOMs can enhance service availability, reduce downtime thus ensuring a good consumer experience.
- **Need for cost optimization** – The poor financial health of Indian DISCOMs necessitates them to optimize their costs. The Indian DISCOMs have a combined ACS-ARR gap of ~INR 0.26/kWh[6]. IT & OT integration will enable the DISCOMs to achieve optimal operational efficiency, increased reliability, reduction of down-time & will ensure effective network management etc. With increased pressures on profit margins along with availability of skilled workforce, efficient deployment of IT-OT systems would be key to reducing operating costs & optimizing resource utilization.
- **Increase in Distributed Energy Resources (DERs) –** DERs are expected to be deployed in India at an increased pace in the next few decades. With EV sales in India crossing 0.3 million in 2021, experiencing a 168 per cent[7] increase from the 2020 sales and the solar rooftop capacity at ~6.8 GW[8] with net metering enabled at multiple locations, there is a rapid increase in the influx of distributed energy resources into the grid. Thus, it

[6] Source: https://www.uday.gov.in/home.php
[7] Source: https://evreporter.com/ev-sales-trend-in-india-in-2021/
[8] Source: MNRE, as on 31st Dec 2021

becomes imperative to implement IT-OT integration solutions to manage the bi-directional grid interactions & enable pro-active asset monitoring.

- **RE integration** - India has set a target of installing ~500 GW non-fossil fuel-based energy[9] sources by 2030. With increasing share of RE in the power mix, its integration in the grid will be a huge challenge. IT– OT integration could enable DISCOMs to integrate RE power by implementing a transactive energy system, where the grid components including RE power, EV charging stations, battery storage & major consumers are integrated with automatic demand response system and the energy supply is managed by analytical scheduling & load dispatch tools to ensure grid stability.
- **Digitization -** Government of India has introduced multiple schemes including IPDS, NSGM and National Smart Meter Program for funding distribution infrastructure development including implementation of specific IT & OT systems. With allocation of ~ INR 97,631 Cr as budgetary support for RDSS scheme which supports installation of 250 million smart meters and strengthening of distribution infrastructure in the next 5-6 years, the DISCOMs are expected to deploy multiple IT & OT systems to reap the benefits of the scheme. Thus, it is important for DISCOMs to leverage the full benefits of the systems deployed through their integration.

Therefore, the DISCOMs have multitude of incentives to implement the IT-OT integration solutions. The subsequent sections further highlight the different use cases and the benefits of implementing various IT-OT convergence solutions.

3.2 Benefits & outcomes

There is an opportunity to generate immense value through integration of IT & OT systems. IT & OT systems have the potential to optimize DISCOMs' operations and business processes by leveraging predictive and prescriptive analytics across processes & business functions. The significance of IT-OT integration would increase rapidly as the grid integrated distributed energy resources (DER) including solar rooftop systems, energy storage systems, and electric vehicles (EV) increases in India. With introduction of penalties and incentives based on power supply and reliability, IT-OT integration for better consumer experience will further be necessitated.

Some of the potential benefits of IT-OT integration are as follows:

- Enhancing revenue through increase in efficiency for metering, billing & collection
- Strengthening operation & maintenance system through predictive analytics
- Reduction in balancing cost through better forecasts and demand response
- Optimizing asset utilization and increasing operational efficiency
- Enriching network management & decision support system
- Automation in monitoring & control of network topology
- Building system resiliency to disturbances, attacks, and natural disasters
- Advanced business analytics to bring out actionable reports

To reap the benefits of IT-OT integration, the DISCOM must examine its current systems and review case studies of successful IT-OT implementation by Indian and international power

[9] Source: https://www.telegraphindia.com/business/india-can-potentially-achieve-500-gw-non-fossil-fuel-target/cid/1844410

distribution utilities to better understand the challenges and learn from them. The subsequent section highlights the current practices of select Indian DISCOMs and key learnings from international DSOs with respect to IT-OT integration.

3.3 Challenges of IT-OT integration

The benefits of IT-OT integration are known to all. However, there are some practical challenges that the organizations face while implementing IT – OT integration:

Proprietary systems – Integration of a proprietary system or closed system is usually difficult with other systems which are not from the same OEM, without proprietary interfaces or gateways. This is also observed in building automation systems in which many solutions providers use proprietary communication protocols instead of open communication protocols, thus making it difficult to integrate.

Technology integration - A major challenge of IT-OT integration is integrating the existing legacy systems with newly built infrastructure and applications. In most cases the legacy systems in Indian DISCOMs are the IT systems like billing or ERP system which need to be upgraded for integration.

Cyber security – Careful consideration of security analysis and audits are required while planning & implementing IT – OT integration, to ensure cybersecurity. Though, IT systems are inherently more secure than OT systems, integrating critical distribution systems like SCADA to IT systems can expose it to external threats. There have been multiple examples of attacks of hackers on electricity distribution system including multiple successful attacks on Ukraine DISCOMs (2015 & 2016).

Capacity building & change management – Traditionally the IT & OT systems have worked in silos within the organization. To leverage the benefits of IT-OT integration, capacity building and a holistic change management programme becomes an imperative to create awareness along with undertaking cross-functional training for the employees.

Lack of standardization – Currently in India, there are lack of availability of standards for IT-OT integration regarding data exchange, interoperability, security, communication & networking etc. Further, as there is very less traction happened on IT-OT landscape in Indian distribution context, the distribution sector is lagging to define condition-based criteria & techno-functional benchmarking of IT-OT products & implementation process. Presence of a standard or benchmark would enable different OEMs to offer products which are easily integrable.

Apart from above mentioned challenges some of the critical difficulties (in Indian distribution context) are discussed below, which had been faced by different utilities across the globe while implementing the IT-OT solutions.

- Interoperability challenges - Challenges in ensuring communication among proprietary, legacy components & other components which follow open standards.
- Difficulty in selection of standards –Various standards are available for overall integration specifications which developed over time with technical maturity, commercial adoption & technology change. Thus, it is difficult for utilities to choose appropriate standards while implementing IT-OT integration.

- System upgradation and maintenance - Different integrated components are deployed & maintained by different vendors and it is important as well as difficult for a utility to ensure that the components are periodically upgraded.
- Handling large volume of data – This challenge may occur after deployment of IT-OT systems for any DISCOM as the system captures different types of data from sensors & field devices like meters, substations, synchrophasors etc. The selected IT- OT platform need to manage heterogeneous data formats / protocols from different smart systems.
- Implementation of asset analytics – If a DISCOM targets to migrate from time-based maintenance strategy to event-based strategy based on real time asset data, it would be a challenge for the utility to change entire maintenance process of the organization.
- Enabling GIS - Real time operational data view on GIS Maps is a complex & challenging task, utility may need to rely on 3rd party GIS solution provider and the IT-OT system need to be accordingly integrated.

3.4 Potential use cases for Indian DISCOMs

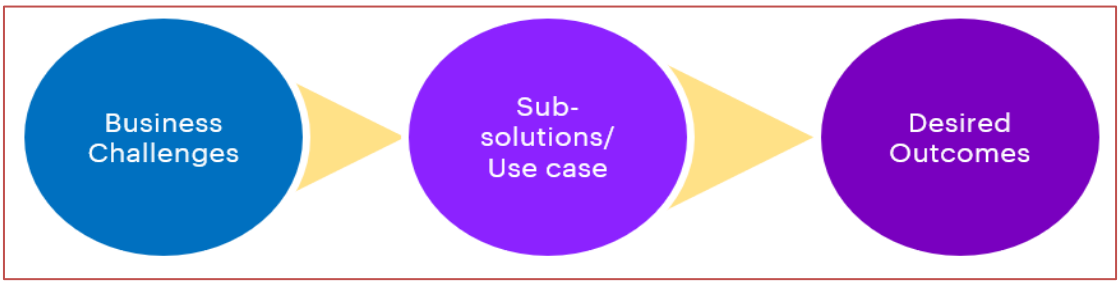
The primary business challenges from Indian power distribution perspective can be broadly classified as below:

- High AT&C losses
- High ACS-ARR gap
- Low RE integration
- Peak deficit
- High O&M cost
- High power purchase cost
- Customer dissatisfaction

Several business functions for Indian distribution utilities such as billing, revenue collection, asset management, asset tracking, maintaining customer information, etc. are supported by various IT applications. On the other hand, OT is associated with front-end field-based devices which perform operations and monitor them for the DISCOMs. Connecting IT systems and OT applications enable several use cases, which collectively have the potential to address several business challenges faced by the Indian DISCOMs.

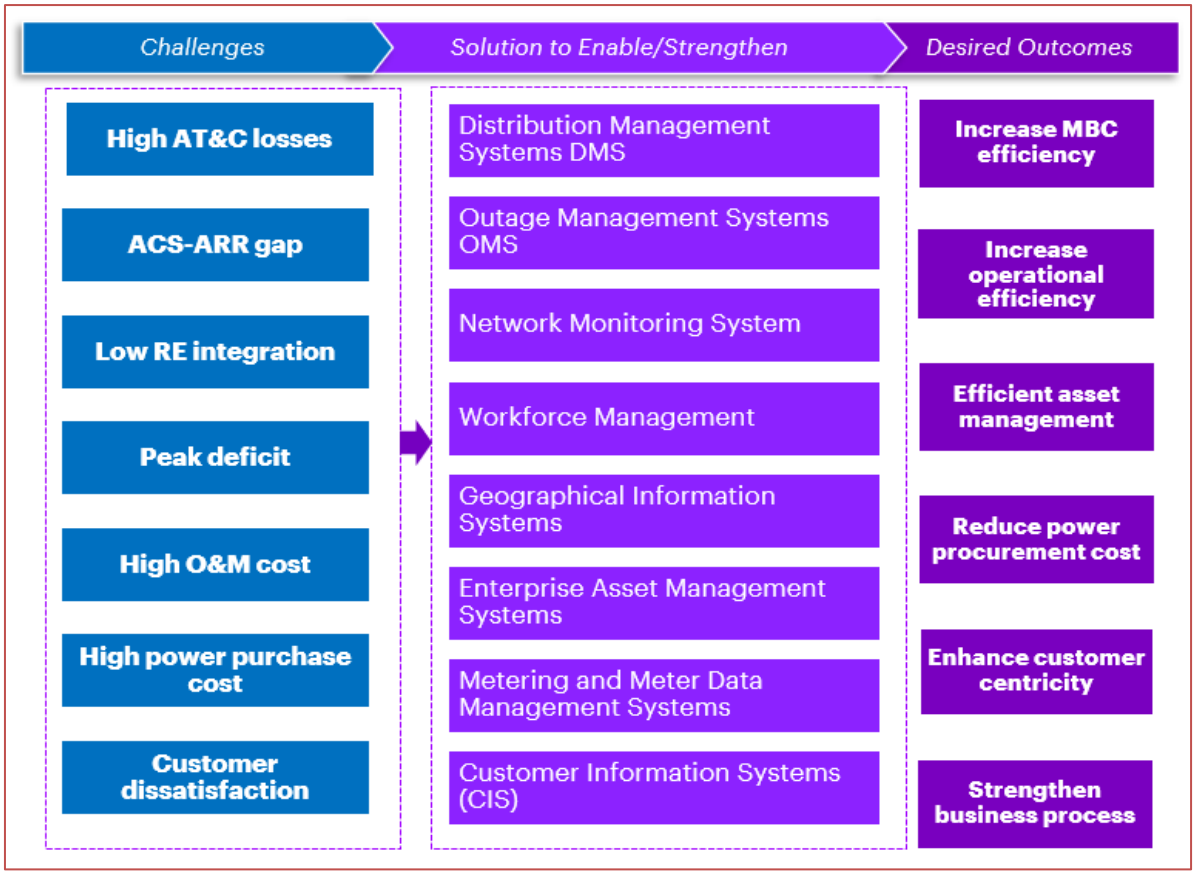
While selecting an IT-OT integration solution, the utility must analyze the unique business concerns it wants to address. The utility should prioritize certain use cases or sub-solutions that need to be enabled or reinforced by understanding its business challenges.
Each of the possible business challenges could be linked to the sub-solutions/use cases, required to be enabled to mitigate the respective challenges, to gain the desired outcomes.

Figure 17 : Business challenge linked with use cases and desired outcomes



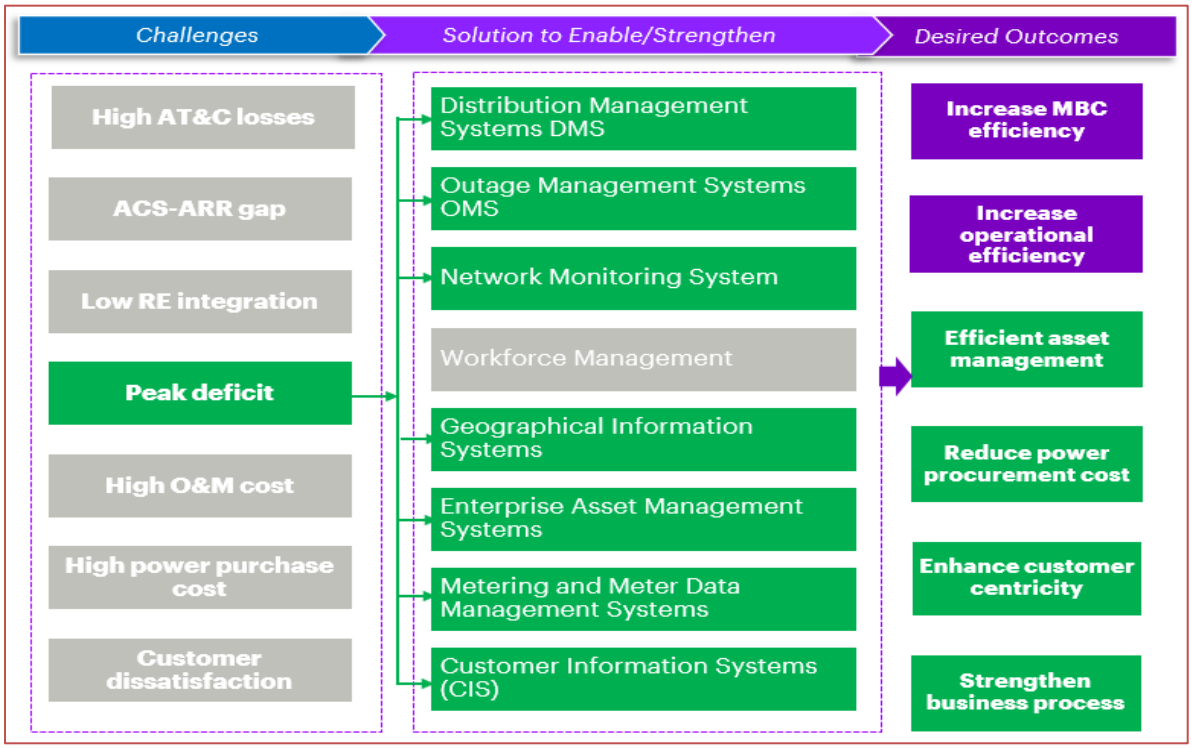
The diagram below illustrates some of the business challenges, selected use cases and the desired outcomes for Indian distribution utilities.

Figure 18 : Solution enablement for business challenges



For example, if a DISCOM wants to address the challenge of managing peak demand, it can leverage a combination of IT-OT features to target not just one but a combination of objectives. As described in the below diagram, peak deficit can lead to implementation or strengthening of use cases like distribution management system, outage management system, network monitoring system, GIS, CIS, etc.

Figure 19 : Use case for peak deficit



The business challenges and the use cases enablement depend on the maturity level of the DISCOMs. DISCOMs with high techno-functional maturity may need to enable few use cases to strengthen business functionalities, whereas DISCOMs with low or moderate maturity may need to start by enabling basic use cases through IT-OT convergence. This study recommends that the DISCOMs analyse their technological maturity and the desired outcomes before going forward with IT-OT integration.

Detailed list of use cases is given in *Annexure 3.*

3.4.1 Selected use cases for Indian DISCOMs

Some specific use cases that are significantly essential to Indian DISCOMs are listed below:

Use case 1: Electricity Consumption & Profiling:

The objective of this use case is to reduce the AT&C losses due to inefficient metering, billing and collection processes.

Challenges:

The common challenges faced by the DISCOMs which hamper the metering, billing & collection (MBC) cycle is -

- Meter stops working
- Meter slows down to zero
- Meter drifts
- 0 consumption for 5 consecutive days
- Identical consumption for 5 consecutive days

System Ability:

The system should have the following abilities & functionalities:

- Ability to identify dead registers/ meter as well as negative/wrong consumption
- Determination of the consumption profile during a past DR event, presented as a report to the back-office
- Ability to retrieve aggregated consumption (kWh) on hourly/ daily/ monthly/ yearly basis

Outcomes:

The overall benefit of this use case is strengthening of metering, billing and collection efficiency leading to reduced AT&C losses via -

- Individual meter visualization using all data types captured at the device level.
- Automated meter incident reporting on an hourly, daily, monthly, and annual basis.
- Deliver a triggered report/communication to the back office and the client for any issue or additional load contribution during the season.
- Analyze and discover variations in consumption patterns over time.

Use case 2: Peak demand management:

The objective of this use case is to reduce the downtime and manage the outage with 24*7 monitoring.

Challenges:

The common challenges faced by the DISCOMs which hamper the peak demand management are as follows -

- Deficit in supply at the time of peak demand
- Less transparency on demand side management
- Lack of reliable and uninterrupted power supply

System Ability:

The system should have the following abilities & functionalities:

Parameters to be captured:

- System ability to retrieve critical parameters with specific time stamps and magnitude of peak demand (kW) of all of the following, and comparing to the capacity:
    1. Real power
    2. Apparent power
    3. Reactive power
    4. Device
    5. Feeder
    6. Meter
- Aggregated consumption data is one of the critical parameters at the transformer-level, might be valuable for feeding a statistical network load forecasting model that aids in forecasting network reinforcement.

System Components Ability:

- Smart meters could also be installed at the transformer to provide direct reading. These meters and their data could be treated the same way the customer meters are. This data could be provided to the operations department on similar timescales as the aggregation reports (i.e., monthly). The difference (or delta) between the transformer reading and the aggregation of the associated meters can be noted as losses or theft.
- System should have the ability to collect the data efficiently from field sensors and devices through data capturing, transformation, transfer & aggregation components.
- Because historical durations are more related to a statistical model than short-term updates, an aggregate report may be provided monthly.

Outcomes:

The overall benefits of the peak demand management are as follows-

- Trends of peak demand over 15 minute/ hourly/ daily and monthly time frames. Report of transformers exceeding limits on a daily/ weekly/ monthly and yearly basis.
- Customer rate structures include peak demand charges within a given tariff. Ad hoc analysis of customer's peak demand can be used to determine whether the customer is on the correct tariff. This can help customers save money, if possible, as well as the utility to find errors in the customer's tariffs.
- Send voltage alerts, such as over/ under voltage, to OMS. Data should be exported after defined persistence limit, which is typically 15 minutes.

Use case 3: Theft identification & incorrect reads:

The objective of this use case is to reduce AT&C loss, incidents of unmetered supply, detection of incorrect readings and provide more clarity on electricity consumption patterns.

Challenges:

The common challenges faced by the DISCOMs are as follows -

- Meter tampering related issues
- Low MBC cycle efficiency
- Lack of visibility of unmetered supply
- Insights into consumption patterns

System Ability:

The system should have the following abilities & functionalities:

- Ability to identify meters with diverted consumption patterns
- Ability to identify customers piggybacking on other customers' meter
- Ability to calculate load factor (LF) values at the meter level and identify meters with LF (Load Factor) value greater than 100%

Outcomes:

The overall benefits of theft identification are as follows-

- Identification and reporting of theft
- Meter calibration requirements

- Manage and reduce unmetered supply

Use case 4: Power quality management:

The objective of this use case is to improve power quality, prevent deviation in synchro phasers, maintain power and load factors etc.

Challenges:

The common challenges faced by the DISCOMs are as follows -

- Inability to prevent deviations in parameters such as voltage, frequency etc.
- Issues in balancing
- Fluctuations in power factor and load factor

System Ability:

The system should have the ability to retrieve power quality, e.g., deviation of voltage by phase or some other measure, power factor and load factor, by device type for all of the following:

- 15-minute interval
- Hourly
- Daily
- Monthly
- Annually

Outcomes:

The overall benefits of the power quality management are as follows-

- Proactive identification of incidents.
- Efficient work management and troubleshooting.
- 24/7 dashboarding of power quality and reliability.
- Proactive incident analysis and operations improvement

Note: A deviation (say 10%) between phases would be considered as bad power quality (PQ). Customers have PQ triggers in their tariffs (typically Commercial & Industrial customers) and could result in penalties or reductions in monthly charges invoiced by the Utility.

Apart from the above-mentioned challenges and use cases, there are several needs and drivers of IT-OT integration for Indian distribution sector as detailed in the subsequent section.

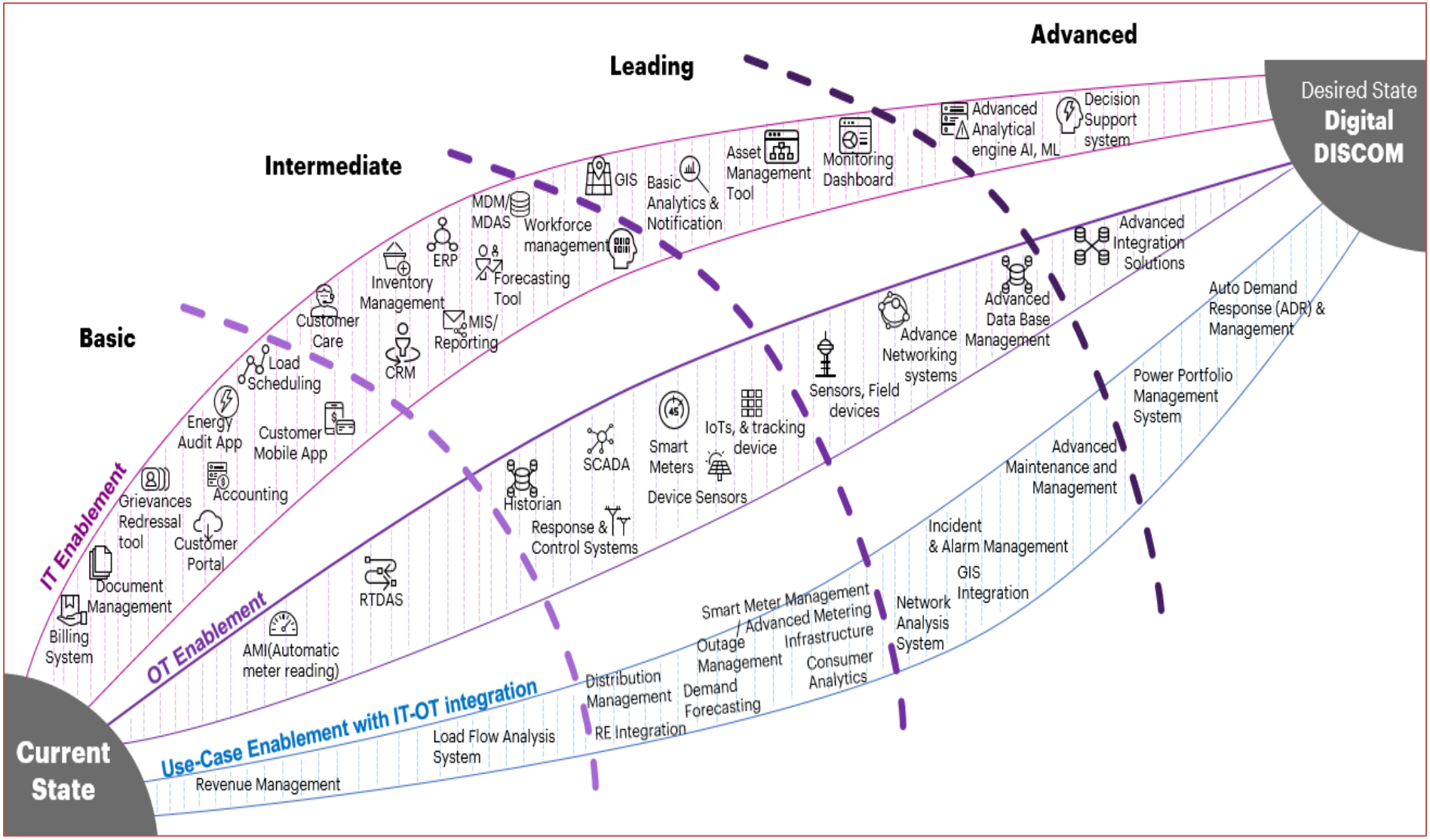
4. DISCOM digitalization journey

DISCOM digitalization is a continuous journey where a DISCOM implements various IT and OT solutions based on their own requirements to achieve aspired performances.
The roadmap highlights different phases of the digital transformation for Indian distribution sector such as:

1. **Basic**: In this phase, basic IT and OT systems and functionality have already been implemented by the DISCOM or will be implemented in the near future.
2. **Intermediate**: In this phase a DISCOM may implement systems and applications that can be enabled to mitigate current challenges and specific to different functionalities & use case enablement.
3. **Leading**: Here the DISCOM may opt of systems, applications & use cases to achieve operational effectiveness. DISCOMs may undertake different use cases through integration solutions which can further help the DISCOM to increase overall performance.
4. **Advanced**: The last phase of digitalization where a DISCOM may plan to implement data-driven solutions, high performing analytical engines, and decision support systems etc. through deployment of AI, ML, deep learning, blockchain technologies with advanced use case enablement.

Digital transformation for Indian DISCOMs is detailed below with each phase of digital journey and respective targets and objectives that can be aimed, not limited to, by any DISCOM.

Figure 20 : DISCOM digital transformation journey



5. Implementation approach for digitalization of Indian DISCOMs

As highlighted in the previous section, digitalization is a continuous process that the DISCOMs need to undertake in a phased manner to experience a seamless transition and achieve the maximum benefits out of their digitalization journey.
We recommend the following approach for the DISCOMs to undertake their digitalization journey.

PHASE 1: Assess

- **Assess maturity level** – The DISCOM should start their digitalization journey by identifying its current maturity level. This helps the DISCOM to gauge the pre-requisites for undertaking deployment of new IT and OT systems and upgradation of existing systems if any. The detailed maturity levels linked with implementation priority are described in *Annexure 4*.
- **Prioritise business challenges** – A DISCOM may face multiple business challenges depending upon its scale and region of operation. A comprehensive study of the major challenges faced by a DISCOM and the challenges which need immediate attention with respect to the industry or government norms should be made the priority in context of the necessary systems to be deployed and subsequently integration of IT & OT systems and what it intends to achieve. (Provided in *Annexure 4*)
- **Define scope** – Subsequently, the DISCOM needs to determine and define the scope of the project – the technical, functional and the economical contours within which the programme should operate. The DISCOM should identify and define the specifications, number of data points required and the assets to be integrated under the programme.
  While defining the scope, it becomes extremely necessary for DISCOM to identify the responsibilities to be shared between different stakeholders. An illustrative matrix has been provided in *Annexure 11*.
- **Plan resource and build cross-functional team** – This is a crucial activity and the DISCOM needs to carefully plan the resources required, with respect to skillsets, talent, budget and time to carry out the digitalization programme. Enabling cross functional teams to spearhead is important for a holistic approach that is scalable in the future.

PHASE 2: Strategise

- **Analyse system requirement** – Based on the current challenges and scope of the digital transformation program, in this stage DISCOMs need to Identify what are the different IT & OT systems that can be implemented or leveraged under on-going digitalization program irrespective of the maturity level. Additionally, the DISCOM should analyse the area of improvements and up to which level each solutions need to be configured based on the current systems orchestrations. This analysis needs to be included in pre-deployment assessment report to communicate with internal and external stakeholders of digital transformation program.
- **Define integration strategy** - This phase entails that the DISCOM post deployment of the IT and OT systems defines the integration strategy in terms of the data sources to converge with common data location and define data flow processes, capture intervals, frequency, methodology, availability, redundancy, data storage strategy based on data

centre or cloud storage (detailed in *Annexure 5*) etc. In this stage, the DISCOM also needs to select the best fit solution based on various internal and external techno, functional (*Annexure 6*) & economical parameters and through the comparative study of the available prominent proprietary and open source solutions (as illustrated in *Annexure 7*).

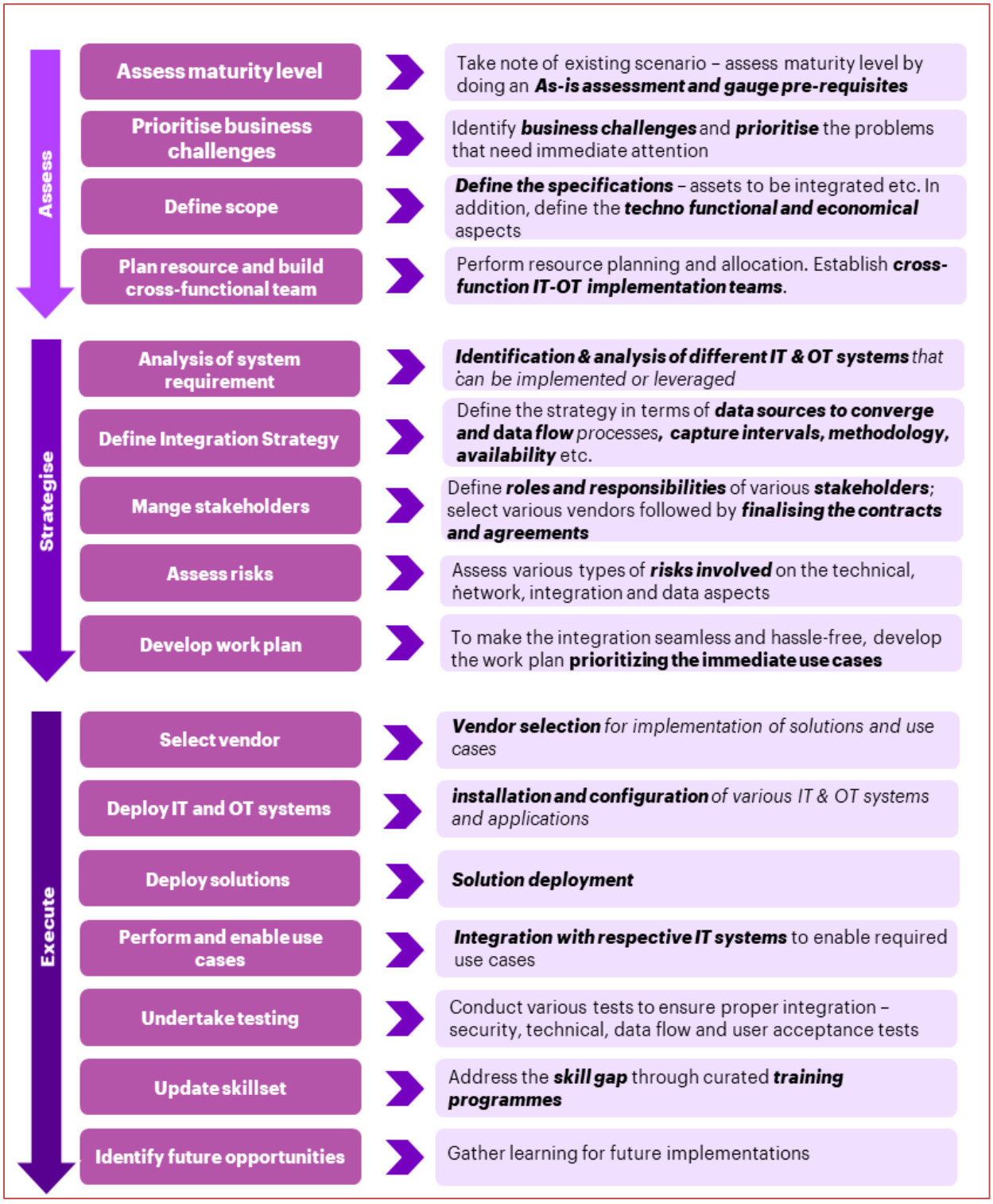
- **Manage stakeholders** – This phase covers all the pre-requisites of the deployment and solution implementation (Communication protocols, standards, vendor selection, system integrator, service level agreements etc.). It also involves defining the roles and responsibilities of various stakeholders and finalising the agreements/ contracts.
- **Assess risk** – In this step, an assessment of various types of risks involved in the implementation plan – technical, network, integration, data loss, system security etc. should be carried out. Data security and system security is one of the key parameters to maintain while assessing the overall risk of digitalization program (System security is detailed in *Annexure 8*) which also includes the data security standards and protocols to maintain, (relevant data security standards for Indian distribution sector are described under *Annexure 9*). For example, the various use cases that the DISCOM wants to enable might not be compatible with their existing systems. Such instances should be foreseen beforehand and planned accordingly to avoid scope creep along with time and cost overruns.
- **Develop workplan –** A detailed workplan indicating the key applications and use case to be implemented in order of priority along with the key activities, timelines and the responsible stakeholders to be developed which would act as the guiding document during the implementation phase.

PHASE 3: Execute

- **Select vendor** – Based on the defined scope and the budget estimation, DISCOM to decide whether to use in house resources or select third party vendors for implementing IT and OT systems and further deployment of integration solutions.
- **Deploy IT and OT systems –** In this stage a DISCOM may install and configure various IT & OT systems and applications (as defined in project scope) with the help of 3rd party and other external service provider as per the workplan and milestones. Broadly this stage includes below steps:
  I. Preparation of the detailed implementation plan using Agile Framework
  II. Selection and Onboarding of Implementation Partner
  III. Installation and configuration of software, hardware of various IT & OT system on current environments.
  IV. Perform testing of the system, UAT, regression test as per decided acceptance criteria and SLA.
  V. 'Shadow support' the deployed system or applications after go-live before hand over.
- **Deploy solutions** - This phase involves the installation of the integration solutions of various IT and OT systems to enable further use case.
- **Perform and enable use cases –** Subsequently, solution will be integrated with respective IT systems to enable the required use cases. DISCOMS can define various performance metrics based on parameters to measure the success of the use cases enabled through integration to solve the bigger business challenges. DISCOMs also need to maintain use case specific data flow and integration framework as described with examples in *Annexure 10*.

- **Undertake testing -** Testing with respect to technical, data flow, user acceptance, security etc. are to be conducted.
- **Update skillset** - The DISCOM should also address the skill gap created due to the new IT-OT systems and undertake workforce trainings to close the gaps.
- **Identify future opportunities -** Lastly, gathering the learnings from the implementation process helps gauge the future opportunities for further integration for future use case deployment.

Figure 21 : Implementation approach of digitalization journey on IT & OT landscape



6. National roadmap for operationalizing digital transformation for Indian DISCOMs

As important it is for the DISCOMs to strategise their own digitalization journey, it is also imperative that the policymakers drive the programme at a sectoral level. This is important for creating an urgency and make the necessary tools available for the DISCOMs to embark on the journey. We recommend the following phases as part of the national roadmap for enabling digitalization for Indian DISCOMs:

Table 6: Strategic sectoral roadmap for DISCOM digitalization journey

Sl. No	Phase	Description	Outcome	Roles and Responsibility
1	Create DISCOM assessment framework*	MoP and CEA should create a checklist/ framework to analyse the current as-is-model of techno-functional operability for DISCOMs	Current state of DISCOMs with respect to different IT and OT systems deployed and integration if any	**MoP and CEA** to create assessment framework for analysing as-is state of Indian DISCOMs **Individual DISCOMs** to analyse their current IT-OT landscape as per the framework
2	Evaluate lagging areas and release guidelines for implementation	DISCOMs in collaboration with State and Central agencies need to take note of the lagging areas with respect to standards, protocols, methodologies, guidelines etc. (specifically in the areas of network communication, infrastructure, IT system enablers, middleware data transfer, system security, data flow methodologies, resource management, skill set required). The Central and State stakeholders also need to establish the guidelines such as suggested vendors, third party integrators, international best practices, and case studies etc. for the implementation.	Identification of pre-requisites, bottlenecks and improvement areas that require interventions before DISCOMs embark on their IT-OT journey	**CEA/ CERC/ SERC** to undertake interventions, especially with respect to regulations
3	Introduce policies and schemes	The stakeholders should evaluate the DISCOM assessment reports and	Enabling DISCOMs to digitalize their	**MoP, CEA and State government** to develop

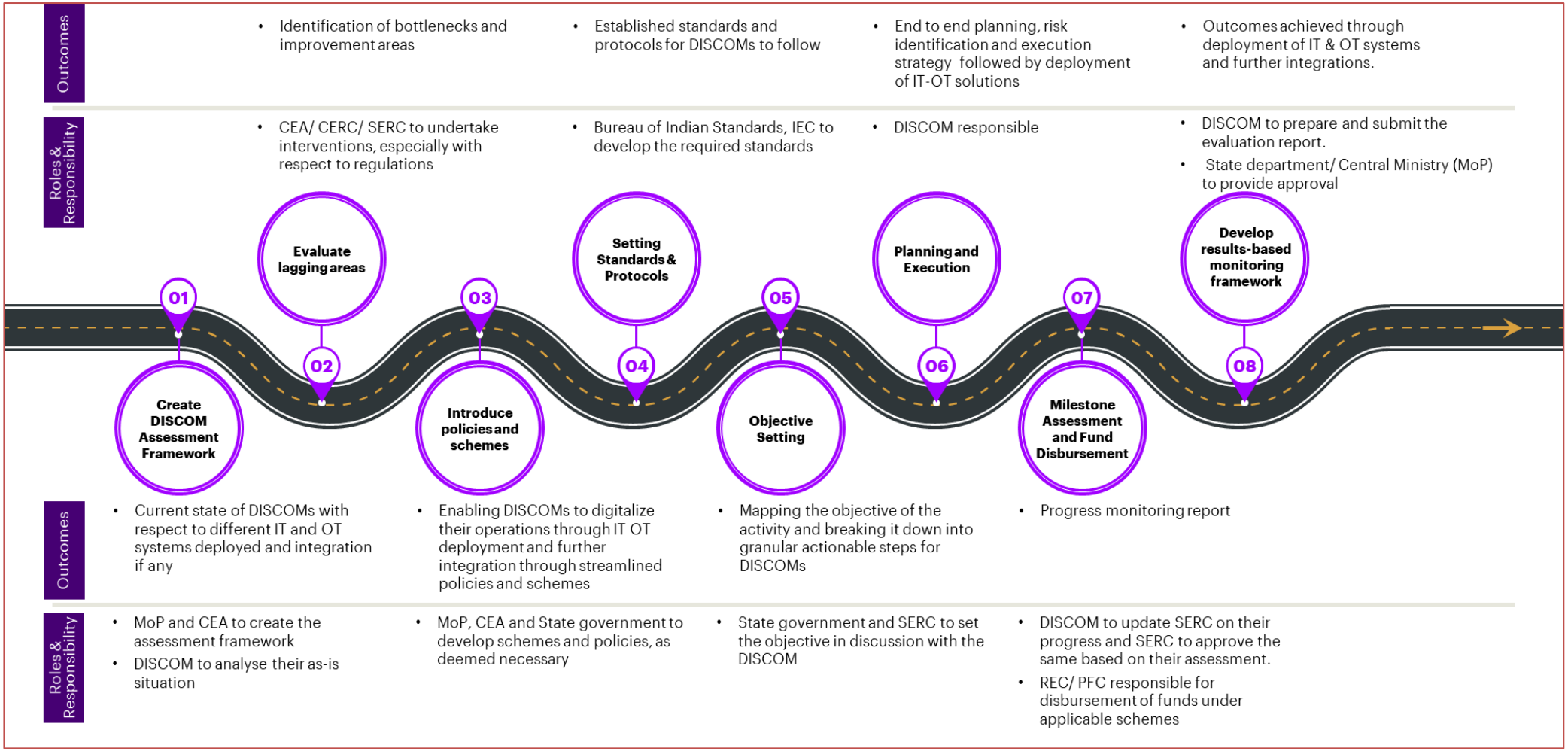
Sl. No	Phase	Description	Outcome	Roles and Responsibility
		the lagging areas of the sector to identify the requirement for any policy level (or schemes in the form of financial aid) intervention to ensure seamless IT-OT integration.	operations through IT OT deployment and further integration through streamlined policies and schemes	schemes and policies, as deemed necessary
4	Setting standards & protocols	The regulatory bodies should choose to either create new standards and protocols or opt for the best practices from the international standards/protocols on the basis of the needs of DISCOMs (Standards and protocols for OT system integrator, device calibration, common data layer, data flow mechanism guidelines, IT infrastructure integration, system security and recourse/ process management etc. should be figured out.)	Established standards and protocols for DISCOMs to follow	Bureau of Indian Standards, IEC to develop standards as required
5	Objective setting for DISCOMs	State governments in collaboration with SERCs should set objectives for individual DISCOMs which are aligned with their maturity levels, based on the milestones to achieve and the prescribed time period for the implementation phase. On the basis of State authorities' guidelines and the schemes, each DISCOM then needs to establish their goals and objectives at a more granular level by identifying the low hanging fruits in terms of use case enablement and	Mapping the objective and breaking it down into granular actionable steps for DISCOMs (based on goals of individual DISCOM)	**State government and SERC** to set the objective in discussion with the DISCOM.

Sl. No	Phase	Description	Outcome	Roles and Responsibility
		the key challenges they wish to address or the ones which are critical for their business. This phase can begin in parallel with the setting of standards and protocols phase.		
6	Planning and execution	This phase involves identification and prioritisation of business challenges to be addressed, defining the scope of the project and planning for the necessary resources. It is followed by defining the integration strategy, stakeholder management and the risk assessment in the implementation process. Final stage involves deployment, testing and skills training for the employees.	End to end planning, risk identification and execution strategy followed by deployment of IT-OT solutions	**DISCOM** to undertake the planning and execution phase
7	Milestone assessment and fund disbursement	As per the objectives and the milestone set, achievements to be monitored to assess the progress of the project. On the basis of timely milestone achievement, fund disbursements (if any) will be done.	Progress monitoring report	**DISCOM** to update SERC on their progress and **SERC** to approve the same based on their assessment. **REC/ PFC** responsible for disbursement of funds under applicable schemes
8	Develop results- based monitoring framework	State governments and funding agencies to create success metrics in line with the guidelines of the MOP to analyse the milestones achieved, business challenges mitigated and the increased operational efficiency of the DISCOM to gauge the level of achievement vis-a-vis the objectives set.	Outcomes achieved through deployment of IT OT systems and further integration	**DISCOM** to prepare and submit the evaluation report. **State department/ Central Ministry (MoP)** to provide approval on the same

Sl. No	Phase	Description	Outcome	Roles and Responsibility
		The evaluation report to be prepared by the DISCCOM and to be sent to the State Government/ MoP after each implementation cycle.		

*Sample DISCOM assessment framework is described as a part of *Annexure 4*

Figure 22 : Digital transformation implementation roadmap for Indian distribution sector



7. Change management and governance

Deploying various IT and OT systems and the subsequent integration of the same is a complex process where the relevant stakeholder across the organization needs to come forward, recognize the need for transformation and collectively address the business needs by learning new behaviours, skills, and ways of working. Thus, change management, defined as the methods and manners in which an organization describes and implements change in both its internal and external processes, becomes very critical for all DISCOMs, undertaking their digitalization journey. This includes preparing the necessary steps for change, monitoring pre- and post-change activities, anticipating challenges, and supporting employees to ensure successful implementation.

Along with change management, it is important to define the change governance framework as well while considering the digitalization journey. Change governance is both a decision-making process and a management philosophy. It is based on the fundamentals of change management, but it is not an implementation activity. It is a framework that starts the process of aligning strategy, objectives, resources, and organizational procedures. Furthermore, change governance takes a 'balcony perspective', thus it is more strategic and examines the project lifecycle as well as the links and alignment across departments, projects, and processes across the company.

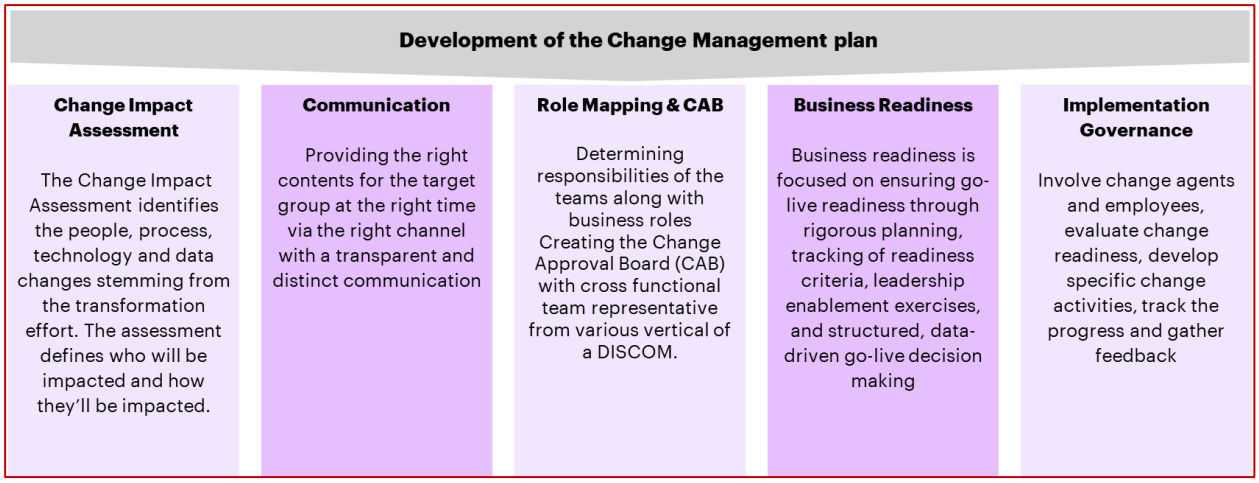
The difference between the two is that change management focusses on implementation, whereas change governance focusses on alignment with the overall strategy, looking at the big picture to identify problems and mitigate risks.
The larger problem is not managing change, but generating organizational alignment around objectives, strategy, tools, and methods. Governance builds on the ethos of change management. It looks at whole systems and fosters meaningful engagement with stakeholders. But where change management focuses on “who” and “how,” governance adds the “what” and the “why.” Change management typically revolves around implementation of a single initiative whereas governance begins earlier, taking an enterprise view.
DISCOMs need to look at the ‘whole picture’ and examine the complexity of the change initiative and its effects on the systems, processes, and people. DISCOMs need to follow a streamlined and well thought out process as digitalization with the focusing on IT-OT implementation is a significant organizational change. It requires many levels of cooperation and involves multiple stakeholders to come together. Increased communication among the employees and stakeholders helps in developing alignment throughout the process and develops change advocates. DISCOMs need to setup roles and responsibilities so that employees are enabled with the right set of skills (via training or activities) and priorities are clearly defined.
Thus, developing a structured approach to change is critical to ensure a smooth transition while mitigating disruption in the systems and processes as detailed below.

7.1 Change management strategies

The ultimate target of digitalization on the lenses of IT & OT system implementation & integration for a DISCOM is to enable a data driven organization. DISCOMs need to undertake change management, governance plan and strategies for the acceptance of various IT & OT system & integrated use-case enablement. In the context of Indian distribution utilities, the change management components can be classified into five dimensions:

1. Change Impact Assessment
2. Communication
3. Role Mapping & CAB (Change Approval Board)
4. Business Readiness
5. Implementation Governance

Figure 23 : Change Management Plan



These change components are described in detail below:

7.1.1 Change impact assessment

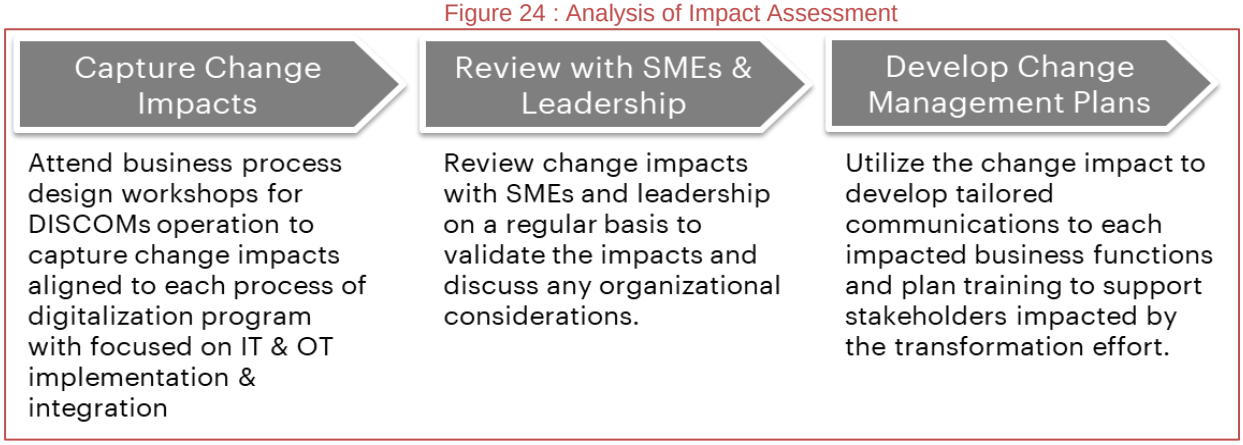
The Change Impact Assessment allows a DISCOM to comprehend the scope and nature of changes that arise from the digitalization transformation effort. The following are the key questions DISCOMs should focus on:

- What is changing and to what extent is the digitalization (based on IT-OT system implementation & integration) being incorporated? This evaluation applies to each DISCOM irrespective their maturity level and is driven by the target use cases to be enabled.
- Who will be affected by the shift? What departments or stakeholders will be impacted by the transformation process as a whole?
- What impact will these modifications have on various business processes? The DISCOM must examine the business processes related to each use case and determine the steps that must be altered in the respective business processes.
- What new employee skills or expertise are required that might have implications for the organisation? This simplifies the process of identifying actions, with respect to learning and development, that must be taken outside of the project operations to prepare for the changes.

Process of Impact assessment:

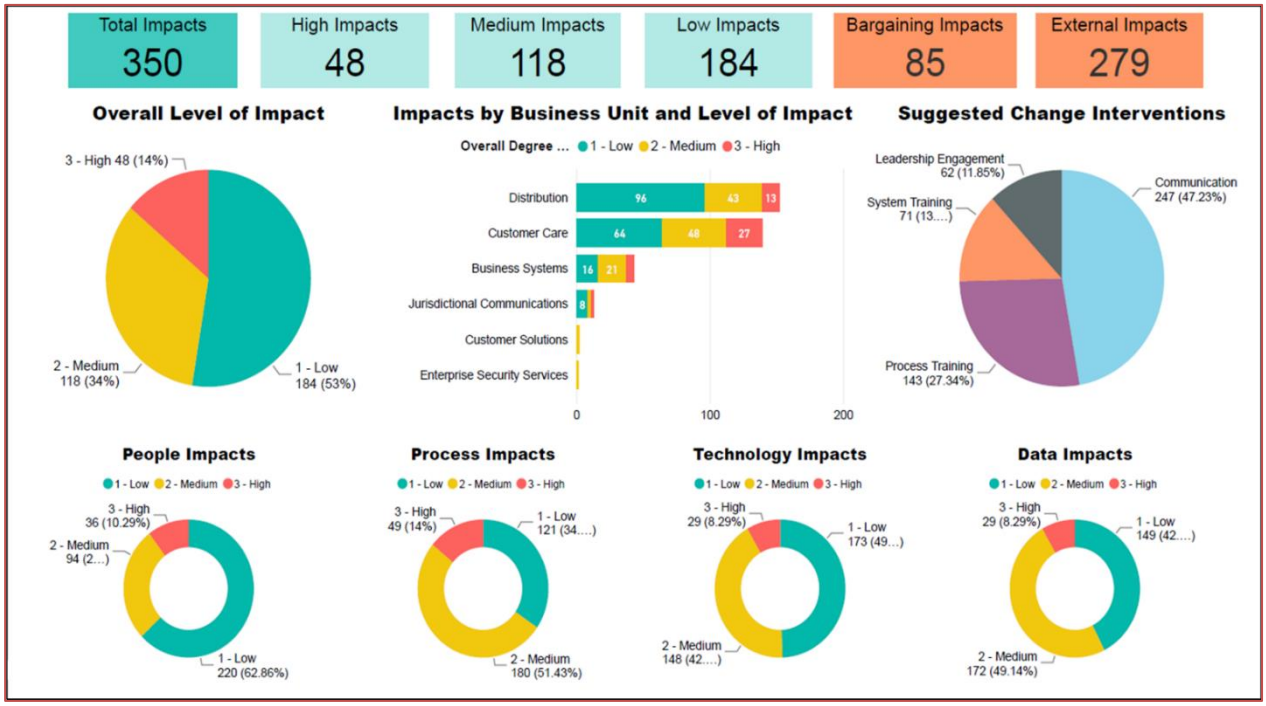
The following is a summary of the approach for analysing the impact of change.

Figure 24 : Analysis of Impact Assessment



The recommended method for communicating the impact of change is via an Impact Assessment Dashboard. Below is a sample Impact Assessment Dashboard:

Figure 25 : Illustrative Dashboard for Impact Assessment



The Impact Assessment dashboard measures the impact as People Related, Process Related Impact, Technological Effects, and Data Related Impacts. The effect assessment dashboard may be built depending on each use case provided by digitalization program on IT-OT implementation landscape.

7.1.2 Communication

One of the most essential aspects of change management is communicating the change and its consequences through the appropriate channels to the relevant stakeholders. To solve

contemporary business issues, the Indian distribution industry is increasingly combining the operation and maintenance of IT and OT systems, which are currently operating in silos. While enabling various IT-OT programmes under digitalization initiatives, many internal and external key stakeholders must make various changes in terms of people, processes, and technology. As a result, the correct communication platform and techniques are critical to the overall success of IT & OT enablement & integration initiatives.

Throughout the project, a combination of written and in-person interactions should be used to gradually raise stakeholders' awareness of system and process related changes. Stakeholders who are significantly affected or are undergoing a complex transition should have even more frequent communication.

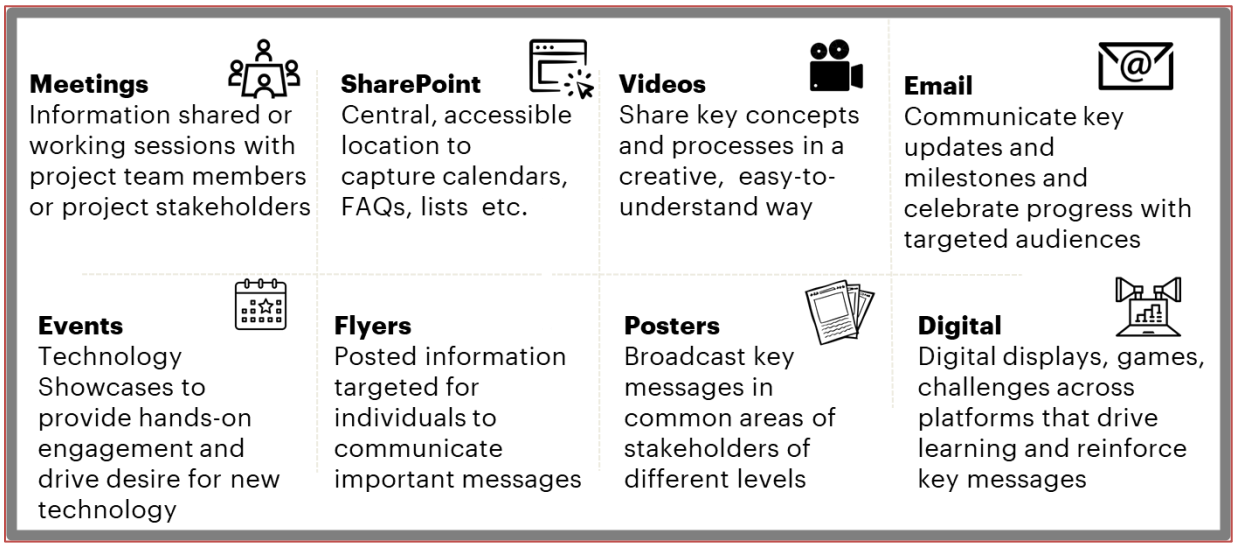
Process/Tools to establish effective communication:
To bring all stakeholders on board with the change management programme, DISCOM must choose the best approach of communicating information. Basic communication tactics may include e-mailing essential updates, using a digital display for quick information delivery, and using a shared file/share point to handle FAQs, among others.

Throughout the lifespan of any IT-OT enablement project, various kinds of messages, updates need to be communicated. Both the stakeholder group and the message being delivered, influence the mode of communication used. In essence, every communication accomplishes one of the following goals:

- Debunk rumours
- Notify Stakeholders
- Give instructions
- Obtain/Request information

Various techniques of communicating change are given below:

Figure 26 : Change communication channels



7.1.3 Change Approval Board

Role mapping is a part of managerial and human resource changes that must be considered while implementing IT-OT projects under digitalization initiatives. This component specifies the responsibilities required regarding the tasks or jobs to be completed for target use cases. Regardless of the maturity level, DISCOMs must redesign the roles and administrative structure, if necessary.
This initiative is crucial in ensuring that individuals have the necessary access to perform their work and that the system's security, integrity, as well as business controls, are maintained.

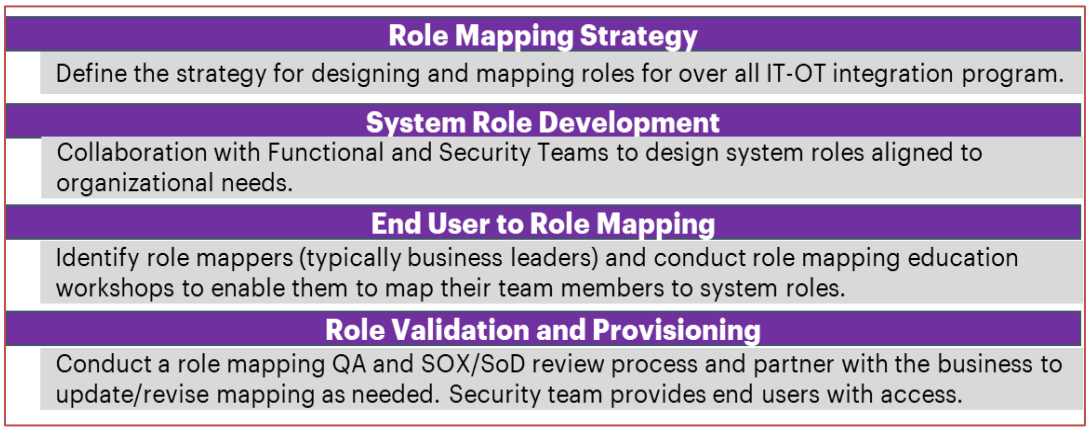
Role mapping is important for several reasons, including:

- It ensures that all the stakeholders (Including IT & OT, digitalization cross functional team) have the appropriate system access to perform their jobs
- It supports process compliance, business controls, and proper segregation of duties (SoD)
- It is used to support role-based training assignments

Process to establish effective role mapping for an Indian DISCOM:
CAB (Change Approval Board) is a key change management team that approves critical changes and makes decisions on business process implementation. Hence, role mapping also includes CAB's roles and structure.

The following are the illustrative steps on how to develop managerial and business roles in the Indian distribution sector.

Figure 27 : Managerial and business role mapping for Indian DISCOM



CAB (Change Approval Board):
Change Approval Board or CAB is a service management governing body that is responsible for identifying, reviewing, authorizing, and monitoring technological changes. CAB's primary role is to validate and authorize changes, as well as to ensure that change proposals and concerns are addressed swiftly and efficiently. Several triggers for escalation to the Change Approval Board can be considered; the board/committee lead is responsible for determining which triggers initiate the escalation process.

Few examples which trigger the escalation to CAB are listed below:

IT-OT Services/ Transitions

- Integration issues across services and service providers
- Significant changes to planned services in service portfolio & IT-OT service catalogue
- Recommended changes to service providers (as a result of poor operational performance)
- Recommendations to move from an internally provided service to a 3rd party vendor

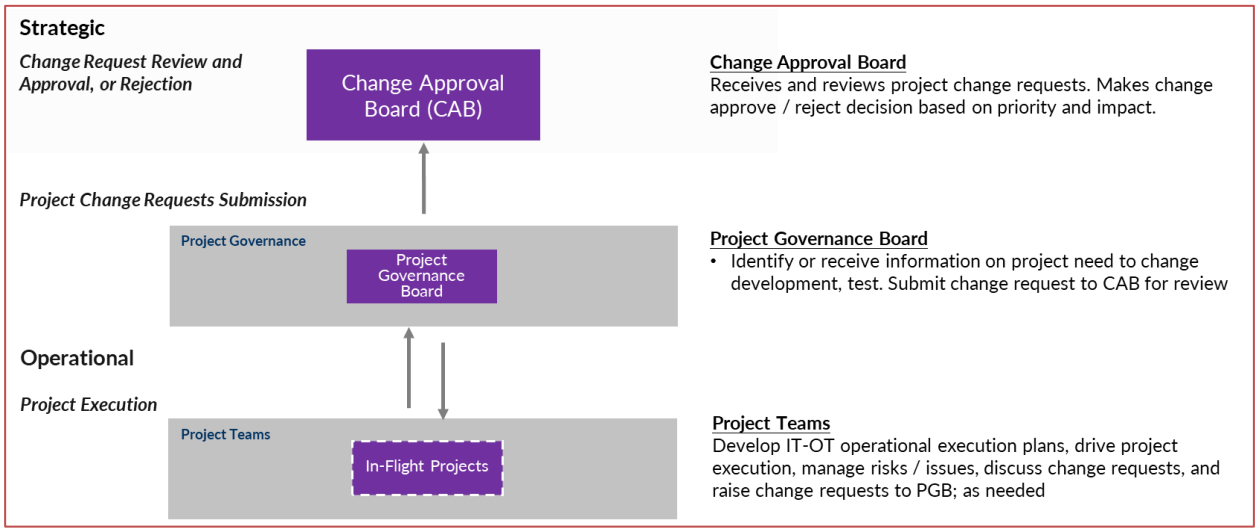
Project Governance

- Recurring lapses on SLAs that require re-negotiation of service agreements
- Project decisions and recommendations to address escalated issues

Change Approval Governance model and interfaces:

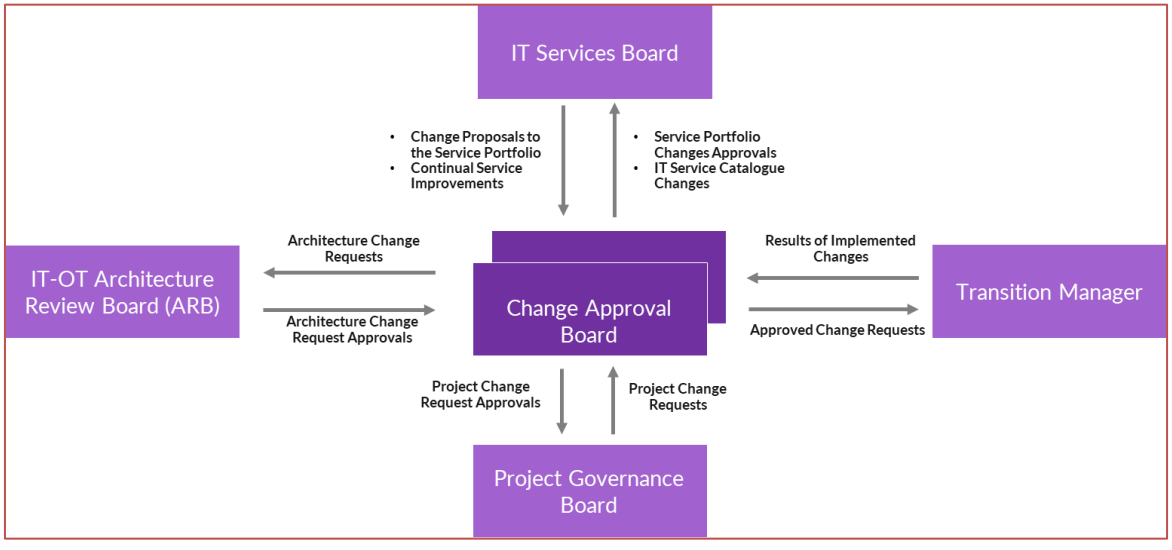
Change Approval Board receives, or approves/rejects change requests raised by project teams or the Project Governance Board. The Generic Model is given below.

Figure 28 : Generic model of change approval governance



Change Approval Board (CAB) has push and pull interactions with the IT & OT governance forums and work groups as illustrated below.

Figure 29 : Organization of IT-OT & digitalization governance forums and work groups



The roles and responsibilities of IT-OT digitalization governance forums & different work groups interfacing with CAB is provided below:

Table 7: Roles and responsibilities of different boards

Sl. No.	Boards & Roles	Responsibilities
1	**IT-OT Architecture Review Board (ARB)**	• Preparation of timely review agenda of the digitalization architecture • Responsible for approval on any architectural changes • Revision/ updation of data transfer protocols • Revision/ updation of data security protocols
2	**IT Services Board**	• Oversee IT organization to ensure alignment of strategy with client business needs • Facilitating any significant changes to planned services in the service portfolio & service catalogue • Addressing integration issues across services and across service providers • Approving service portfolio changes • Develop IT service strategy, monitor performance & drive improvements and retirements aligning to client business needs
3	**Transition Manager**	• Provide and implement recommendations for moving an internally provided service to a 3rd party vendor • Review new changes and the risks/ impact assessments: – Impacts to services & SLAs – Impacts to infrastructure, applications, security, business processes, and architecture – Impacts to resource capacity if the change is implemented – Ensure all proposed changes adhere to standard methods, procedures and quality requirements (i.e., testing is completed, roll-back plans are in place, and implementation plan is complete) • Defining roles and responsibilities of different stakeholders with communication strategies of change management (including sharing the change request, escalations, priorities etc.) • Planning, facilitating, and monitoring learning & development programs related to new changes.
4	**Project Governance Board**	• Oversee & monitor project performance including tracking budget, scope, and schedule • **Assurance, Compliance & Security** - Oversee & monitor alignment with technology security standards • **Portfolio Management -** Oversee & monitor portfolio & program performance, capturing and prioritizing new demand and tracking overall investment and portfolio performance. • **Vendor Management -** Define and measure supplier performance to optimize level of service provided.

Roles of CAB and its mode of operation:

The basic structure of roles of CAB with respect to Indian distribution is given below:

Table 8: CAB roles and responsibilities

Sl. No.	Roles	Responsibilities
1	**Change Management Lead (Chair)**	• Prepares CAB agenda • Has ultimate approval authority for change requests. • Publishes CAB meeting decisions in terms of minutes of meeting, and updates change requests as and when required.
2	**Change Requestor**	• Presents new change requests on behalf of the project team • Provides clarification for change requests as needed
3	**PO Lead**	• Represents the applications / infrastructure, service area to understand impacts of changes to applications / infrastructure services • Ensures appropriate operational service documentation is created & accepted by CAB stakeholders prior to authorization of a new change • Ensures all pre - deployment activity is prepared prior to authorization by the CAB (e.g., test plans, back-out plan, implementation plans are documented and complete) • Provides input on success or failure of recently implemented changes
4	**Relationship Managers (as needed based on discussions)**	• Represents business units to understand impacts of changes to business processes, services, etc. • Communicate change approval decisions with the appropriate business stakeholders
5	**Project Manager (as needed)**	• Answers questions about a release or test results
6	**Service Desk Manager (as needed)**	• Checks incidents that have occurred as a result of recently implemented changes in the live environment

To promote effective and efficient decision making, the Change Approval Board (CAB) functions in three different modes.

Table 9: CAB functioning models

Sl. No.	Working Model	Description	Frequency
1	**Standing Meeting**	A series of standing, in-person or virtual meetings that enable the CAB members to come together and make decisions.	Bi-weekly
2	**Ad-hoc Meeting**	An urgent meeting held outside of usual occurrence, to resolve unexpected issues or make a quick decision.	As required
3	**Offline**	A mix of offline (e.g., written communication) and online communications for following up on any unresolved issues from Standing CAB Board sessions and/or to make quick decisions.	As required

7.1.4 Business readiness

Business readiness encompasses organizational, functional, and technological readiness, all of which will be tracked and tested across several criteria on the Readiness Wheel. Continuous monitoring and measurement of the established criteria prior to the go-live stage ensures that decision makers have all the information they need to make an informed decision.

Figure 30 : Business Readiness Wheel

The entire business preparedness team is organized into readiness squads based on business verticals. The duties of these squads are to assess readiness based on the impacted business processes that are part of the change program under the IT & OT system implementation & integration project. These squads establish project readiness standards based on technological and functional needs. They also govern the readiness plan and take the go-live decision.

A good business preparedness operation offers several advantages:

- Ensures that business concerns are considered when deciding whether to release capabilities into the DISCOM.
- Allows for continuous evaluations of the DISCOMs preparedness to undertake and enable change and engage in interventions for a successful deployment of the system, process, applications, software, and hardware.
- Assists in preparing leaders to be "ready" from day 1 to support the transformation (from Indian DISCOM's siloed operation to integrated IT-OT architecture).

Business Readiness Process:

An example of business preparedness approach in the context of Indian distribution scenario shown below:

Figure 31 : Generic approach for the Business readiness plan

The business readiness team must assess readiness based on technological guidance, resource planning & vendor contract planning. DISCOMs must establish CoE (Center of Excellence) with readiness champion squads to oversee various readiness components such as software, hardware, network or infrastructure readiness, and so on.

- **Technological Guiding Principles**
  Techno-functional squads must be assigned to ensure that the technical and functional prerequisites are in place. The following are some of the tasks of the preparedness squad:
  - Existing applications/software like SCADA, RT-DAS, Monitoring, Billing systems etc. need to be tested and checked with respect to version readiness, data security readiness, system & configuration readiness etc.
  - The respective squad needs to check the standards, policies and frameworks which are essential to establish several integration layers, security systems, communications etc.
  - The hardware and infrastructure squads are responsible to check what are the old models of hardware/legacy infrastructures followed by how to update the necessary hardware and infrastructure to establish target use cases. As an example: old version of smart meters might not be supported by modern communication protocols, the squads need to identify the smart meter's new aligning features and a way to modernize the meter (lastly submitting a readiness report to the CAB team).
  - Stakeholders' engagement squad needs to guide & monitor the readiness of different stakeholders, update contracts and agreements.
- **IT-OT implementation & integration resource planning**
  The centre of excellence team must identify essential IT & OT resources, as well as their respective roles and responsibilities. Furthermore, the DISCOM must establish centralized IT-OT cross-functional teams to manage diverse business process implementations enabled by the IT & OT systems implementation & integration program. These teams must also establish progress related communications using CAB working mechanisms.
- **Vendor contract planning:**
  IT-OT integration solutions are made up of a variety of systems, software, hardware, and communication technologies. A standalone product must be integrated with various third-party solutions, external apps, and devices. Each of the integration components (OT system integrator, Common data layer, IT infrastructure integrator, as previously described) may have a distinct vendor or OEM. To handle multiple agreements and

contracts, the COE team must have dedicated vendor management squads. IT-OT integration solution/product suit execution often employs two distinct forms of contracts or licensing structures as detailed below:

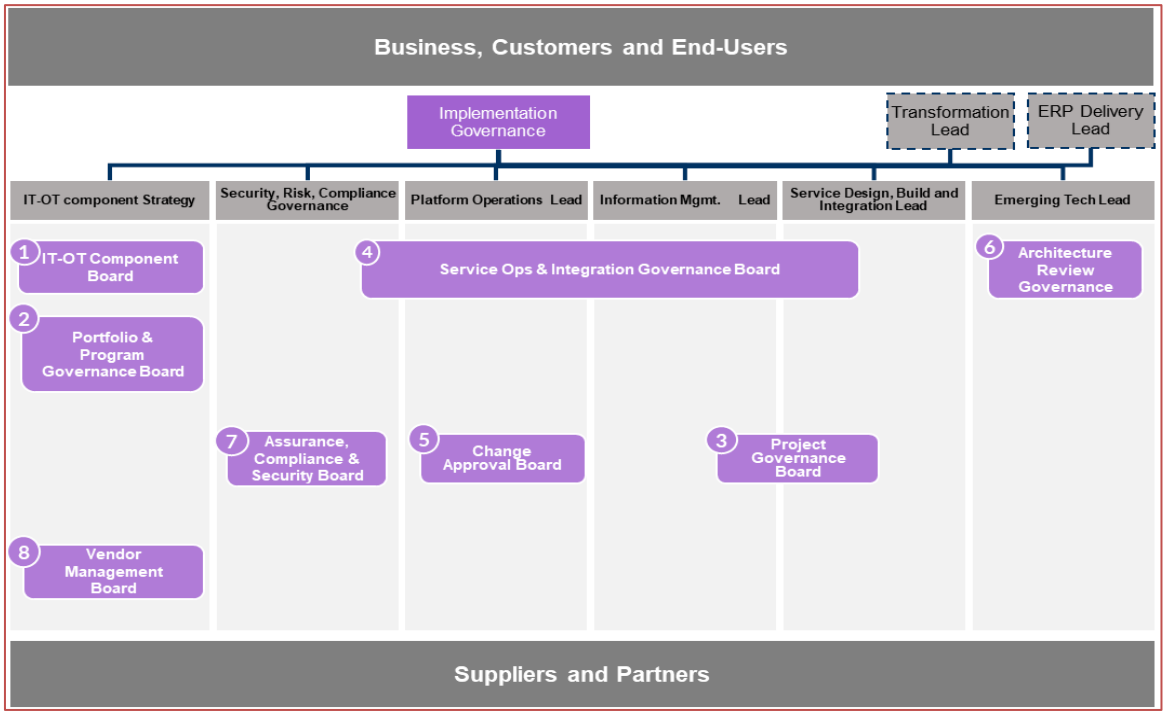
i. **Perpetual licensing**: This is a long-term licensing/contracting strategy that pertains to all components of an IT-OT integration solutions. A DISCOM needs to pay a lump sum amount to get a license as required, the range of which varies according to the number of data points that need to be connected to the central data location. DISCOM must also pay 15-20% of the total lump sum payment as annual maintenance costs. This type of contract is more prone to vendor lock-ins and are ineffective in the Indian setting since they rely on a single solution approach. This poses a challenge for the DISCOMs in addressing potential business issues and enabling new use cases in the foreseeable future.

ii. **Subscription based licensing**: This type of license is more prevalent because IT-OT solutions are increasingly offered as product as a service. This contracting model allows a DISCOM to choose a pay-as-you-go strategy. In general, these solutions include a one-year subscription and a payment structure that includes yearly maintenance costs. DISCOMs can subscribe to the solution or enable features as needed or depending on the planned use case enablement program; also, a distribution utility can remove any individual feature from the overall offering if it is no longer necessary. This contracting/licensing process reduces the risk of vendor lock-in, but it is more susceptible to pricing modification and repeating contract making.

7.1.5 Implementation governance

IT-OT implementation & integration initiatives must be collaboratively overseen by various governing boards. These boards, within the operational model procedures, assist in the facilitation of choices necessary for execution and management across a DISCOM's IT-OT enablement & convergence program.
A basic illustration of such a governance model is given below:

Figure 32 : Implementation governance model for IT-OT integration initiatives



- **IT-OT Component Board** - Oversee IT and OT components such as smart meters, devices, SCADA, billing, and current software and hardware, as well as select upcoming hardware and software convergence methodologies. Assist the DISCOM in ensuring that strategy design and implementation are in line with the business challenges.
- **Portfolio & Program Governance Board** - Oversee & monitor portfolio & program performance, capturing and prioritizing new use case enablement and tracking overall investment and portfolio performance.
- **Project Governance Board** - Oversee & monitor project performance including tracking budget, scope, and schedule.
- **Service Operations & Integration Governance Board** - Develop IT-OT enabled business process service strategy, monitor performance & drive improvements aligning to targeted use case enablement.
- **Change Approval Board-** Identify, evaluate, approve, and manage technological changes.
- **Architecture Review Governance** - Maintain alignment of IT-OT integration architecture & manage innovation.
- **Assurance, Compliance & Security** - Oversee & monitor alignment with technology & networking security standards.
- **Vendor Management** - Define and measure IT & OT device supplier performance to optimize level of service provided.

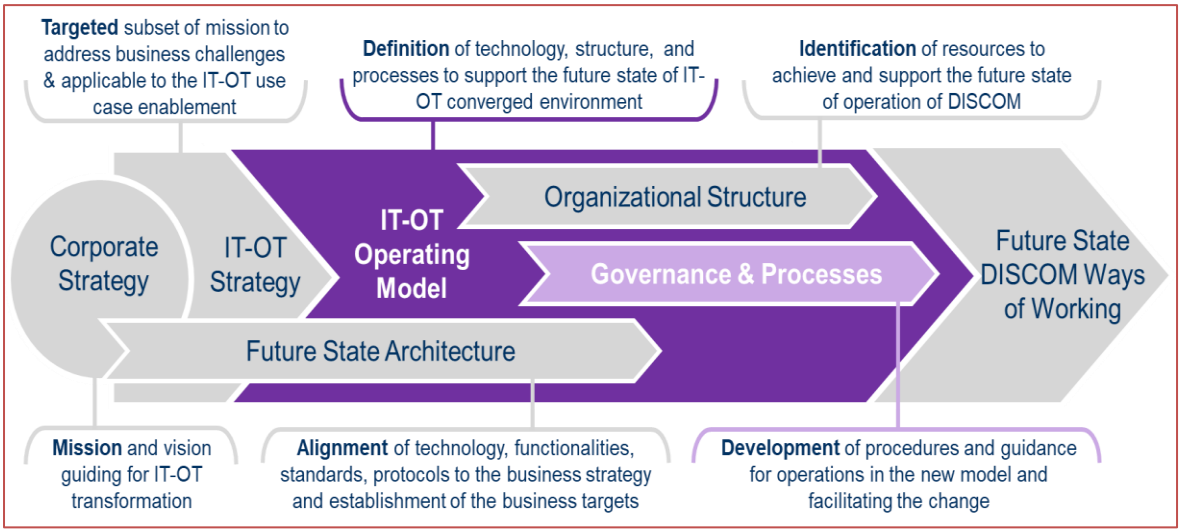
7.2 Change governance framework

Digitalization with the focusing on IT-OT implementation & convergence strategies comprise of a wide variety of technological, managerial, and business process related changes. The majority of Indian DISCOMs continue to run their business applications and solutions in silos, whereas the organizational and operational changes require integrating existing system operations and implementing new business solutions using IT-OT convergence.
This section demonstrates how the change governance model is used for OT-IT implementations in the Indian distribution sector, as well as a basic roadmap for achieving the specified future state of IT-OT operations.

7.2.1 Change governance model

DISCOM must implement an IT & OT system enhancement & convergence program based on the existing business challenges and selected use cases. IT-OT integration is part of the Indian distribution sector's large-scale transformation to create a specialized model to regulate and oversee the technological, functional, management, and process changes.
An illustrative model of governance is outlined below:

Figure 33 : Change governance model for IT-OT operating model

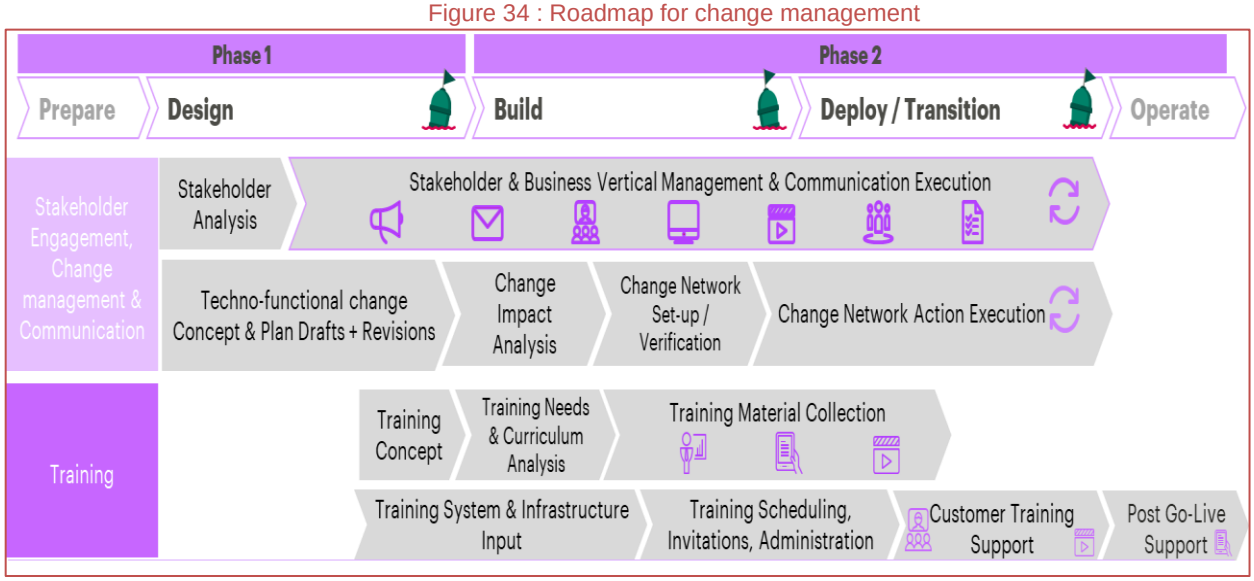


7.2.2 Change roadmap & milestones

To promote process clarity and transparency, a comprehensive change roadmap must be presented to all relevant departments and stakeholders. This roadmap is an element of the governance model, and a comprehensive framework must be established before implementation.

A detailed roadmap-based strategy can assist DISCOMs secure funds from financial institutions based on the milestones achieved. The following is a basic roadmap for an Indian DISCOM to facilitate the change management during the IT-OT convergence.

Figure 34 : Roadmap for change management



7.2.3 Capability program strategies

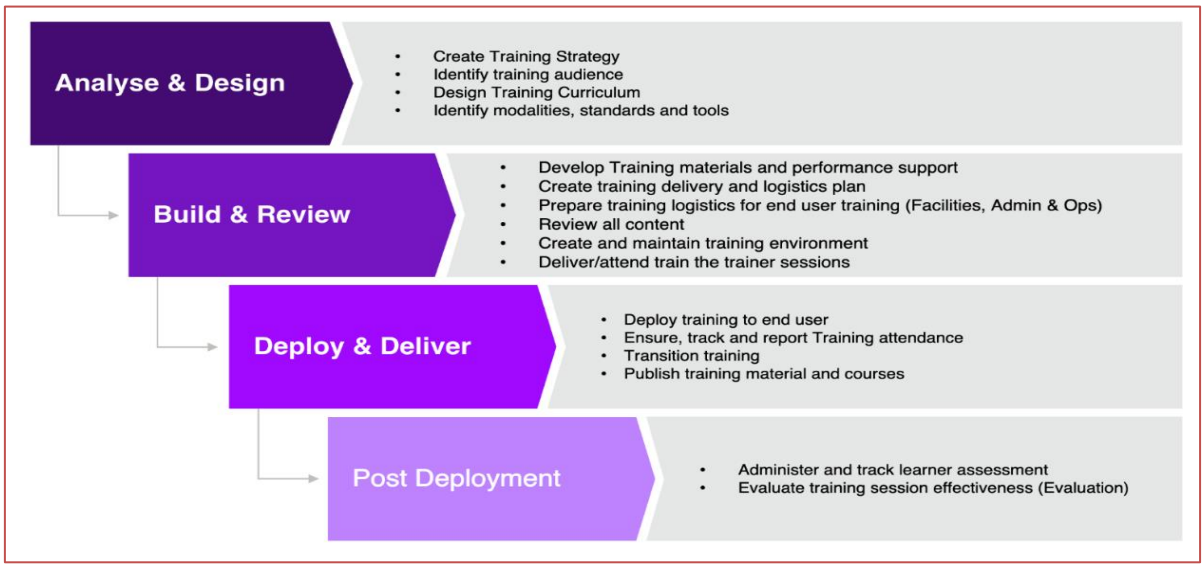
Learning & Development (L&D), also known as Capability Programs, is a continuous process of upgrading employees' knowledge, competencies, and abilities to increase their productivity. DISCOMs can accomplished swift change management with the help of a variety of learning programs that assist the employees in upskilling them with the specifics of IT-OT integration.

Goal of Learning & Development:
The purpose of learning and development is to assist individuals or teams to improve or modify their behaviour by sharing knowledge and insights that help them do their jobs better or nurture attitudes that help them perform better. The following are the broad goals of the program:

- Individual self-actualization
- Employee satisfaction
- Improved business performance

The L&D process can be broken down into the following key steps:

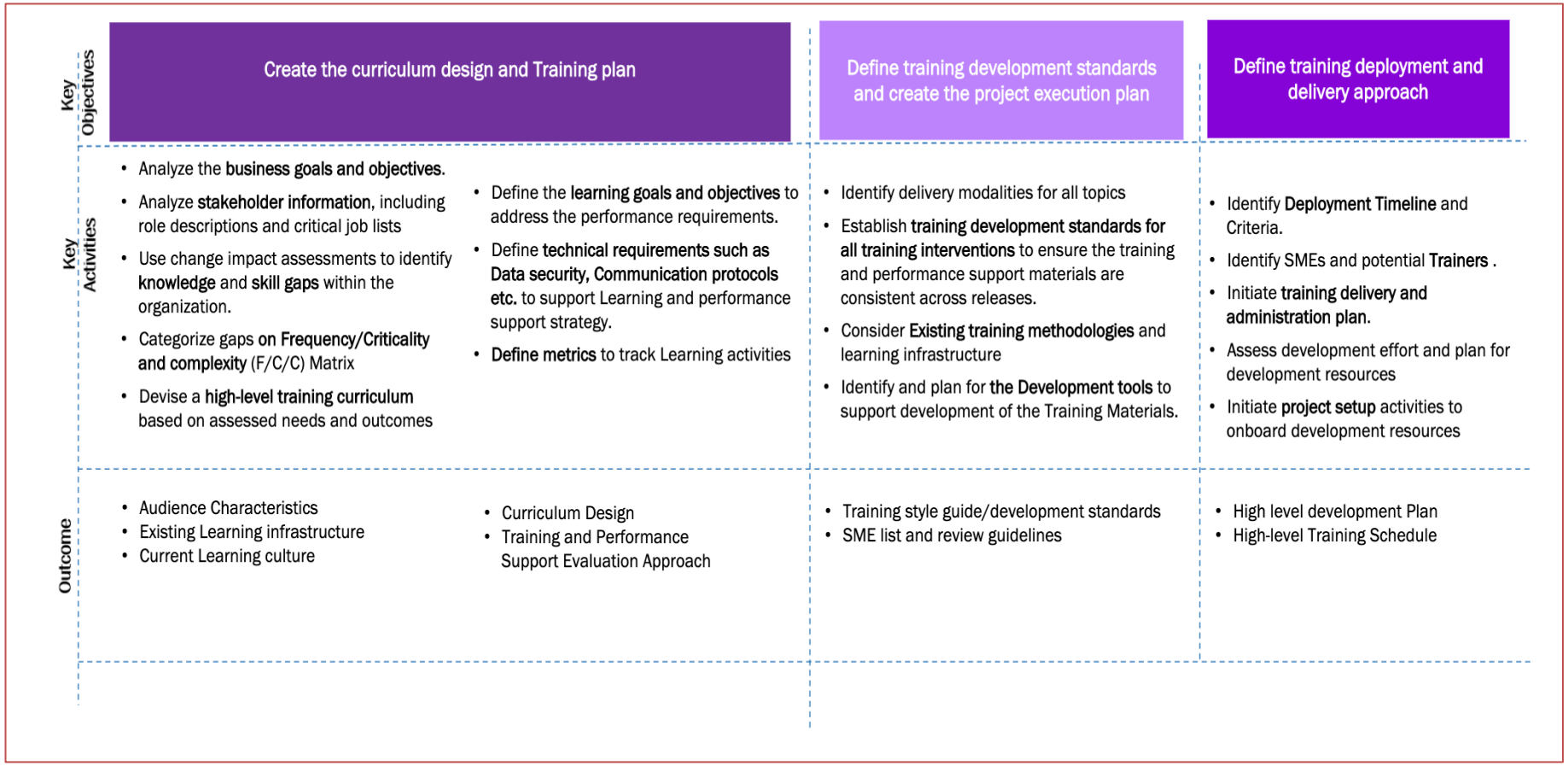
Figure 35 : Overview of L&D process



The individual phases of the Learning and Development process in detail are described below:

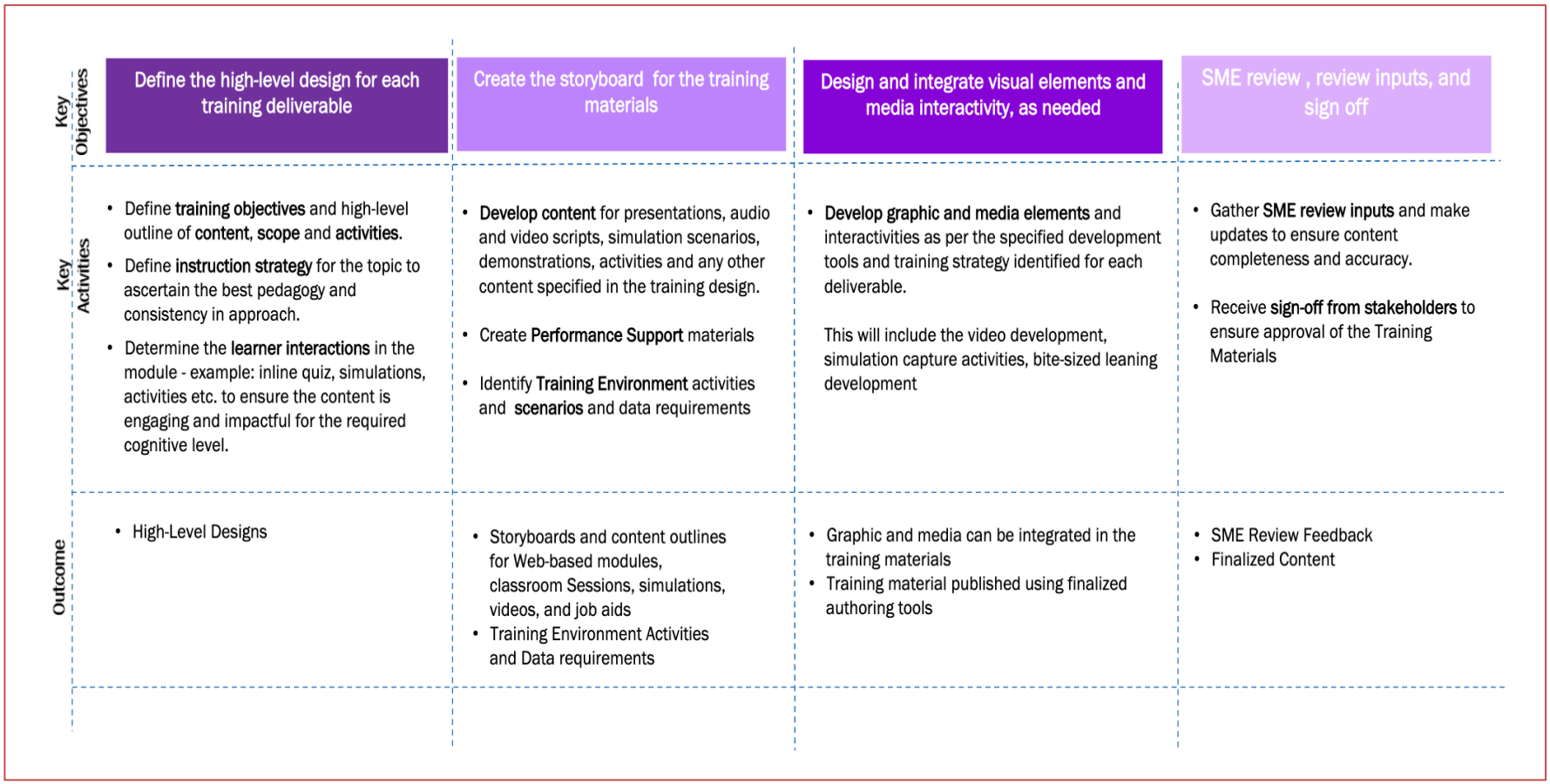
- **Analysis & Design Phase and Activities Overview**
  The DISCOMs should partner with process and business teams to identify the gaps; with training teams to assess the learning infrastructure and promote learning culture to finalize the delivery modalities that aligns with the business outcomes.

Figure 36 : Overview of activities in 'Analyse & Design' phase



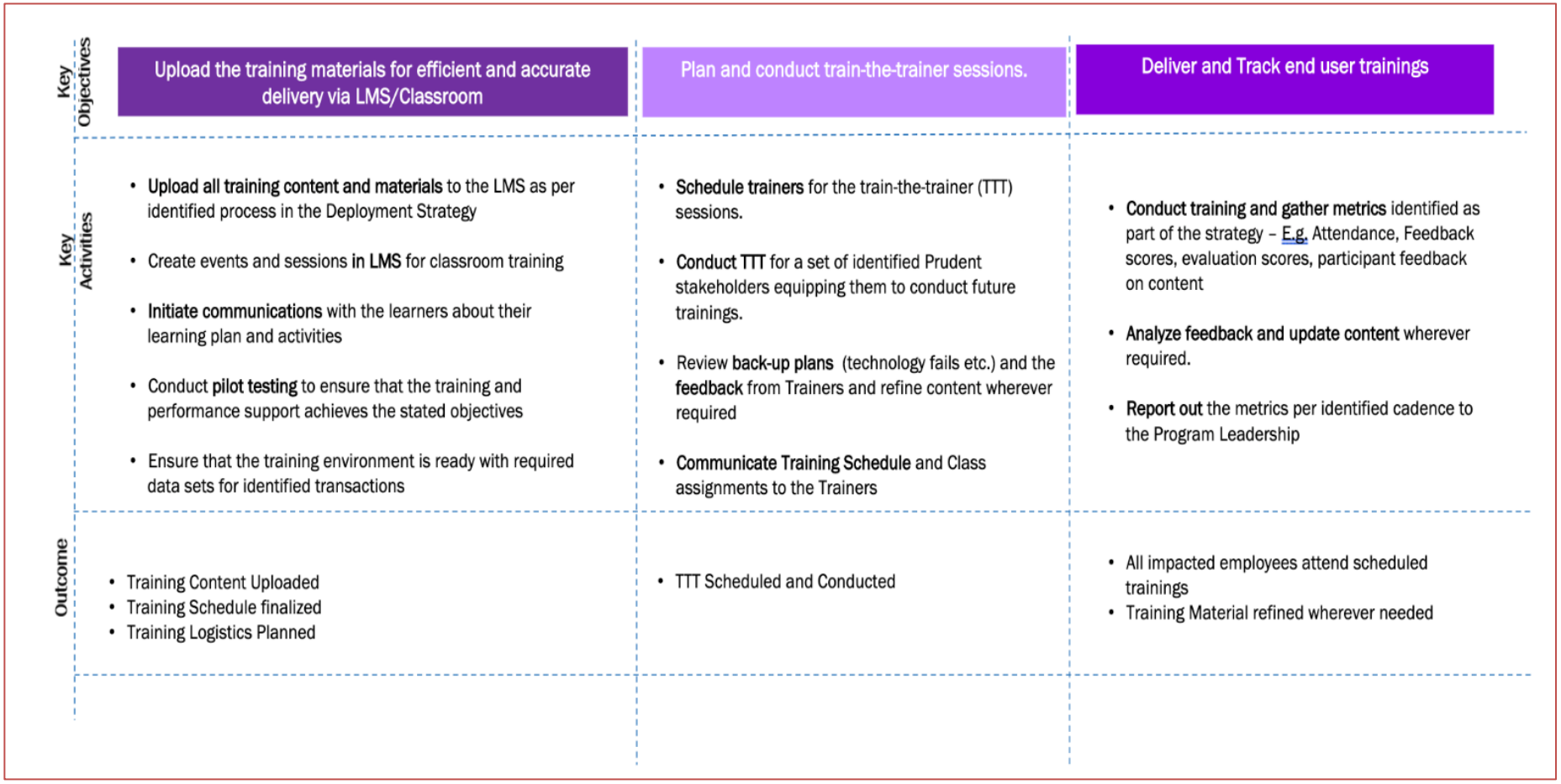
- **Build & Review Phase and Activities Overview:**
  DISCOMs should focus on creating course-specific designs and final training materials

Figure 37 : Overview of activities in 'Build & Review' phase



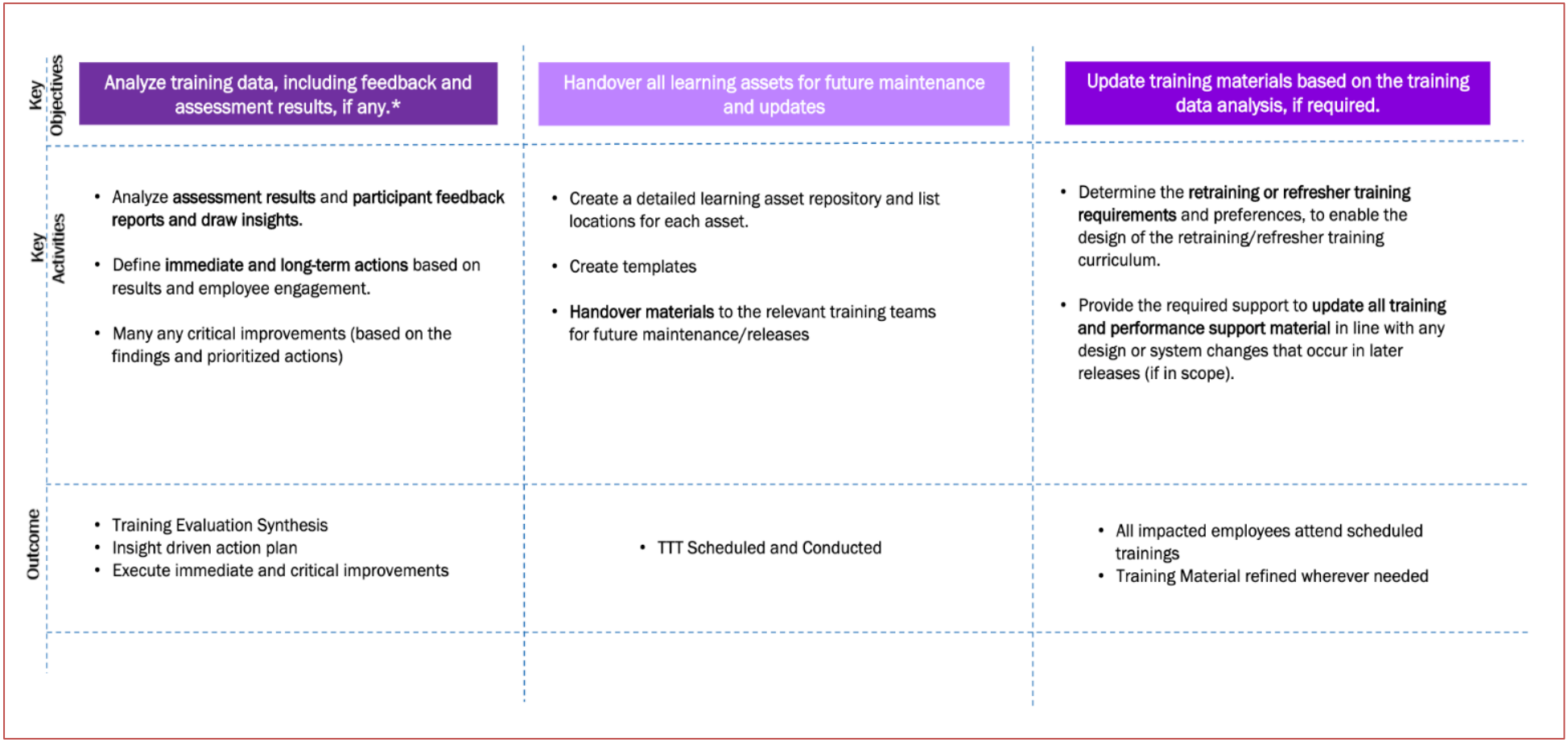
- **Deployment & Delivery Phase and Activities Overview:**
  DISCOMs need to ensure a timely rollout of the training material to maximize retention and minimize cognitive overload which will be critical to the success of the learning program for any digitalization program including IT & OT implementation & integration initiatives.

Figure 38 : Overview of activities in 'Deployment & Delivery' phase



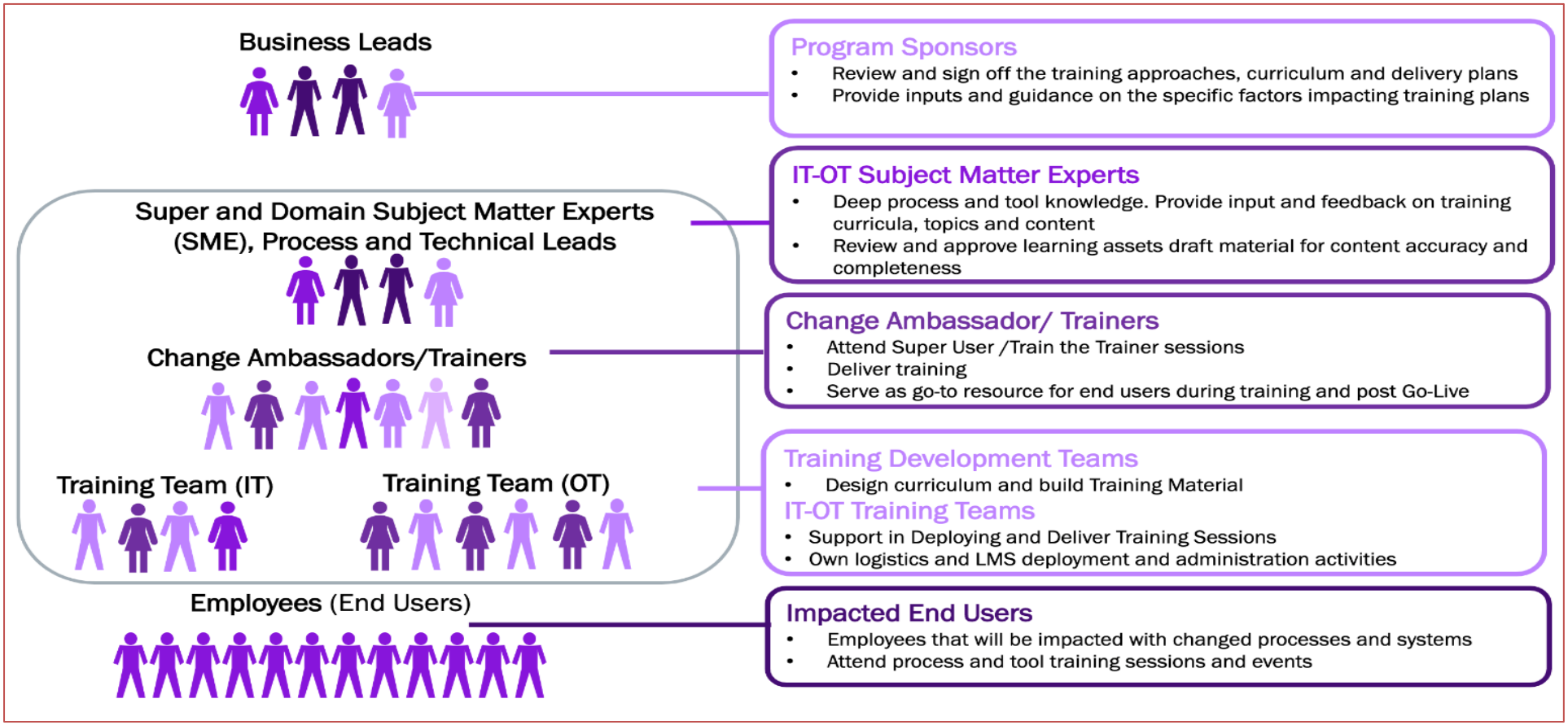
- **Transition & Sustainability and Overview:**
  In the last stage of the training development lifecycle, DISCOMs should ensure smooth transition of all content and material to the respective training teams will be conducted

Figure 39 : Overview of activities in 'Transition & Sustainability' phase



The Learning and Development team can be organized as shown below, with the Business Leads serving as program sponsors, reviewing training methodologies and providing advice and assistance as needed. Subject matter specialists in IT and OT assist in the development of training courses, themes, and material. Furthermore, change ambassadors and cross-functional IT-OT teams assist in the deployment and delivery of training sessions.

Figure 40 : Organization structure of Learning & Development team



8. Annexure

Annexure 1 – Questionnaire & research background

Research Background

The technical, functional, and economical parameters are evaluated and rates as high, moderate & low. The approach followed is provided below:

- The study of several solutions is done through rigorous interviews and discussions with different OEMs and vendors.
- The evaluation of features & offerings of the solutions (on technical economical and functional aspects) are done through interviews with different Indian DISCOMs.
- Networking, communications, and several integration methodologies are evaluated through discussion with network service providers, device manufacturers along with an in-depth study of their product brochures and websites.
- Current scenario of Indian distribution sector has been evaluated with several discussions and workshops with different DISCOMs, CEA, CPRI other Government agencies.
- Intensive secondary research has been undertaken into consideration of techno-functional features evaluation of each solution in this study.
- Remarks made on the technical, functional, and economical aspects are done in concurrence with subject matter experts from various geographical regions along with our learnings and experience gathered from past engagements of similar nature.

Questionnaire for OEMs

The questionnaire used for discussion with OEMs is provided below –

Table 10 : Questionnaire for OEMs

S. No.	Question
1	What is the portfolio of IT OT applications/ solutions (both hardware and software) deployed by your organization in the Indian power distribution space?
2	Which are the Indian DISCOMs that you have worked with in the past and are currently working with?
3	What is your business model in the Indian distribution space? (Capex/ Opex/ any other)
4	What is the mode of consumption of your product /services? (one time installation/ installation + AMC/ others)
5	Does your product conform to any specific standards / guidelines for integration with other products?
6	What are your thoughts on integration of your products/ solutions with other IT-OT solutions of Indian DISCOMs? Are your products capable of being integrated with other solutions? If no, what are the barriers?
7	What are the tools and solutions used for integration of your products with other IT-OT solutions of Indian DISCOMs?
8	What are the challenges/ learnings from the integration processes attempted so far for your products across all industries?

S. No.	Question
9	Are your integration solutions vendor specific or based on open-source technology? Please cite some examples.
10	What should be the preferred mode of IT-OT integration amongst the following. Please also provide reasoning.
11	Has IT-OT integration increased the vulnerability of your products/ solutions to cyber-risk? If yes – • What are the additional risks attributable to this integration? • What has been done to mitigate the same?

Table 11 : Questionnaire for DISCOMs

S. No.	Question
1	Which key IT applications (ERP, Billing, CIS, MDM, etc.) are currently deployed in your organization? - Name and function of the applications - Make (OEM) and Model - Backend database OEM - Upstream and downstream application - When was it deployed?
2	Which OT technologies (Smart Meters, SCADA, GIS, OMS, etc.) are currently deployed at your company? - Name and function of the applications - Make (OEM) - OT data sources and frequency - Make of OT database - When was it deployed? ** How is the data extracted from the SCADA system?
3	What are the communication technologies being used? What are the specifications being used?
4	Are the IT-OT applications integrated in your organization? If yes, what is the level of IT OT integration? How is the data compressed and stored? How is this being contextualized (real time time-series data to useful structured IT data)? What are the protocols and standards used?

S. No.	Question
5	Please give examples where it is done and the use cases through this integration?
6	What was the motivation for undertaking integration of IT-OT applications? Efficiency improvement Improved customer services Mandate from government Business case Any other? Please mention
7	What is the business benefit derived from IT-OT Integration so far? Please cite examples. Were you able to achieve the benefits envisaged during planning for IT-OT Integration?
8	What are the challenges/ learnings from the IT-OT integration attempted so far?
9	In your view, is increased usage of DERMS making IT/OT integration more important? If yes, why?
10	Are your integration solutions vendor specific or based on open-source technology? Please cite some examples.
11	Has IT-OT integration increased the vulnerability of your systems to cyber-risk? If yes – What are the additional risks attributable to this integration? What has been done to mitigate the same?
12	What were the steps taken to develop capabilities and willingness in the workforce to undertake IT-OT integration?
13	If integration has not been undertaken yet, what are the barriers faced for not integrating IT-OT applications?
14	Also, what are the challenges faced due to lack of integration?

Annexure 2 – As is assessment of Indian and global DISCOMs

Traditionally, IT-OT systems of Indian distribution utilities have been developed, maintained, and used in silos. To merge the IT-OT boundaries of a DISCOM and convert real-time data to actionable intelligence, a DISCOM needs to maintain shared standards and platforms across the IT-OT landscape. However, the lack of standards in the Indian context is one of the barriers to integrate IT-OT systems.

Thus, leveraging international standard ISA-95 ("ANSI/ISA-95 Enterprise-Control System Integration"), which sets out a standard model & terminology and acts as a guiding principle, within a power distribution utility can help create the right strategy and roadmap to bring a company-wide perspective to system integrations in order to achieve business and operational objectives.

Indian DISCOMs in different phases of their journey towards 'Industry 4.0' have identified their data and assets as per the ISA-95 standard, which helps merge all the siloed applications together so that they can utilize the power of integrated data. The primary struggle now is to come up with the best strategy to integrate all the layers of ISA-95.

Before understanding the landscape and maturity of IT-OT operations of Indian DISCOMs it is important to understand various levels of ISA-95 to map the existing IT-OT landscape of Indian DISCOMs. The levels as defined by ISA 95 are as follows:

- **Level 0 -** This is the lowest level, defines the actual physical processes with intelligent devices like sensors, IoTs, smart meters etc.
- **Level 1 -** Defines the activities involved in sensing and manipulating the physical processes, Programmable Logic Controllers (PLCs), and other communication systems
- **Level 2 -** Defines activities for monitoring and controlling the physical processes, supervisory control, and field level automation
- **Level 3 -** Defines the activities of workflow to produce the desirable performance, including scheduling, planning, dispatch, etc. The generic time frame are hours, minutes, seconds
- **Level 4 -** Defines the business-related activities needed to manage the operations and maintenance activities of any utility

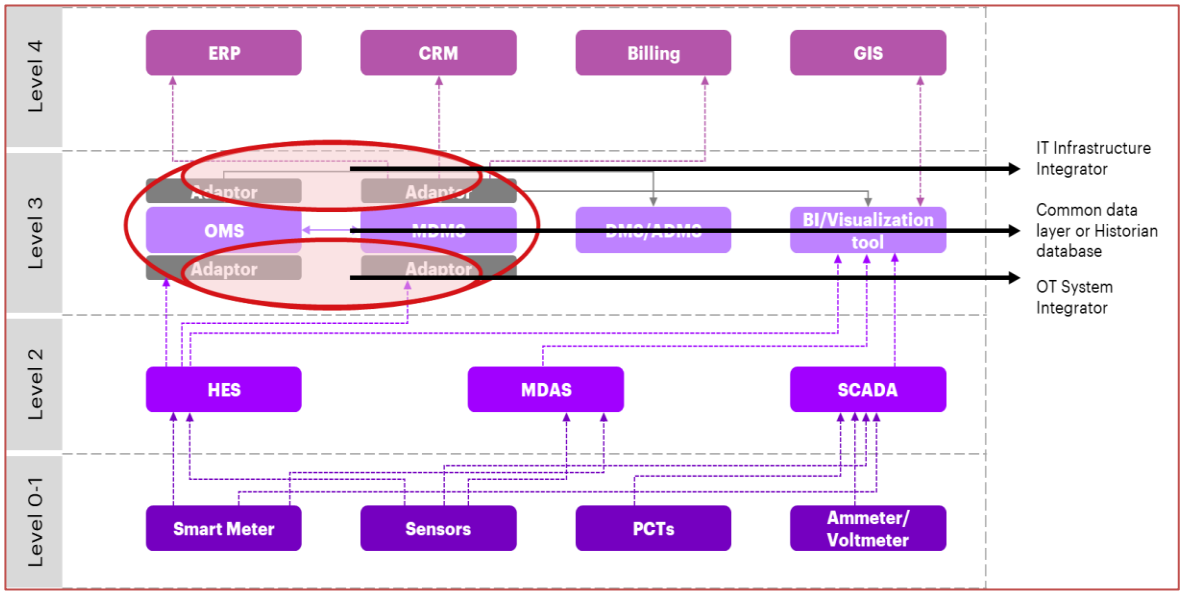
The Level 0 – 1 is where real time data is captured through field devices like smart meters, sensors, PCTs etc. and is then sent to HES, MDAS or SCADA i.e., Level 2 (the Supervisory Controls & Data Consolidation level), at specific time intervals. Level 3 acts as a connecting bridge between OT systems (Level 0 to Level 2) and IT systems (Level 4). The consolidated data from the Level 2 is sent to a common data location (e.g., MDM) in Level 3 which converts it in acceptable data format for Level 4, where the enterprise IT applications & analytical solutions are hosted, ensuring IT-OT integration. Level 3 is also known as "IT-OT layer" and since it is critical in ensuring IT-OT integration, typical solutions for IT-OT integration are a part of Level 3.

The following section illustrates the various components of a typical IT-OT solution with respect to ISA 95 in detail.

Components in a typical IT- OT integration solution

The basic architecture of a typical integration solution can be mapped as shown below, as per ISA-95 (as discussed above).

Figure 41 : Components in a typical IT - OT Integration solution



A typical IT-OT integration solution has three key components:

1. **OT System Integrator –** It connects the data collector in Level 2 and common data layer in Level 3.
2. **Common Data Layer or Historian Data Base –** It captures, stores & processes real time data and translates it to a data format that can be accessed by Level 4 applications.
3. **IT Infrastructure Integrator -** It connects the enterprise applications in Level 4 and common data layer in Level 3.

As-is assessment of selected Indian DISCOMs

The study highlights the as-is scenario of select Indian DISCOMs, namely, Uttar Haryana Bijli Vitran Nigam limited (UHBVNL), CESC Limited and BSES Rajdhani Limited (BRPL). Detailed discussions were held with the DISCOM officials which was leveraged to develop an understanding on the current landscape of IT-OT integration.

A broad questionnaire used to guide the discussion with the DISCOMs to understand different aspects of the IT-OT systems, including the key IT-OT applications deployed and experiences of integration if any.[10] The key takeaways from the discussions are provided below.

[10] Note - The consent of the utilities was also sought prior to incorporating the shared information in this study.

Table 12: Summary of IT-OT landscape of select Indian DISCOMs

Sl. No.	DISCOM	DISCOM Overview	IT-OT Landscape
1	Uttar Haryana Bijli Vitran Nigam Limited (UHBVNL) - Haryana	- One of the two DISCOMs in Haryana - Services ~ 33 lacs customers - Current AT&C Loss ~ 20% - Currently implementing Smart Meter programme with the aim of installing 5 lac meters under the R-APDRP Scheme	Level 0-1: Smart Meter with LAN, WAN, GPRS (Backup)
			Level 2: SCADA
			Level 3: MDMS, Distributed Automation System
			Level 4: GIS, Billing & Collection Systems, Payment Gateway
2	CESC Limited	- Services ~4 million customers - Operates in power generation and distribution business - Generation capacity ~800 MW	Level 0-1: Smart meter with Cellular (2G), PLC, RF Mesh technologies
			Level 2: SCADA
			Level 3: Outage Management system, In house MDMS, Distribution and Feeder automation
			Level 4: ERP, Billing systems, GIS, In house AI/ML based use cases, centralized dashboard for real time analysis of system disturbances
3	BSES Rajdhani Power Limited	- Formed as a joint venture between Delhi Power Company Limited and Reliance Infrastructure Limited - Services ~2.6 million users	Level 0-1: Smart meters, GPRS (2G) and 3G as a backup
			Level 2: SCADA
			Level 3: Outage management system, load management system, DMS, Automated Power Schedule Optimization module, Central monitoring services platform
			Level 4: Billing system, Customer Information system, AI/ML based demand forecasting

International best practices

IT & OT system implementation & integration has been successfully deployed across many international electricity distribution utilities. The digitalization program in the lenses of IT-OT implementation & integration of two international utilities have been studied in this report which would enable the Indian utilities to understand the international best practices and the learnings which can be applied in the Indian context. The specifications and reasons for selecting the two utilities are mentioned below -

- **Kansas City Power & Light (KCP&L) Smart Grid Demonstration Project (SGDP):**

Kansas City Power & Light (KCP&L) is a leading energy provider headquartered in Kansas City, Missouri., USA. KCP&L was awarded a Regional Smart Grid Demonstration Project (SGDP) cooperative agreement by the US Department of Energy (DOE) to deploy a fully integrated Smart Grid Demonstration in an economically challenged area of Kansas City, Missouri.

Some of the prominent IT & OT system that has been deployed by the DISCOM is:

Table 13: KCP&L different IT & OT systems

Categories	Systems/Applications/Devices Deployed
IT systems	• Advanced Metering Management & Meter Data Management system. • Customer Billing Tool • Enterprise Resource Planning System • Home Energy Management Portal (HEMP) • Commercial Building Energy Management System (BMS) • EV charging tool • Demand Response Software • CRM tool • Data Mining & Analytical Tool
OT Systems	• Smart meters • DT Projection Sensors • Feeder Monitoring Devices • Emission Indication Devices • Distributed Control & Data Acquisition (DCADA) • Distribution Management System • Outage Management System • Distributed Energy Resource Management • GIS Integration System *For networking & communication the DISCOM configured home area network (HAN) with in house display (IHD)

As a part of smart grid demonstration project (SGDP), KCP&L integrated IT-OT systems to build innovative smart grid solutions in 2015. KCP&L smart grid demonstration project has similar objectives and goals as NSGM (National Smart Grid Mission) which was launched by GOI in 2015 to accelerate the smart grid deployment in Indian T&D sector. Indian distribution sector shares similarities with KCP&Ls' IT-OT integration implementation in terms of business challenges, use cases, robustness and techno-functional specifications (data points, initial use cases to target, technical specifications).

- **San Diego Gas & Electric Utility:**

San Diego Gas & Electric (SDG&E) is a regulated public utility that provides natural gas & electricity to San Diego County & southern Orange County in southwest California, United States. It serves ~3.4 million consumers in ~25 cities with an area of ~10,600 sq. kms. The utility provides electricity to its customers through ~1800 miles of electrical transmission lines and ~21,600 miles of electric distribution lines. It has ~700 distribution RTUs and ~120 transmission RTUs.

Below are some major IT & OT solutions deployed in the distribution circle of this DISCOM:

Table 14: SDG&E different IT & OT systems

Categories	Systems/Applications/Devices Deployed
IT systems	• Meter Data Management system. • Customer Billing Tool • Enterprise Resource Planning System • Energy Management & Auditing Tool • Load Flow Analysis Software

Categories	Systems/Applications/Devices Deployed
	• Distribution Response System • CRM Tool • Synchro-phasor Monitoring Tool: Wide area situational awareness (WASA) & visualization • Analytical Engine & Visualization Dashboard
OT Systems	• Smart meters • Various Asset Condition Monitoring Sensors • Feeder/ Line Parameter Measuring Devices • Emission Indication Devices • Supervisory Control & Data Acquisition (SCADA) • Distribution Management System • Outage Management System • Distributed Energy Resource Management • GIS Integration System *For networking & communication the DISCOM configured broad range of networking technologies like: RF, broadband, PLC & Cellular systems. JDBC, ODBC & OLEDB protocols are used for IT data base integrations to enable high performance use cases like analytics, reporting, visualization.

The San Diego Gas & Electric utility implemented OSIsoft's PI platform to implement IT-OT integration. The use cases that were targeted by SDG&E (optimal asset management, predictive monitoring, outage management system, DER integration etc.) have similarities with current target use-case enablement for Indian distribution sector. Initially the utility faced the problem of siloed operation, de-synchronized enterprise IT solutions, high O&M costs etc. resembling Indian DISCOMs.

The table below summarizes the IT-OT landscape at KCP&L and SDG&E along with the learnings and the challenges encountered.

Table 15: Summary of IT-OT landscape of selected International DSOs

Sl. No.	DISCOM	Overview	IT-OT Landscape	Learning & Challenges
1	KCP&L (Kansas City Power & Light Company)	- Leading Energy provider headquartered in Kansas City, Missouri, USA. - Awarded a Regional Smart Grid Demonstration Project (SGDP) by US Department of Energy (DOE) to deploy a fully integrated Smart Grid Demonstration. [11]	**New systems were added under the SGDP programme** **-** Distribution Management System - Distributed Control & Data Acquisition - Advanced metering Infrastructure and Meter Data management - Distributed Energy Resource Management - Home and vehicle management	**Challenges** - Security Challenges - Interoperability Challenges - Firmware Upgradation **Learnings** - Cross-functional utility workforce is beneficial - Incorporate security into procurement

[11] Objective of the programme is to demonstrate feasibility of integrating the existing and emerging smart grid technologies and solutions to build innovative smart grid solutions and report its financial and business model viability.

Sl. No.	DISCOM	Overview	IT-OT Landscape	Learning & Challenges
				process - Create security zones in the sub-station field environment - Focus on device firmware version & settings management - Define interoperability strategy - Continuous knowledge transfer
2	SDG&E (San Diego Gas & Electric)	- Regulated public utility - Provides natural gas & electricity to San Diego County & southern Orange County in southwest California - Services ~3.4 million consumers in ~25 cities - Deployed OSIsoft's PI platform to implement IT-OT integration	**Key functionalities** - Condition based maintenance - High Performance predictive maintenance - Synchrophasors - Non-Billing Smart Meter Data Analytics - Grid Modernization	**Challenges** - Handling large volume of data from various field devices - Manage heterogeneous formats - Manage asset health - Integration of renewables and Micro grid - Real time operational data view on GIS Maps - Migration to new strategy based on real time asset data **Learnings** - Exploration workshops - Phase-wise Implementation - Opting for Enterprise Agreement - Implementation of condition-based maintenance (CBM) for asset performance management

Sl. No.	DISCOM	Overview	IT-OT Landscape	Learning & Challenges
				- Data Sharing - Unified resource management

Annexure 3 – List of use cases

Table 16 : List of critical Use Cases

S. No.	Category	Use Cases
1.	Advanced Metering Infrastructure	Customer Initiated Remote Service Order Completion
		Utility Initiated Remote Service Order Completion (Future)
		On Demand Meter Read
		On-Demand Meter Status Check
		Automated Daily Meter Read
		SmartMeter Alarm Events
		SmartMeter Advisory Events
		SmartMeter Log Only Events
		SmartMeter Source Power Events
		AMI FAN Device Alarm Events
		AMI FAN Device Advisory Events
		AMI FAN Device Log Only Events
		Remote SmartMeter Update
		Field SmartMeter Update
		Remote AMI FAN Device Update
		Field AMI FAN Device Update
		SmartMeter Replaced by Field Crew (Future)
2.	Meter Data Management system	MDM Distributes Daily Service Delivery Point Updates (Future)
		MDM Distributes Daily Meter Data
		MDM Creates Billing Determinants
		SmartMeter Inventory Management (Future)
3.	Substation system	SCADA Monitors and Controls Substation Devices
		SCADA Monitors and Controls Field Devices
		SCADA Monitors Equipment for Condition-Based Maintenance Programs
		Substation IEC 61850 GOOSE Protection Schemes
		Substation Transformer Dissolved Gas Analysis and Thermal Monitoring (Future)
		Substation Transformer Dynamic Ratings (Future)
		Feeder Cable Dynamic Ratings (Future)
4		SCADA Performs Fault Detection, Location, Isolation, and Restoration

S. No.	Category	Use Cases
	Fault Restoration system	DCADA Performs Volt/VAR Management
		DCADA Performs Dynamic Voltage Control (Future)
		DCADA Performs Localized Feeder Load Transfer
		DCADA Initiates Relay Protection Re-coordination (Future)
5.	Distribution Management System	DMS Network Model Maintenance
		DMS Monitors and Controls Substation Devices
		DMS Monitors and Controls Field Devices
		DMS Monitors and Controls Grid Battery
		DMS Coordinates Control Authority Responsibility with DCADA
		DMS Processes Protective Device Alarms for Outage Analysis
		DMS Performs Emergency Load Transfer
		DMS Schedules Required Load Transfer
		DMS Initiates Load Reduction with DERM
		DMS Performs Fault Detection, Location, Isolation, and Restoration
		DMS Operator Returns Grid to NORMAL Configuration
		DMS Performs Volt/VAR Management
		DMS Performs Dynamic Voltage Control
		DMS Initiates Relay Protection Re-coordination (Future)
6.	Demand Response Management	DERM Network Model Maintenance
		DR/DER Resource/Asset is Registered in DERM
		DERM Manages DR/DER Resource Availability
		DERM Creates DR/DER Event for DMS Load Reduction
		DERM Creates DR/DER Event for Power Market Operations (Future)
		DERM Distributes Demand Response Information Messages (Future)
		DERM Distributes DR/DER Event Schedules to Resource/Asset to Control Authority
		HEMP Manages DR Events for HAN Connected Resources
		DRAS Manages DR Events for AMI Connected Resources
		DRAS Manages DR Events for Commercial Building Resources (Future)
		CBMS Manages DR Events for Commercial Buildings (Future)
		VCMS Manages DR Events for EV Charging Stations
		DMS Manages DR Events for DVC and Grid Connected DER
		Verification of DR/DER Event Participation

S. No.	Category	Use Cases
		DERM Generates Retail Pricing Signals (Future)
7.	Distributed Energy Resources	Utility Operates Grid Storage for Capacity and Economic Benefits
		Utility Operates Grid Storage for T&D Asset Deferral and Power Quality
		Utility Operates Grid Storage for Service Continuity
		Customer Installs Premise Solar PV Distributed Generation
		Customer Installs Premise Energy Storage System in Conjunction with Solar PV
		Customer Operates Premise Energy Storage System for Economic Benefits
		Utility Installs Grid Connected Rooftop Solar Distributed Generation
		Utility Operates Premise Energy Storage System for Grid Benefits
8.	Significant Energy User	Customer Views Historical Energy Information via HEMP
		Customer In-Home Display – Basic Functions
		Customer In-Home Display – Daily Bill True-Up
		Customer In-Home Display – Prepayment (Future)
		Customer Uses HEMP to Register HAN Gateway
		Customer Uses HEMP to Provision HAN Device to HAN Gateway
		Customer Uses HEMP to Monitor Real Time Usage via HANs
		Customer Uses HEMP for Programmable Communicating Thermostat Mgmt.
		Customer Uses HEMP for Load Control Switch Management
		Customer Uses HEMP to Opt Out of DR Event
		Customer Initiates De-Provisioning of Customer HAN Device
		Customer Enrols in Time Based Pricing Program
		Customer Configures HEMP with Energy Usage Preferences (Future)
		Customer Uses HEMP to Respond to Energy Signals (Future)
		Customer Uses HEMP to Manage PV and PESS (Future)
		Customer Uses HEMP to Manage PEV Charging (Future)
9.	Home Area Network	Utility Commissions Home Area Network
		Utility Provisions HAN Device to SmartMeter
		Utility Sends Text Message to HAN Device
		Utility Cancels Text Message
		Utility Sends Pricing Signals to SmartMeter and HAN Devices
		Utility Home Area Network Device Information

S. No.	Category	Use Cases
		Utility De-Provisions HAN Device on Utility Home Area Network
		Utility De-Commissions Utility Home Area Network
		HAN Device Vendor Change Control (Future)
		HAN Device Status Check (Future)
10.	Electric Vehicle & Charging	PEV Charging at a Public Charge Station
		Customer Participated in Utility PEV Charging Program
		Customer Registers PEV to Home Premise (Future)
		Customer PEV Charging at Home Premise (Future)
		Un-Registered PEV Charging at Premise EVSI (Future)
		Charge Validation and Settlement via Clearinghouse (Future)
		Utility Controls PEV Charging at Public Charge Station (Future)
		Utility Controls Customer On-Premises PEV Charging (Future)
11.	Networking	AMI Field Automation
		DA Field Automation Network
		Utility Home Area Network
		Customer Home Area Network
		Public EV Charge Network
		Substation Distribution Automation Network
		Substation Distribution Protection Network

Annexure 4 – Implementation priorities and maturity level with a sample assessment framework

Implementation priorities of IT& OT systems along with integration are driven by the need to enable several business use-cases or sub-solutions. Use case enablement for any DISCOM is associated with the challenges faced by the DISCOM, the current business scenarios and the various government schemes.
According to the study, Indian DISCOMs are at different degrees of maturity in their digitalization journey when it comes to IT-OT system deployment. Thus, the maturity levels identified for a DISCOM are based on the extent, technical scope, and potential implementation of the elements across levels of IT-OT deployment and integration.

The three maturity levels can be defined as below:

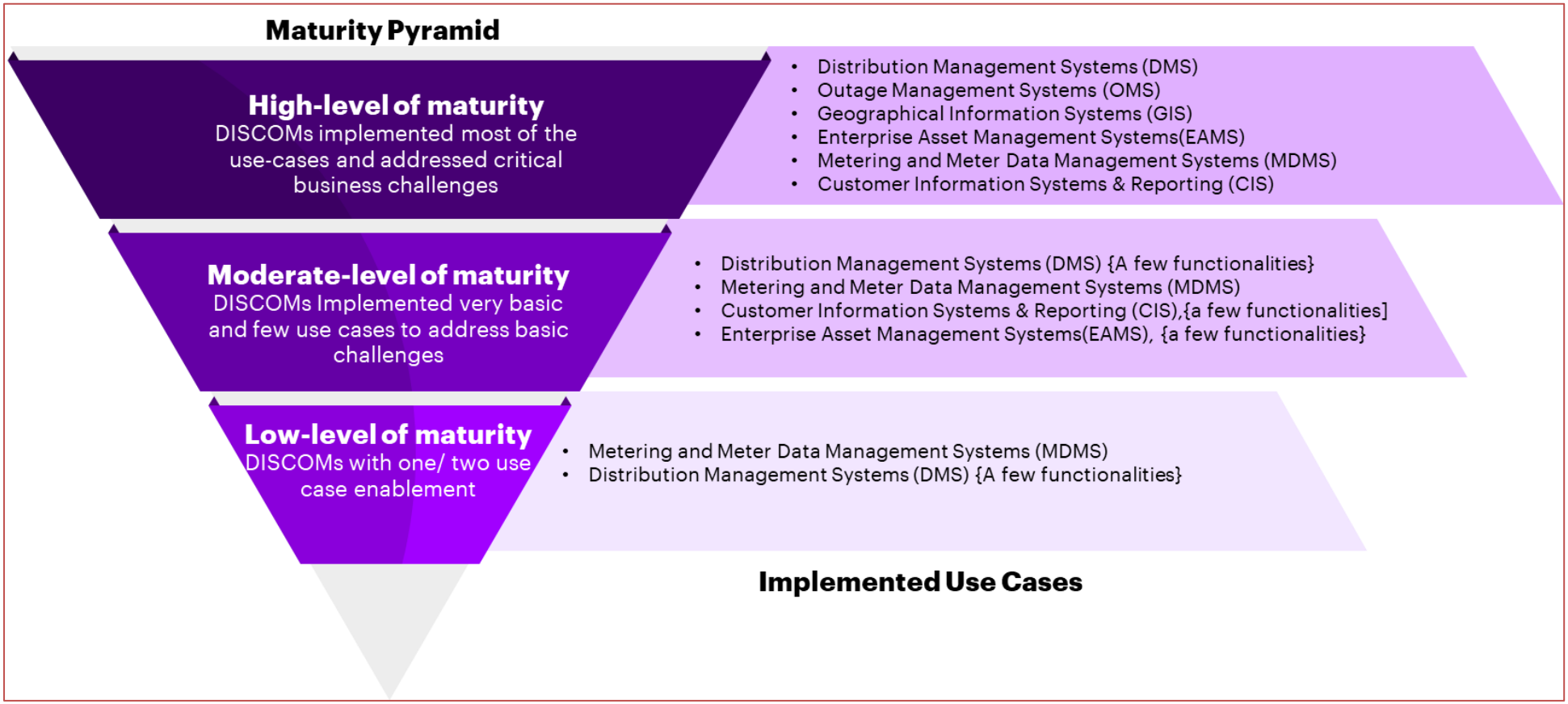
- **High maturity level:** A high maturity level indicates that the DISCOM has already implemented the major IT and OT systems and some elements of IT-OT integration to enable use cases like distribution management, theft reduction, outage management, geographical information system integration, enterprise asset management, customer information system and reporting etc. in its region of operation for most of its customers and is now focusing on potential improvements.

- **Moderate maturity level:** A medium maturity level indicates that the DISCOM has run successful pilots and has started implementing (with a few solutions already implemented) a host of elements on the digitalization landscape with the focusing on IT & OT applications & integrations in its region of operation(such as revenue management tool, billing applications, MDM systems, CRM applications on IT side and smart meters, device tracking and GIS integration on OT side).Few use cases with limited functionalities are considered to be enabled by these DISCOMs such as meter data management system, enterprise asset management systems, distribution management systems etc. A DISCOM in medium maturity has an increased focus on solving the major business challenges such as reducing the ACS-ARR gap, improving customer experience, reducing AT&C losses etc. to a minimum by utilizing the IT-OT infrastructure.

- **Low maturity level:** A low maturity level indicates that the DISCOM has vary basic IT and OT applications deployed such as billing system, document management system, financial management software, customer portal, inventory management system etc. in IT side and few smart meters in low scale in OT side. However, they are yet to start implementing digitalized solutions in the lenses of IT & OT components deployment & integration in its region of operation and has not yet shifted focus on solving the major business challenges such as reducing the ACS-ARR gap, improving customer experience, reducing AT&C losses etc. to a minimum by utilizing the IT-OT infrastructure.

The image below illustrates a maturity pyramid for Indian DISCOMs.

Figure 42 : Maturity pyramid for Indian DISCOMs



DISCOMs should adopt different approaches and prioritize IT-OT integration based on use cases according to their maturity level. The sections that follow focus on the maturity level-based implementation priorities for DISCOMs.

DISCOM can identify the level of maturity by themselves in Phase 1 of DISCOM digitalization journey (explained in section 5 of this document), in which each DISCOM need to assess the as-is condition based on following illustrative DISCOM assessment framework. Each DISCOMs need to mention the OT systems {from table XX (illustrative OT system lists)} & IT systems {from table XX (illustrative OT system lists} involved in each use cases enabled along with the methodologies of data capturing; level of algorithms & technology used.

DISCOM assessment framework

Table 17 : DISCOM assessment framework

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
1.	**Advanced Metering Infrastructure**	Customer Initiated Remote Service Order Completion	*DISCOM need to select from illustrative list of OT systems (Table 18)*	*DISCOM need to select from illustrative list of IT system (Table 19)*	**1. Data capturing methodology :** **2. Level of algorithms :** **3. Technologies used :**
		Utility Initiated Remote Service Order Completion			
		On Demand Meter Read			
		On-Demand Meter Status Check			
		Automated Daily Meter Read			
		Smart Meter Alarm Events			
		Smart Meter Advisory Events			
		Smart Meter Log Only Events			
		Smart Meter Power source related Events			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		AMI FAN Device Alarm Events			
		AMI FAN Device Advisory Events			
		AMI FAN Device Log Only Events			
		Remote Smart Meter Update			
		Field Smart Meter Update			
		Remote AMI FAN Device Update			
		Field AMI FAN Device Update			
2.	**Meter Data Management system**	MDM Distributes Daily Service Delivery Point Updates			
		MDM Distributes Daily Meter Data			
		MDM Creates Billing Determinants			
		Smart Meter Inventory Management			
3.	**Substation system**	SCADA Monitors and Controls Substation Devices			
		SCADA Monitors and Controls Field Devices			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		SCADA Monitors Equipment for Condition-Based Maintenance Programs			
		Substation IEC 61850 GOOSE Protection Schemes			
		Substation Transformer Dissolved Gas Analysis and Thermal Monitoring			
		Substation Transformer Dynamic Ratings			
		Feeder Cable Dynamic Ratings			
4	**Fault Restoration system**	SCADA Performs Fault Detection, Location, Isolation, and Restoration			
		SCADA Performs Volt/VAR Management			
		SCADA Performs Dynamic Voltage Control			
		SCADA Performs Localized Feeder Load Transfer			
		SCADA Initiates Relay Protection Re-coordination (Future)			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
5.	**Distribution Management System**	DMS Network Model Maintenance			
		DMS Monitors and Controls Substation Devices			
		DMS Monitors and Controls Field Devices			
		DMS Monitors and Controls Grid Battery			
		DMS Coordinates Control Authority Responsibility with DCADA			
		DMS Processes Protective Device Alarms for Outage Analysis			
		DMS Performs Emergency Load Transfer			
		DMS Schedules Required Load Transfer			
		DMS Initiates Load Reduction with DERM			
		DMS Performs Fault Detection, Location, Isolation, and Restoration			
		DMS Operator Returns Grid to NORMAL Configuration			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		DMS Performs Volt/VAR Management			
		DMS Performs Dynamic Voltage Control			
		DMS Initiates Relay Protection Re-coordination			
6.	**Demand Response Management**	DERM Network Model Maintenance			
		DR/DER Resource/Asset is Registered in DERM			
		DERM Manages DR/DER Resource Availability			
		DERM Creates DR/DER Event for DMS Load Reduction			
		DERM Creates DR/DER Event for Power Market Operations			
		DERM Distributes Demand Response Information Messages			
		DERM Distributes DR/DER Event Schedules to Resource/Asset to Control Authority			
		HEMP Manages DR Events for HAN Connected Resources			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		DRAS Manages DR Events for AMI Connected Resources			
		DRAS Manages DR Events for Commercial Building Resources			
		CBMS Manages DR Events for Commercial Buildings			
		VCMS Manages DR Events for EV Charging Stations			
		DMS Manages DR Events for DVC and Grid Connected DER			
		Verification of DR/DER Event Participation			
		DERM Generates Retail Pricing Signals			
7.	**Distributed Energy Resources**	Utility Operates Grid Storage for Capacity and Economic Benefits			
		Utility Operates Grid Storage for Distribution Asset Deferral and Power Quality			
		Utility Operates Grid Storage for Service Continuity			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		Customer Installs Premise Solar PV Distributed Generation			
		Customer Installs Premise Energy Storage System in Conjunction with Solar PV			
		Customer Operates Premise Energy Storage System for Economic Benefits			
		Utility Installs Grid Connected Rooftop Solar Distributed Generation			
		Utility Operates Premise Energy Storage System for Grid Benefits			
8.	**Significant Energy User**	Customer Views Historical Energy Information			
		Customer In-Home Display – Basic Functions			
		Customer In-Home Display – Daily Bill True-Up			
		Customer In-Home Display – Prepayment			
		Customers Monitor Real Time Usage via HANs			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		Customer Uses HEMP for Programmable Communicating Thermostat Mgmt.			
		Customer Uses HEMP for Load Control Switch Management			
		Customer Uses HEMP to Opt Out of DR Event			
		Customer Initiates De-Provisioning of Customer HAN Device			
		Customer Enrolls in Time Based Pricing Program			
		Customer Configures HEMP with Energy Usage Preferences			
		Customer Uses HEMP to Respond to Energy Signals			
		Customer Uses HEMP to Manage PEV Charging (Future)			
9.	**Home Area Network**	Utility Commissions Home Area Network			
		Utility Provisions HAN Device to SmartMeter			

S. No.	Category	Use Cases	OT system involved	IT system involved	Methodologies undertaken
		Utility Sends Text Message to HAN Device			
		Utility Cancels Text Message			
		Utility Sends Pricing Signals to SmartMeter and HAN Devices			
		Utility Home Area Network Device Information			
		Utility De-Provisions HAN Device on Utility Home Area Network			
		Utility De-Commissions Utility Home Area Network			
		HAN Device Vendor Change Control			
		HAN Device Status Check			
		Substation Distribution Protection Network			

List of OT systems:

Table 18 : List of OT systems

S. No.	Category	OT system involved
1.	**OT Devices**	Smart meters
		Sensor devices (thermal sensor/pressure sensor, vibration sensor etc.)
		IoT devices
		Digital multimeters (smart ammeter/ voltmeters)
		Line parameter sensing devices, etc.
		HES
2.	**Communication & Networking**	RF mesh
		Cellular/GPRS (2G/3G/4G) etc.
		HAN, FAN,WAN etc.
		LoRaWAN, LPWA etc.
3.	**OT Systems**	SCADA
		RT-DAS
		M-DAS
		DCADA
		Control unit
		HES system
		Network gateway applications
		Command Unit

List of IT systems:

Table 19 : List of IT systems

S. No.	Category	OT system involved
1.	**IT Applications**	GIS system
		HEMP (Home energy management portal)
		CIS/CRM (Customer data management)
		Load forecasting tool
		Load scheduling tool
		Network monitoring tool
		Market data analytics
		WDL (weather data layer)
2.	**Data Integration**	Common middle layer
		Enterprise service bus
		Data integration application
		LoRaWAN, LPWA etc.
3.	**IT Systems/ platforms**	Demand response system
		MDM
		Historian data base
		Common data layer
		Visualysation platform
		Basic analytics
		Advanced analytical platform (with AI/ML)
		MIS reporing tool
		Analytics with virtual reality simulation

Implementation priorities of highly matured DISCOMs

The below diagram illustrates the use case enablement priorities based on the business challenges of highly matured DISCOMs.

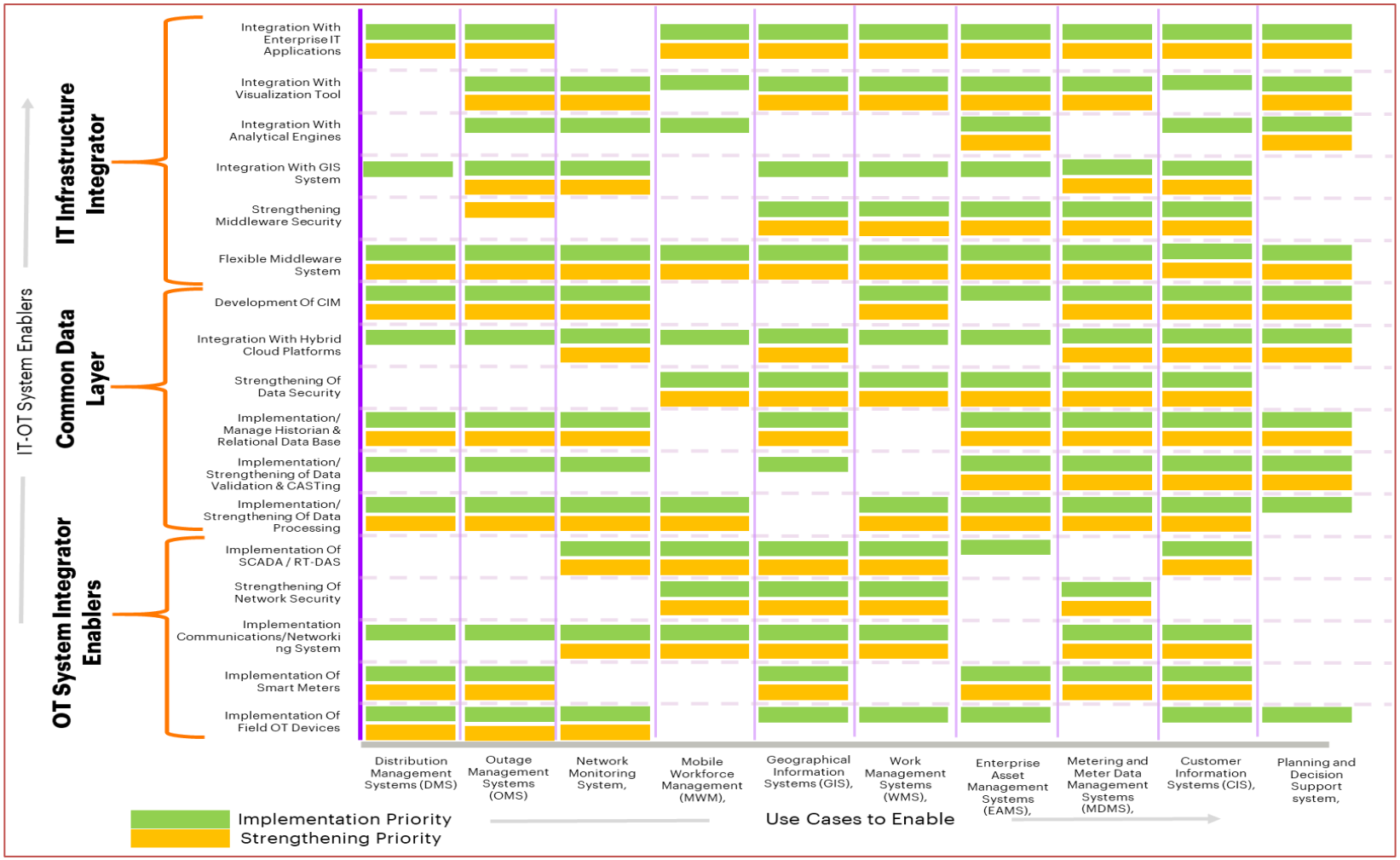
The subsequent figure shows the IT-OT system enablement priorities to empower or implement the desired use cases. The study assumes that the DISCOM has matured with respect to the IT-OT integrations (smart meters, SCADA, some of the field devices, networking system, data processing system, middleware system etc. have already been implemented). Hence, such DISCOMs need to either strengthen or implement their respective IT-OT system enablers to mitigate associated challenges for any use case.

The below figure illustrates the different combination of use cases that help in mitigating the pressing business challenges.

Figure 43 : Business challenges vs. use-case enablement priorities (high maturity level)

Post identification of the use cases needed to be defined for solving the business challenges, it is important to understand the different IT-OT system enablers needed to be implemented and strengthened as illustrated below.

Figure 44 : Use-case enablement vs IT-OT system enablers (high maturity level)



Implementation priorities of moderately matured DISCOMs

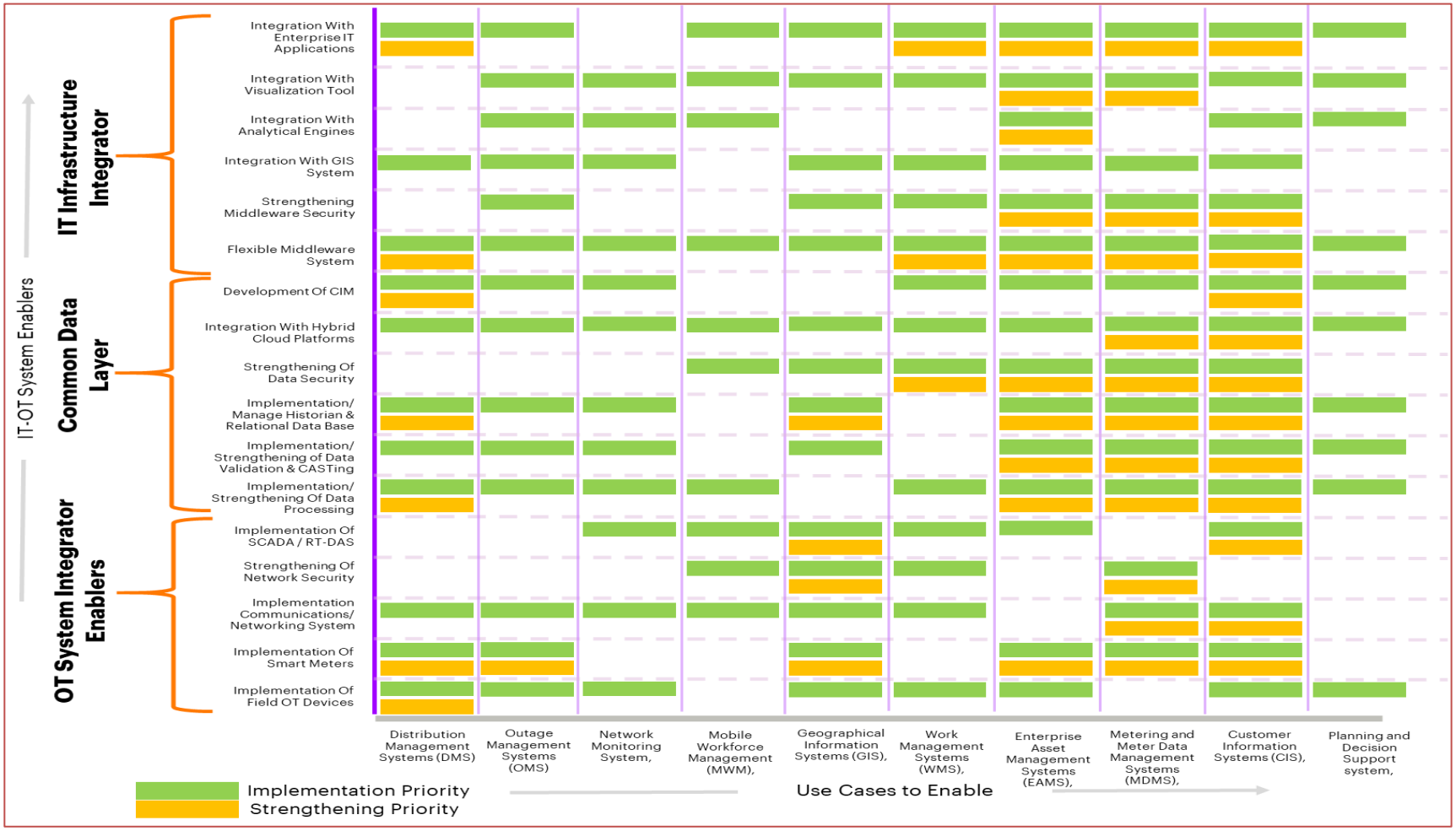
The below diagram illustrates the use case enablement priorities based on the business challenges of moderately matured DISCOMs. The subsequent figure shows the IT-OT system enablement priorities to empower or implement the desired use cases. The study assumes that DISCOMs in medium maturity have few levels of the IT-OT integrations (smart meters, few of the field devices, networking system, basic data processing, middleware system, basic integration with enterprise IT applications etc.). Hence, to mitigate associated challenges of any use cases, these DISCOMs need to strengthen their respective IT-OT system enablers, in case the enablers are already implemented or implement such IT-OT system enablers to begin with.

The below figure illustrates the different combination of use cases that help in mitigating the pressing business challenges.

Figure 45 : Business challenges vs. use-case enablement priorities (moderate maturity level)

Post identification of the use cases needed to be defined for solving the business challenges, it is important to understand the different IT-OT system enablers needed to be implemented and strengthened as illustrated below.

Figure 46 : Use-case enablement vs IT-OT system enablers (moderate maturity level)



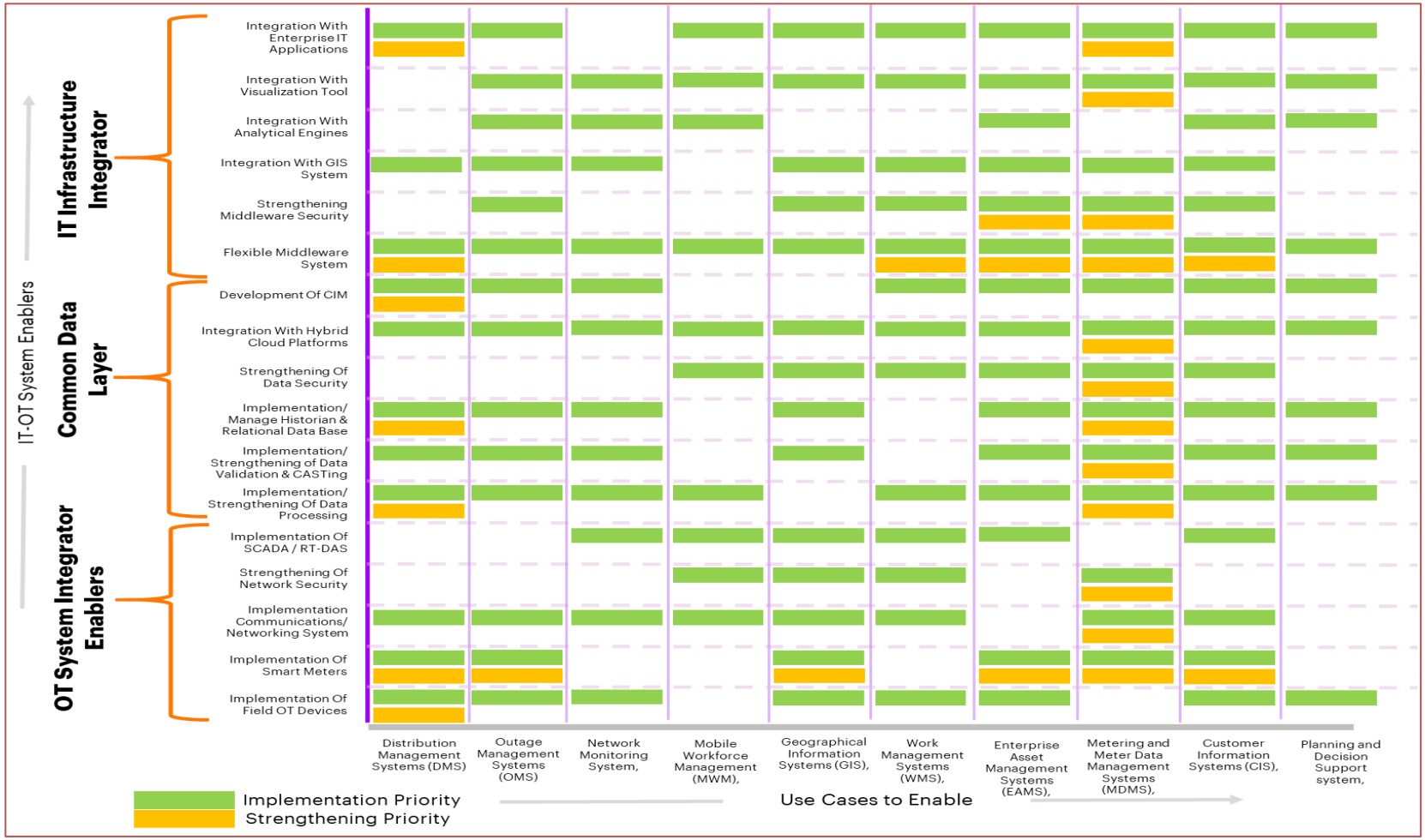
Implementation priorities of less matured DISCOMs

The below diagram illustrates the use case enablement priorities based on the business challenges of less matured DISCOMs. While assessing the priorities, the research assumes that DISCOMS in low maturity level may already have implemented very few of the use cases (such as: MDM in few customer zones), in such a case the recommendation is to strengthen the existing use case to mitigate related business challenges. The subsequent figure shows the IT-OT system enablement priorities to empower or implement the desired use cases. The below figure illustrates the different combination of use cases that help in mitigating the pressing business challenges.

Figure 47 : Business challenges vs. use-case enablement priorities (low maturity level)

Post identification of the use cases needed to be defined for solving the business challenges, it is important to understand the different IT-OT system enablers needed to be implemented and strengthened as illustrated below.

Figure 48 : Use-case enablement vs IT-OT system enablers (low maturity level)



Annexure 5 – A comparative study of data centre & data from cloud

The main difference between a cloud data location and a data centre is where the data is stored. In a data centre, data is most often stored on the premises of the utilities. Some data centres may be in locations not owned by the utility—in this case, the data centre is co-located, but not in the cloud. The cloud is completely off premises, and the data is accessible from anywhere via the internet.

The Data Centre

An on-premises data centre is a server, or a collection of servers, that the utility purchase and keep on site to serve the need of data storage. In some cases, this may be a disadvantage; as the distribution utility must purchase the server hardware along with networking hardware. Like any other technology, it will age and need to be replaced. Along with the cost of purchasing all of this equipment, utilities also need to prepare skilled resources & staff to configure, customize, manage, maintain, and secure. These staff members need to be highly trained and keep their skills up to date.

Finally, this model is also limited when it comes to scalability. A distribution utility can always buy more hardware, but it takes time to bring additional servers online & it also associates with technical risks of server failure, these can affect the utility business.

Reliance on a data centre is not all bad; there are a number of advantages to this model. For one, the utility will have complete control over the data and equipment. No one, other than the people of the power distribution organization & authorized third party will have access, as the overall system will be maintained by self and authorized persons only. Because as the utility owns the equipment, so it also controls exactly what hardware and software are required, making customizations much easier because the utility don't need permission from a vendor. Finally, if the utility is running any legacy systems, then the utility can set up an environment that will cater to these solutions. This gives flexibility when it comes to migrating to a newer system.

The Cloud

With a cloud-based solution, the utility stores the data on someone else's hardware and infrastructure. Being an asset intensive sector, many utilities are concerned about the idea of giving up so much control. Even though employees at reputable cloud hosting vendors undergo background checks, some utilities just aren't comfortable with someone else handling and possibly accessing their data, customer details or asset data.

Security is also a concern with the cloud-based option. Even though the vendor is storing the data of assets or end consumers, utilities are still ultimately responsible for protecting it. If data is compromised, the utilities are the only one who winds up paying the price. Additionally, there is the issue of accessibility. If the internet connection goes down, users can't access the remote data stores, and for some critical scenarios, this can be a big problem.

Ironically, security is also seen as an advantage of cloud-based hosts. Reputable vendors hire highly trained, experienced staff members to make sure that everything is configured properly, constantly maintained, and adequately secured.

Other benefits that are associated with cloud-based data are cost and scalability. Because the utility isn't laying out any up-front costs to purchase hardware and infrastructure that will be outdated, the business can see instant savings. Also, with cloud computing vendors, companies/ organizations only pay for what they need, so utilities don't have servers sitting dormant and waiting to be put to use. This leads into the scalability argument. When the utility needs additional space, it is readily available. It may cost a bit more, but it is there when you need it. Likewise, if the data storage needs scale back, the usage costs will be reduced.

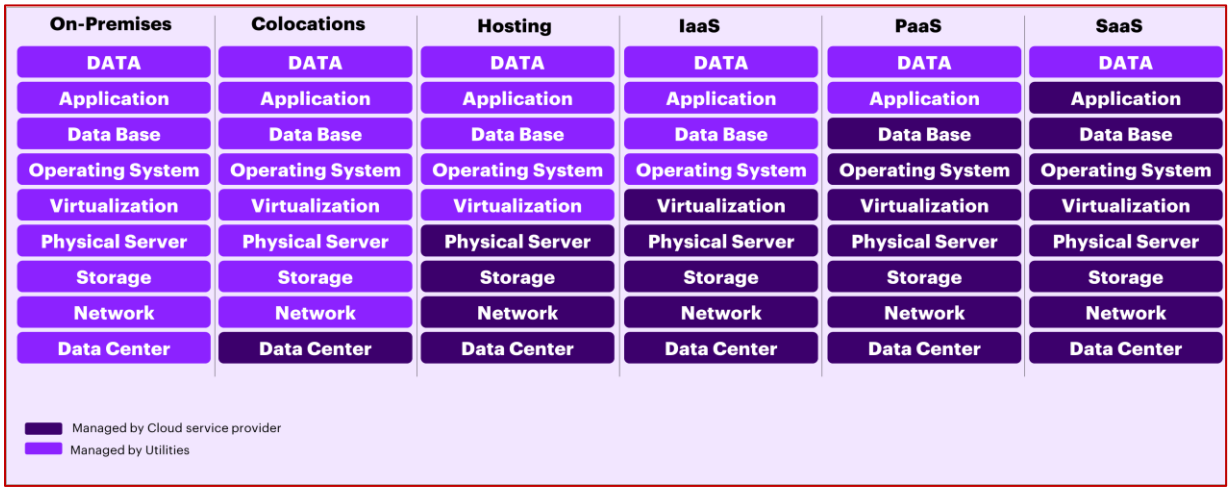
Hybrid model of data storage using both concepts, on premise & cloud is a new trend to the industry. In this model the utility has the flexibility to choose what are the data handling modules that can be handled by the utility itself and for which infrastructure stacks cloud service providers are responsible.

The Shared Responsibility Model

Many companies have hybrid cloud data centers which have a mix of on-premises data center components and virtual data centers components. In the figure below it has been shown that, how as-a-service models are shifting ownership of data center and infrastructure components from a fully owned and operated on-premises facility towards a commodity service model. In some of the cases on-premises is advantageous in some areas on cloud system is efficient, any of the solutions cannot achieve ultimate reliability alone. Hybrid system is a combination of both of the solutions opted/ implemented as per the requirement by many international DSOs.

These models promote a sharing of responsibilities between the cloud customer (the DISCOM) and service provider (cloud provider). Depending on the model selected, an organization may be responsible for maintaining and securing more or less of their infrastructure stack.

Figure 49: Hybrid models of data storage & handling



Based on the current scenario of an Indian distribution utility or depending upon the requirement for near future, the utility can choose any of the hybrid model mentioned in above diagram (On-premises or Colocation or Hosting etc.). The responsibility of the infrastructure stacks will be shared as per the selected hybrid model. The DISCOM need to analyze the requirement on the basis:

- Required near future scalability of the data storage.
- Resource flexibility based on the need to acquire, provision, or update appliances.
- Cost of the system.
- Availability and complete control over data.
- Security of the overall system.

Annexure 6 – Solution comparison framework

Selection of parameters for comparison

The two selected IT-OT integration solutions are compared on a specific set of criteria based on their relevance for the distribution utility.

The analysis and comparison of the IT-OT integration solution is further divided in three sub-segments I) Technical comparison ii) Functional Comparison iii) Economic Comparison

Parameters for technical comparison:

The aim of the analysis is to understand the technical points of comparison of the solutions and their impact on their deployment. For technical comparison the integration solutions are compared across the three key components: OT system integrator, common data layer & IT system integrator.

The three broad themes for which each component is analysed include: i) Standards & Protocols ii) Technology and iii) Methodology

Parameters for functional comparison:

The integration solutions are analysed from a functional point of view [12]to help to understand the suitability of each solution for deployment in Indian DISCOMs. The parameters are listed below. Each of the parameters have been rated as high, moderate & low for each of the solutions based on the evaluation criteria in the table.

Key factors affecting the decision for selection of an IT-OT integration solution are as follows:

Table 20 : Description of parameters for functional comparison

S. No.	Attributes	Definition	Evaluation Criteria
1.	Existing credentials in the industry	This parameter defines the deployment of any IT-OT product in distribution sector & the diversity/versatility of the features.	• Types of field devices/protocols that can be handled • Data base characteristics • Diverse IT application integration
2.	Solution scalability	For an IT-OT solution, scalability defines the volume of data sources that can be successfully handled, processed & integrated by any IT -OT product.	• Data CASTing (Clean, Augment, Shape and Transform) • Field device integration capacity • IT applications/analytical tool integration capacity
3.	User acceptance/adaptability	User acceptance is defined as how good the product meets the users requirements & how comfortable the users are to use the solution.	• Number of DISCOMs where the solution has been implemented • User satisfaction on solution approach

[12] '*Functional point of view*' refers to characteristics and features of the solutions and the proposed value in various aspects (capabilities, serviceability & useability) of each IT-OT product/solution. Functional features of any IT-OT solution include the purpose of the product that intends to fulfill and desired objectives such as support, flexibility, scalability, user acceptance etc.

S. No.	Attributes	Definition	Evaluation Criteria
4.	Solution history & maturity	This parameter defines how developed an IT-OT integration solution is in terms of upgradation to new technologies, coverage, etc.	• Adoption of new age technologies • Number of business area or sub-solution covered
5.	Critical use cases covered	In Indian distribution context, there are many business challanges which can be mitigated through various use case enablement. This parameter defines the instances of such use cases that have been implemented with a solution.	• Number of critical use cases covered
6.	Ease of Implementation/Flexibility	The ability for the solution to adapt to possible or future changes as per requirements allong with ease of the deployment with existing systems is defined as the ease of implementation/flexibility.	• Challenges faced while deployment • Challenges during incident management • Challenges faced while customization
7.	Product Support	The support and maintenance(including version upgradation) handled by the product owner or 3rd party after deployment is defined as product support.	• Improvement in operation/maintenance efficiency • Support on Asset management effectiveness • After Implementation Support
8.	Integration with 3rd party solutions	This parameter also defines the flexibility of the solution to integrate with existing and near future enterprise IT/OT applications.	• Easy to integrate with legacy system • Easy to integrate with existing IT/OT applications • Easy to connect with cloud platforms • Easy to implement analytical engine or business intelligence algorithms

Parameters influencing the cost of integration solution:

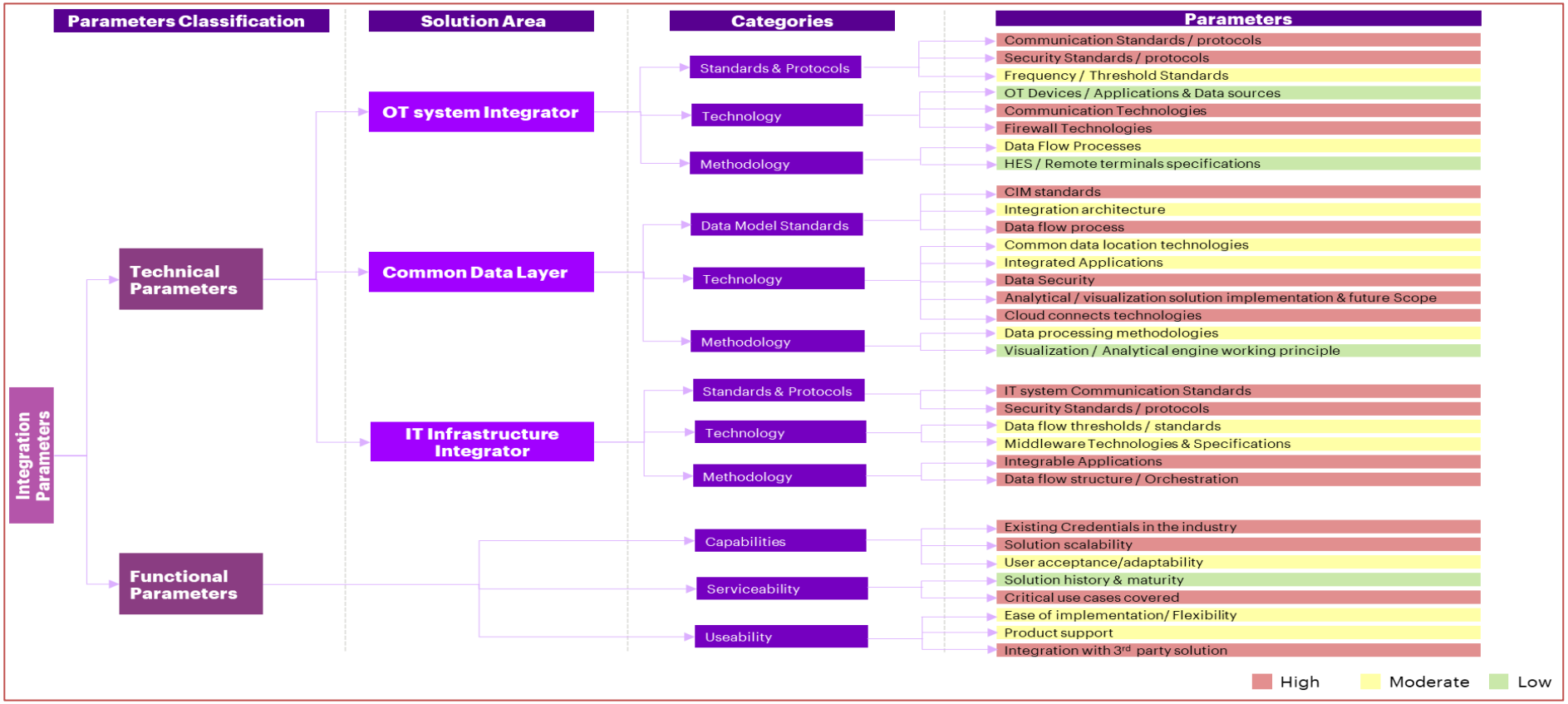
The cost heads in procurement of an IT-OT integration solution are as follows:

1. Software, Servers Charges - This covers licensing cost of various software components and databases (excluding HES)
2. Deployment Charges - This Covers one-time implementation cost of deploying cloud infrastructure and software components
3. Annual Maintenance Charges - This is yearly maintenance charges with respect to software support, cloud, and application maintenance charges

Parameter prioritization

The parameters selected for technical & functional comparison of the two solutions have been prioritized based on their level of criticality in selection of a solution for IT-OT integration from the perspective of Indian DISCOMs. The parameters are rated high, medium & low based on their priority level. The detailed parameters selected for technical & functional comparison for the integration solutions and their priority is illustrated below:

Figure 50: Technical & Functional Comparison Parameter Prioritization



Annexure 7 – Comparative study of integration solutions

Integration of different IT and OT applications requires use of different types of solutions. An IT – OT integration solution provides a platform where the data from the field OT devices (incl. sensors, smart meters) can be integrated with enterprise IT applications to provide business value to organizations by unlocking various new use cases. These IT – OT integration solutions may also act as a platform to build other applications to help the utilities in effectively utilizing the integrated IT & OT data.

Many solutions for enabling IT – OT integration in electricity distribution sector have been developed across the globe. However, only a few such solutions have been implemented in Indian DISCOMs. Thus, there is a need to understand the IT - OT integration solutions available in the market along with their benefits & challenges for adoption by Indian DISCOMs.

This chapter is intended to provide a guideline and a framework to Indian DISCOMs on the parameters to be studied to select an IT-OT solution or product specific to their need including various technical, functional & economic criteria along with the priorities to compare various IT-OT products and solutions. It also provides a comparison framework between different vendor specific and open-source solutions while undertaking the IT-OT integration programme. Therefore, the characteristics of two vendor-specific solutions and one generic open-source solution were explored to undertake a comparative analysis. The solutions studied here are selected to illustrate the results using the comparison framework only and not to provide any result or conclusion related to solution selection.

- **Integration solution 1** is a leading IT-OT integration solution globally, currently in use by all the North American Independent System Operators (ISOs)/ Distribution System Operators (DSOs) & Regional Transmission Organizations (RTOs). The solution is used by more than 1000 power generators including 17 out of top 20 wind power generation companies.
- **Integration solution 2** is also a prominent global integration solution for electricity distribution utilities and has already been implemented by a few Indian DISCOMs including Tata Power – Delhi & Bihar DISCOMs. It has also been consistently categorized as a “Leader” in the Gartner’s Magic Quadrant for Meter Data Management Products. Globally, the solution has been implemented in 200+ electric, water, gas & heat utilities.
- **Open-source solutions** are critical for certain use cases, supporting distribution utilities with specific business concerns. Grid optimization, transmission, renewable generators, as well as distribution utilities, all deploy various types of open-source technology. These solutions have been adopted by several of the world's DISCOMs that operate with a limited amount of data points. The generic parameters and features of multiple open-source solutions were assessed for a consolidated comparative view of the open-source solution with respect to the vendor specific solutions.

The analysis and comparison of the IT-OT integration solution is further divided into two sub-segments i) Technical Comparison and ii) Functional Comparison, which are covered in detail in the following sections.

Technical comparison:

The selected IT-OT integration solutions are compared based on multiple key technical parameters. However, nine critical parameters have been distilled from those technical parameters. The critical parameters have been identified based on their relevance to the integration solution's performance in the Indian context. The comparison of the two selected solutions & generic technical features of a typical open-source solution on those parameters have been represented. The critical parameters correspond to the technical parameters analysed as follows:

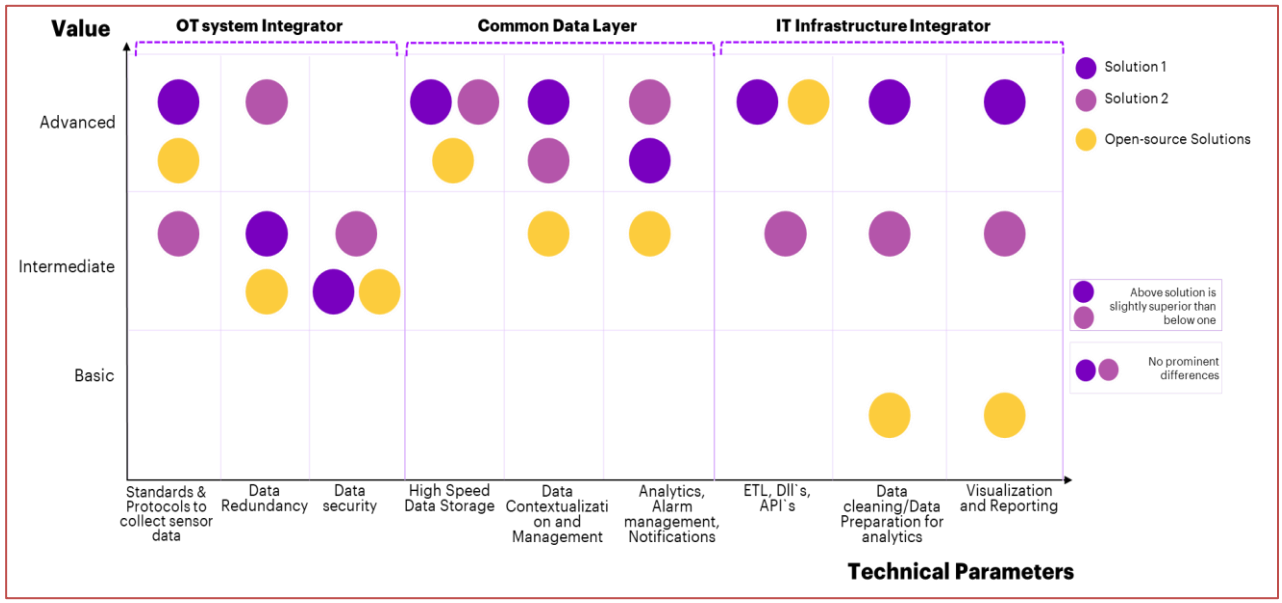
Table 21: Critical technical parameters

S. No.	Solution Division	Technical Parameters	Critical Parameters
1.	**OT system Integrator**	Communication Standards / protocols	Standards & Protocols to collect sensor data
		Frequency / Threshold Standards	
		Data Flow Processes	Data redundancy
		Communication Technologies	
		Security Standards / protocols	Data security
		Firewall Technologies	
2.	**Common Data Layer**	Cloud connects technologies	High Speed Data Storage
		CIM standards	
		Integration architecture	
		Data flow process	
		Common data location technologies	Data Contextualization and Management
		Data Security	
		Data processing methodologies	
		Analytical / visualization solution implementation & future Scope	Analytics, Alarm management, Notifications
		Visualization / Analytical engine working principle	
3.	**IT Infrastructure Integrator**	IT system Communication Standards	ETL, Dll`s, API`s
		Data flow thresholds / standards	
		Security Standards / protocols	
		Integrable Applications	Visualization and Reporting
		Data flow structure / Orchestration	Data cleaning / Data Preparation for analytics

Each solution has been rated as either basic, intermediate, or advanced on each of the technical parameters. The solutions are rated based on whether the solutions just meet the minimum requirements of an Indian DISCOM (Basic); have additional capabilities which enhances the utility of the solution (Intermediate) or have best-in-class capabilities for that specific technical parameter (Advanced).

The following is a snapshot of the technical comparison of the two selected solutions as per the comparison framework discussed.

Figure 51 : Technical comparison of integration solutions



Functional comparison

The selected IT-OT integration solutions are also compared based on the key functional parameters to evaluate their suitability. Each of these solutions have been rated as either high, medium, or low on each of the functional parameters. The following is a snapshot of the functional comparison of the selected solutions as per the comparison framework discussed.

Figure 52 : Functional comparison of integration solutions

Cost Drivers of IT- OT Integration Product Suite

The cost heads in procurement of an IT-OT integration solution are as follows:

1. **Software, Servers Charges** - This covers licensing cost of various software components and databases (excluding HES)
2. **Deployment Charges** - This Covers one-time implementation cost of deploying cloud infrastructure and software components

3. **Annual Maintenance Charges** - This is yearly maintenance charges with respect to software support, cloud, and application maintenance charges

The software pricing models typically available in the market are as follows:

1. **Flat rate pricing** – Flat rate pricing refers to the business model where the products & services are offered at a fixed price, irrespective of the extent to which the software is used. The pricing is not dependent on the number of users or consumption etc.
2. **Usage based pricing** – This is a pricing model based on the user's consumption, it is also known as a "pay as you go" pricing model. In this pricing model customers are only charged when they use a product or service.
3. **Tiered Pricing Model** – In tiered pricing, the costumers are charged fees based on the customer's consumption tier (e.g., number of licenses). Usually, consumers in higher tier get discounts for higher incremental purchase.
4. **Per User / Per Active User Pricing model** – In this pricing model, the software license is priced based on the number of users or active users using the software.
5. **Freemium pricing model** – In this pricing model, companies offer free services to the consumers along with options of additional paid features.

All of the pricing models discussed above are reliant on specific cost heads, which are often the parameters or pricing variables. These cost heads have their own set of solution costing drivers.

The following are the deployment and installation cost heads that DISCOMs should keep track of in order to evaluate a solution's costs.

IT- OT Solutions Price Range:

Global prominent vendors, typically charge based on use cases enablement and number of tags or data points to connect. A typical case of a DISCOM which implemented a proprietary solution with 10,000 tags or data points is provided below.

Software license & Maintenance**:** The one-time license cost includes server licensing, interface licensing, licensing of core functionality of the solution, Licensing of data linkage.

Table 22 : Basis of pricing for an IT-OT integration solution

Major components	Sub-components
Mandatory	
Software Licenses	One time licensing/Periodic licensing
Connectors	Total no. of Data sources
Real Time Data Storage Units	1.Total no. of tags 2. Total no. of process tags
Notification and analytical engine	One time licensing/Periodic licensing
Optional	
System Access Licenses/Person	Total no of access for each role of access
Visualisation tool	Licensing based on 1.Named users 2.Concerrant users
3rd party data access	Licensed cost on: Number of data set access
Software Reliance Program	Periodic costing based on total no of tags

**Note: Training & skill enhancement costs are not included.*

Apart from above pricing range the costing also includes installation & deployment costs. This cost depends upon the number of resources deployed, skillsets & duration of deployment.

A comparison between vendor specific & open-source solutions:

It was widely observed that an open-source solution is a good fit for the DISCOMs in the nascent stages, due to its ability to support wide variety of protocols and scope of trial and error to find out the right fit. However, as the DISCOM gains maturity over a period, open-source solutions become increasingly complex to manage and upscale, due to which vendor specific solutions gain advantage over open-source solutions in the long run. In the following table, we compare both the solutions against predominant attributes which have potential to be value levers.

Table 23 : Comparison of vendor-specific and open-source solutions

Sl. No	Attributes	Vendor Specific Solutions	Open-Source Solutions
Technical comparison parameters:			
1.	Standards & Protocols to collect sensor data	Vendor specific solutions are designed as a product suite or solutions platforms, which can be customized to support a broad range of protocols and communication standards.	Open-source historian data base mostly uses OPC variants as a standard way to play with data and the DISCOM may have legacy systems which will create a challenge to support.
2.	Data Redundancy & data security	These solutions can be customized as per the business need. Mostly vendor specific solutions support a broad range of data sources with high scalability. Firewalls and security standards vary for different geographical area, but basic security features are strong with layered firewall architecture.	Most of the open-source data supports a broad range of data source and networking technologies. The only challenge with these solutions is scalability issues for large scale DISCOMs. These solutions provide layered security architecture for each data access points, maintaining global security standards.
3.	High Speed Data storage capacity	Most of the vendor specific solutions are made with a basic feature of storage capacity for any specific business sector. Although scaling up the data storage system may	Few open-source solution maintain CIM standards and layered architecture for data capturing. Some of the open-source solutions have good data storage capacity.

Sl. No	Attributes	Vendor Specific Solutions	Open-Source Solutions
		raise as a challenge for some of the solutions.	
Sl. No	Attributes	Vendor Specific Solutions	Open-Source Solutions
4.	Data Contextualization and Management	Data contextualizing methodologies are vast and well-structured in most of the vendor specific solutions, these solutions can also be scalable easily.	Most of the open-source solution made up with basic technologies and features as designed for specific use cases and limited scale up potential.
5.	Analytics, visualization & Alarm management, Notifications	Most of the proprietary solution has separate analytical and visualization engine on top of the historian data base. These can be easily configured with existing data points and also scalable adding new data points.	In the case of open-source solutions, some offer data collecting and analytics, while the vast majority do not. And because these are designed to address specific business concerns, they may not be linked to all IT applications. DISCOMs will need to build in the functionality using other applications as per their requirement.
Functional comparison parameters:			
1.	Solution Utilization	Vendor specific solutions provides the integration layer of IT-OT convergence solution, on top of which a DISCOM can leverage any use cases.	Open-Source Historian mostly used to solve particular use cases or business challenges and not used as enterprise historians for any DISCOMs.
2.	Solution Relevancy	Large scale distribution utilities with requirement of more than 10,000 data points need best in class historians which can store	If DISCOMs' requirement is 5,000-10,000 tags (OT data source points) or less, open source works quite well.

Sl. No	Attributes	Vendor Specific Solutions	Open-Source Solutions
		millions of data without any issues and there are hundreds of running system with more than 15 years of data.	Therefore, small scale DISCOMs may find the open-source solutions attractive for the cost effectiveness but it poses challenge over time when the DISCOM scales up its business.
3.	Product Support	Vendor specific integration solutions are mainly provided as IT-OT integration platforms. These in-class standard solutions have after deployment product support, version upgradation and business requirement related customization offerings.	As Historian is generally customized, it's difficult to get OEM support. It depends on 3rd parties to provide support which is difficult and expensive. Sometimes organizations do buy additional support from open-source OEM to solve this challenge, but they provide standard product support. Any customization on top of it is not supported by OEM.
4.	Product Roadmap	• OEM of solutions are liable for change management and timely deployment release as per service contracts. • Other historian can upgrade from one version to another or a complete server upgrade without data losses with SLA based response.	• Historians' data base follows local/national IT policies. Timely patch deployment is another challenge of this open-source solutions. e.g., a new Microsoft Patch created (version upgradation) an issue with open-source historian or solution, therefore the open-source systems' OEM may provide delayed response for the solution of version upgradation. • Upgrading from one version of open-source historian data

Sl. No	Attributes	Vendor Specific Solutions	Open-Source Solutions
			base or IT-OT integration platform to another is a complex task which can cause data loss. Other historian can upgrade from one version to another or a complete server upgrade without data losses with SLA based response.
5.	Software Warranty	Vendor specific warranty for each layer is available for all standard IT-OT solutions.	The open-source software is provided "as-is", without any kind of warranty. In no event shall the authors or copyright holders be liable for any claim, damages, or other liability, whether in an action of contractor or otherwise.
6.	User Friendly	Most of the standard IT-OT solution need proper support with skilled resources along with timely skill upgradation programmes.	Open-source solutions are easy to use, requires less user training & skillset for operation.

The suitability of an open-source solution vs. a vendor specific solution is dependent on the need, use cases, resource availability and the vision of the DISCOM with respect to the objectives it wants to achieve.

Annexure 8 – System security

The IT-OT integration involves installing and configuring new elements across various layers of ISA-95 or making changes to the existing systems/networks which are already in place. The integration may pose new challenges and risks to the systems of DISCOMs, thus making it imperative to determine a strategy to deal with these new challenges. The following sections discuss the challenges of integrating IT-OT applications with respect to cybersecurity and the measures needed to successfully secure the systems.

Challenges of deploying and integrating IT-OT applications owing to cyber security issues in Indian power distribution utilities

Deployment of IT and OT systems and subsequently, its convergence can increase efficiency and productivity for DISCOMs. However, this convergence increases connectivity and new attacks may surface which can expose the organization to additional cyber security related risks. The primary challenge of IT-OT deployment and convergence is to integrate the systems without compromising the intrinsic structure of the OT systems to ensure safety, resilience, and reliability.
The following are the common challenges of integrating IT and OT infrastructures (applications, networks, etc.):

- **Lack of trust, understanding, and/or collaboration between IT and OT departments.**
  IT teams mainly focus on confidentiality, integrity, and availability. On the other hand, OT is more concerned with availability, reliability, and safety. It is a common industry practice to have IT and OT teams working independent of each other in their own silos. However, a successful IT-OT convergence requires close cooperation between previously siloed departments. Having IT and OT under an integrated security strategy will help eliminate security gaps and reduce the organization's overall cyber risk. Therefore, it is imperative to start any IT-OT integration implementation effort with the people on both sides of the fence, to build trust around the common goals of understanding, measuring, and mitigating cyber risk across the entire enterprise.

- **Lack of dedicated trained OT cybersecurity staff and IT teams that do not have the necessary expertise or insight to understand the OT environment.**
  IT teams need to work alongside their OT engineers to ensure they have a deep understanding and appreciation of both what needs to be protected, and how to protect these assets without disrupting production. Very often, it is this knowledge-trust gap, including their mindset of quick-fix solutions, which leads IT SecOps (security operations) personnel to assume that the same approach they use to secure their IT networks will work in the OT environment. On the other side, measures should be put in place to ensure that the OT personnel receive the required level of cybersecurity training to perform their jobs adequately. For IT-OT collaboration to be successful, both sides must have something to gain and a way to contribute to the overall business bottom line.

- **The presence of legacy systems on the OT network in need of security patches, software updates, etc., which are often unavailable.**

IT networks tend to be more dynamic and adaptable to rapid changes which is quite opposite to the OT environment. The lifetime of IT equipment is considered as three to five years, while it is not uncommon to find OT equipment that is well over 20 years in service, and yes, still up and running.

The IT toolset is primarily made up of off-the-shelf hardware and operating systems, and a standard set of applications better equipped to support business operations and tasks. The more 'standard,' the better for IT purposes. They are easily deployed, managed, upgraded, and secured (patched). To the contrary, OT equipment is specialized, and highly likely to be supported by an OEM vendor with a contract stipulating that the plant engineers cannot upgrade or patch the system because the warranty will be voided. Organizations planning IT and OT integration projects should include action items to review and renegotiate existing OEM vendor contracts to ensure that they accommodate for cybersecurity measures; the cyber controls should align with the requirements and organization's cybersecurity policies. Additionally, any new contracts must also include these requirements. Finally, where technically feasible, there should be a consistent application of cybersecurity measures across the organization; this includes the OT environment. Compensating cybersecurity measures should be put in place to protect legacy systems that cannot employ updated controls.

- **Lack of visibility due incomplete inventory and network diagrams of the OT environment.**
  It is common for electric utilities not to have a complete picture of their endpoints in the OT environment and accurate diagrams of the network. However, it is difficult for an organization to adequately secure the enterprise without knowing what is installed on its networks and access points to them. The organization should, therefore, perform a complete discovery of its networks, endpoints, etc. and implement adequate security controls, before integrating their IT and OT environments. Additionally, the organization should ensure that the convergence point between its enterprise/ business network and that of its OT environment is designed and configured securely. This can be achieved by employing a framework such as the Purdue Enterprise Reference Architecture.

- **Regulatory compliance pressures**
  While the integration of IT and OT can increase efficiency and productivity, it can also add regulatory compliance liabilities. If not done correctly, IT systems become subject to regulatory norms applicable to the OT environment. As a result, the work to maintain compliance increases, as do the chances of violations and fines. Organizations should weigh their pros and cons when deciding how to utilize their technologies for both IT and OT; ensure that it is still feasible to maintain compliance with the new designs and configurations.
  The following sections talk about the various steps organizations can take to ensure network and data security.

Cybersecurity measures to ensure network security

Ensuring that steps are taken to secure network and protect customer's data should be of paramount importance while implementing IT-OT Integration elements such as - Advanced Metering Infrastructure (AMI), Distribution management system, outage management etc. Regardless of the vendor, the following cybersecurity measures should be a part of the network security -

i. Create a governance framework

Ensure that the roles, responsibilities, and accountability are clearly defined. In addition, to auditing and reporting functions to allow for adequate risk management, senior management must set the tone that requires every employee, contractor, vendor, etc. to comply with the utility's security policies. Security governance and security management programs help align information security strategy with business objectives and compliance requirements, while helping manage risk. This will leave less room for malicious actors to find an alternate route into the system or for employees to make innocent mistakes that can harm the security of the network.

ii. **Develop clear policies and procedures**

The utility should develop controls that will cover all aspects of system security. It is imperative that high level policies clearly define roles - responsibilities for security management and list the rules and controls required for network access. The policies also need to be supported with standards and guidelines that detail out mandatory and non-mandatory controls. These are supported by procedures that cover step by step instructions for implementation, for example in asset health monitoring use case implementation (under distribution asset management), specific operational steps for setting up firewalls, handling the encryption keys or performing backups should be laid down. A security awareness and training program rounds this out. These steps will help protect the utility, and in the event of a problem, there'll be guidelines on how to address the issue.

iii. **Create and implement a deployment plan**

Proper planning is required to make sure that deploying security controls during deployment goes smoothly. Working with the vendor and performing a security assessment help identify all assets that need protection, as well as potential threats to the network. For each threat, risk assessment and risk prioritization will lead to the development of an actionable plan for secure deployment.

The following technologies may be implemented will help in the design and deployment of a layered defence for a communication network system:

- **Demilitarized Zone (DMZ) DMZs**
  Dual firewall architecture provides a layer of security to the utility's network by tightly regulating traffic entering and exiting the network. A DMZ network usually contains three zones, a trusted zone (Internal), a DMZ (Less Trusted) and an External Zone (Untrusted). For example, when deploying the OT servers, it can be integrated with existing DMZ network. Typically, the head-end server(s) resides in the DMZ behind the perimeter firewall, while the OT database and other OT components reside in a more trusted zone that is separated from the DMZ by the back-end firewall. Other remote

components of the OT system such as Collector/Gateways may be configured to securely communicate with the head-end server over virtual private networks (VPN). Access to servers that will be a part of the network is controlled through role-based access control (RBAC). This is an approach to restricting access to authorized users based on the role of the individual. Operations on the OT servers are assigned to specific roles, and the RBAC restricts access based on permissions associated with each role. For example, different roles may be assigned for users responsible for managing separate field devices, sensors, smart meters etc. versus administrators.

- **Secure remote access with multifactor authentication**
  Administrators and other users may require remote access to IT interface systems. Ensure that multifactor authentication (MFA) is utilized for remote access. MFA is a security system that requires more than one method of authentication from varying categories of credentials to verify a user's identity. For example, remote users may be prompted to use an entry code generated on a security token to access the system in addition to their username and password. This is a more secure method for remote access and can greatly reduce the attack surface compared to using only username and passwords.

- **Intrusion detection systems (IDS), and Intrusion Prevention systems (IPS)**
  IDS and IPS for the IT-OT system creating a properly protected network, including careful placement of intrusion detection systems (IDS), and Intrusion Prevention systems (IPS), is critical to safeguarding against cyberattacks. These technologies should be placed at critical ingress or egress points within the network to ensure maximum coverage of traffic. In addition to network protections, Host Based IDS/IPS software should be deployed on IT-OT interface systems to provide additional layers of security against local system threats. During the configuration of all these technologies, it should be ensured that the auditing and logging are properly enabled, along with continuous monitoring and recording of all events to alert about any suspicious activity.

- **End to end encryption:**
  Encrypt network level traffic while deploying an IT-OT system, it is critical to enable encryption on all relevant portions of your network. Encryption is the process of encoding messages or information in a way that only authorized users with encryption keys can access it. Should someone break into the communication system, message encrypting prevents the interceptor from reading the information. By encrypting network traffic on all parts of the communication network, the overall system can be protected till the end point of data fetching to the head-end system.

- **Create redundant communication channels:**
  In addition to enabling encryption on the communication network, make sure that communication channels have redundancy with multiple paths. This protects from denial of service (DOS) type cyberattacks. The communications networks should be designed so that all endpoints, such as electric meters, devices, sensors can communicate with more than one collector. This way, if a certain collector is taken

down (either for regular maintenance or due to a cyber- attack), the endpoint communication with the head of the system can continue without interruption.

- **Secure Configuration and Patching**
  From the very start of the communication network deployment, make sure that all systems are properly configured to reduce exposure. During configuration, make sure that the underlying operating system, as well as any applications and additional software is securely configured and hardened to prevent intruders from accessing OT information. In addition, these systems also need be continuously updated with latest software patches and hot fixes from the operating system and application vendors.

iv. **Test and re-test before roll-out**
Implement a testing program to ensure that systems are tested before they are implemented on the secure network and/or to customers. This will allow for the remediation of bugs and errors during the testing phase. It is recommended that the implementation of new software/systems in the production environment be done in phases; do a pilot of a few endpoints at first to test software/system in production before doing systemwide rollout.

v. **Schedule regular maintenance**
Schedule time for regular maintenance and patching to maintain a secure system. Have an operations team whose sole job is maintaining the security of the system, conduct routine maintenance checks. To get the most out of technology investment, schedule regular updates, patching and maintenance.

vi. **Get third-party pen-tests and reviews**
It is important to get a second or even third pair of eyes to review any work. There are third-party reviewers and penetration-test venders who specialize in checking the security of system. Consider conducting an annual or bi-annual pen-test, especially when the utility is going through major system changes. These experts can look at the system security to identify weaknesses and give recommendations on ways to improve the program.

To summarize, here is a checklist of security best practices and controls that should be considered while implementing IT-OT integration:

- Software and hardware (with embedded software) vendors are required to check for evidence (e.g., third-party assessment) that the software is free of software weaknesses.
- Perform remote attestation of smart meters to ensure that the firmware has not been modified.
- Make use of the communication protocol security extensions (e.g., MultiSpeak security extensions) to ascertain that the data integrity and origin integrity of smart meter data.
- Establish and maintain secure configuration management processes (e.g., when servicing field devices or updating their firmware).
- Ensure that all software (developed internally or procured from a third-party) is developed using security aware SDLC.
- Apply a qualified third-party security penetration testing to test all hardware and software components prior to live deployment.

- Decouple identifying end-user information (e.g., household address, global positioning system [GPS] coordinates, etc.) instead use a unique identifier.
- Implement physical security controls and detection mechanisms when tampering occurs.
- Ensure that a reliable source of network time is maintained.
- Disable the remote disconnect feature that allows electricity to be remotely shut down using a smart meter.

Additionally, the utility should ensure the following security requirements and controls for common data layers or meter data management (MDM):

- Data arriving to be stored in the common data layer or historian or MDM system does not come from a compromised device or smart meters etc.
- Data arriving to be stored in the common data layer or historian or MDM system is syntactically and semantically valid.
- The system parsing the data arriving in the common data layer or historian or MDM system should make use of all the appropriate data validation and exception-handling techniques.
- The historian or MDM system has been designed and implemented using security aware SDLC.
- The historian or MDM system has passed a security penetration test by a qualified third-party.
- Denial-of-service attempts (from compromised meters) are handled gracefully.
- Data stored in the historian database or MDM system should be cleansed from all private information.

Cybersecurity guidelines followed by international DSOs

Popular cyber security and system security practices has been maintained by many U.S., European utilities. Below listed are the cybersecurity guidelines, standards and frameworks followed by some International DSOs:

Table 24 : List of standards of international best practices

Sl. No	Standard	Description
1	ANSI C12.22-2012	American National Standard Protocol Specification for Interfacing to Data Communication Networks
2	Department of Homeland Security (DHS): Cyber Security Procurement Language for Control Systems	This document summarizes security principles that should be considered when designing and procuring control systems products and services (software, systems, maintenance, and networks)
3	DHS National Communications System (NCS) Catalog of control systems security	Presents a compilation of practices that various industry bodies have recommended to increase the security of control systems from both physical and cyberattacks.
4	Framework for Improving Critical Infrastructure Cybersecurity V1.1 April,16, 2018	Focuses on using business drivers to guide cybersecurity activities and considering cyber-Security risks as part of the organization's risk management processes.

Sl. No	Standard	Description
5	IEC TR 61850-90-12:2015	Communication networks and systems for power utility automation - Part 90-12: Wide area network engineering guidelines.
6	IEC 62351-1:2007	Power systems management and associated information exchange
7	IEC 62351-3:2014+AMD1:2018	CSV Consolidated version Power systems management and associated information exchange
8	IEC 62351-4:2007 Part 4	This standard specifies procedures, protocol extensions, and algorithms to facilitate securing ISO 9506
9	IEC 62351-5:2013 Part 5	This standard specifies messages, procedures and algorithms for securing the operation of all protocols based on or derived from IEC 60870- 5
10	IEC 62351-6:2007 Security for IEC 61850 profiles Part 6: Security for IEC 61850 profiles	This standard specifies messages, procedures, and algorithms for securing the operation of all protocols based on or derived from the standard IEC 61850.
11	IEC 62351-7:2017	Security through network and system management
12	IEC 62351-8:2011	Power systems management and associated information exchange
13	IEC 62351-9:2017	Power systems management and associated information exchange
14	IEC TR 62351-10:2012	Power systems management and associated information exchange
15	IEC 62351-11:2016	Power systems management and associated information exchange
16	IEC TR 62351-12:2016	Resilience and security recommendations for power systems with distributed energy resources (DER) cyber-physical systems.
17	IEC TR 62351-13:2016	Guidelines on security topics to be covered in standards and specifications.
18	IEC TR 62357-1:2016	Power systems management and associated information exchange - Reference architecture
19	IEC 62541-2:2016	OPC unified architecture - Security Model
20	IEC 62541-6:2015	OPC unified architecture - Mappings
21	IEEE 1686-2013	Standard for Intelligent Electronic Devices Cyber Security Capabilities
22	IEEE 1701-2011	Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables
23	IEEE 1702-2011	Standard for Telephone Modem Communication Protocol to Complement the Utility Industry End Device Data Tables
24	IEEE 1815-2012	Standard for Electric Power Systems Communications Distributed Network Protocol (DNP3).
25	IEEE 2030.5 (SEP 2) -2013	IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard
26	MultiSpeak Security-V1.0-V5.0	Real time MultiSpeak interfaces use web services to define and implement the data transport. MultiSpeak uses Web Services Description Language (WSDL) files to document the methods and define which messages are required to achieve the goals of each method.

Sl. No	Standard	Description
		Messaging components are defined in a messaging schema (in Version 2.2) or in web services (Versions 3.x, 4.x, 5.0). All transports support request/response, publish/subscribe and asynchronous message exchange patterns.
27	NAESB REQ.21	Energy Services Provider Interface Model Business Practices (MBPs)
28	NAESB RMQ.26 OpenFMB	The OpenFM framework provides a specification for power systems field devices to leverage a non-proprietary and standards-based reference architecture, which consists of internet protocol (IP) networking and Internet of Things (IoT) messaging protocols. The framework supports Distributed Energy Resources that communicate based on a common schematic definition and then can process the data locally for action (control, reporting).
29	NEMA SG-AMI 1-2009 (R2015)	Requirements for Smart Meter Upgradeability: This standard is used by smart meter suppliers, utility customers, and key constituents, such as regulators, to guide both development and decision making as related to smart meter upgradeability. This standard serves as a key set of requirements for smart meter upgradeability. These requirements should be used by smart meter suppliers, utility customers, and key constituents, such as regulators, to guide both development and decision making as related to smart meter upgradeability.
30	NERC Critical Infrastructure Protection (CIP) 002-009	These standards cover organizational, processes, physical, and cybersecurity standards for the bulk power system.
31	NIST SP 800-53-Rev 5-2017	Security and Privacy Controls for Information Systems and Organizations: This publication provides a catalogue of security and privacy controls for federal information systems and organizations to protect organizational operations and assets, individuals, other organizations, and the Nation from a diverse set of threats including hostile attacks, natural disasters, structural failures, human errors, and privacy risks.
32	Security Profile for Advanced Metering Infrastructure, v 1.0, December 10, 2009	The scope of this work extends from the meter data management system (MDMS) up to and including the home area network (HAN) interface of the smart meter. Informative security guidance may be provided for systems and components relevant but beyond the explicitly designated scope.
33	NIST Special Publication 1108	NIST Framework and Roadmap for Smart Grid Interoperability Standards, Revision 1.0. The reference model, standards, gaps, and action plans described in this document provide a solid foundation for a secure, interoperable Smart Grid, including AMI, smart devices, sensors etc.
34	ISO/IEC 27019:2017	ISO/IEC 27019:2017 provides guidance based on ISO/IEC 27002:2013 applied to process control systems used by the

Sl. No	Standard	Description
		energy utility industry for controlling and monitoring the production or generation, transmission, storage, and distribution of electric power and for the control of associated supporting processes. This includes Advanced Metering Infrastructure (AMI) components, e.g., smart meters, field devices like sensors, IoTs etc.
35	European and Information Security Agency (EISA) Smart Grid Security	ENISA's provides guidelines and recommendations on cybersecurity targeted at the energy sector to address the increase significant cybersecurity threats to the power industry. This is due to the escalation in the integration of IT and OT; especially with the legacy electricity infrastructure to make the power gird "smart". The guidelines include: i. Smart Grid Security Recommendations ii. Smart Grid Threat Landscape and Good Practice Guide iii. Communication Network Interdependencies in Smart Grids iv. Power Sector Dependency on Time Service: Attacks against Time-sensitive Service

System security standards, guidelines & policies for Indian DISCOMs

The relevant data security standards in Indian distribution context are described in that may be considered when implementing IT/OT integration projects. Relevant CEA standards are listed below:

Table 25 : List of standards mandates by CEA

Sl. No.	Respective CEA Standard	Description
1	ISO/IEC 15408	Common Criteria Certification Standard
2	ISO/IEC 17011	General requirements for accreditation bodies accrediting conformity assessment bodies
3	ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories
4	ISO/IEC 21827	Systems Security Engineering - Capability Maturity Model (SSE-CMM)
5	ISO/IEC 24748-1	Systems and software engineering — Life cycle management — Part 1: Guidelines for life cycle management.
6	ISO 27001/2	Information Security Management
7	ISO/ IEC 27019	Information technology — Security techniques — Information Security controls for the energy utility industry
8	ISO/IEC 61508	Functional Safety of Electrical / Electronic / Programmable Electronic Safety Related Systems
9	IEC 61850	Communication networks and systems for power utility automation
10	IEC 62351	Standards for Securing Power System Communications
11	IEC 62443	Cyber Security for Industrial Control Systems
12	IS 16335	Power Control Systems – Security Requirements.

CEA (Cyber Security in Power Sector) Guidelines, 2021 provides the guidelines on below areas:

- **Cyber Security Policy** – The entity should be ISO/IEC 27001 certified and should have a cybersecurity policy drawn upon the guidelines issued by NCIIPC. The entity shall ensure annual review of their Cyber Security Policy.
- **Identification of Critical Information Infrastructure (CII) -** The entity needs to submit the details of Cyber Assets and Critical Business Processes (with underlying information infrastructure). The entity should ensure that all cyber assets of their identified/notified CIIs are recorded in the asset register and considered for risk assessment.
- **Electronic Security Perimeter -** The entity should ensure that every Critical System resides within an Electronic Security Perimeter. Thus, ensuring that all critical, high and medium vulnerabilities identified as a result of cyber–Vulnerability Assessment shall be closed and verified for the effective closure.
- **Cyber Security Requirements -** The entity shall have an Information Security Division (ISD), headed by CISO. The entity must routinely audit and test security properties of the Critical System and must act upon, in case if any new vulnerabilities are identified through testing or by the equipment manufacturer.
- **Cyber Risk Assessment and Mitigation Plan -** The entity shall document in their Cyber Security Policy a Cyber Risk Assessment and Mitigation Plans drawn upon the best practices and clearly define the matrix for assessing the cyber risk of both IT and OT environment and risk acceptance criteria.
- **Phasing out of Legacy System -** As the life cycle of the Power System Equipment/System is longer than that of IT Systems deployed therein, the entity should ensure that all IT technologies in the Power System Equipment/System have the ability to be upgraded. It should also document a Standard Operating Procedure for safe and secure disposal of outlived or legacy devices.
- **Cyber Security Training -** The entity should establish, document, implement, and maintain an annual cyber security training program for personnel having authorized cyber or authorized physical access (unescorted or escorted) to their Critical Systems. It should review this training program and ensure that Cyber Security training program designed for their IT as well as OT O&M Personnel must include the relevant topics.
- **Cyber Security Incident Report and Response Plan -** The entity should report all cyber security incidents, classified as reportable events. The root cause analysis of the incidents should be performed, and the entity should ensure that all the details of the incident
- **Cyber Crisis Management Plan(C-CMP) -** The entity shall prepare a Cyber Crisis Management Plan and ensure that it's reviewed yearly.
- **Sabotage Reporting% -** The entity should incorporate procedure for identifying and reporting of sabotage in their Cyber Security Policy.
- **Security and Testing of Cyber Assets -** The entity should ensure security of all in-service phase as well as standby Cyber Assets through regular firmware/Software updates and patching, Vulnerability management, Penetration testing (of combined installations), securing configuration, supplementing security controls. It should also carry out regular Vulnerability Assessment of all Cyber Assets owned or under their control.
- **Cyber Security Audit -** The entity should implement Information Security Management System (ISMS) covering all its Critical Systems. The entity should also through a CERT-

In Empanelled Cyber Security OT Auditor get their IT as well as OT System audited at least once in every 6 (six) months.

Annexure 9 – Relevant data security standards for Indian distribution

Table 26 : Relevant data security standards

Sl. No	Standard	Description
1	ANSI C12.22-2012	This standard describes the process of transporting C12.19 table data over a variety of networks, with the intention of advancing interoperability among communication modules and meters.
2	Department of Homeland Security: Cyber Security Procurement Language for Control Systems	This document summarizes security principles that should be considered when designing and procuring control systems products and services (software, systems, maintenance, and networks), and provides example language to incorporate into procurement specifications.
3	DHS NCS Catalog of control systems security: recommendation for standard developers	This catalogue presents a compilation of practices recommended to increase the security of control systems from both physical and cyberattacks.
4	Framework for Improving Critical Infrastructure Cybersecurity	The Framework focuses on using business drivers to guide cybersecurity activities and considering cyber-Security risks as part of the organization's risk management processes.
6	IEC 62351-1:2007	The scope of the IEC 62351 series is information security for power system control operations. Its primary objective is to undertake the development of standards for security of the communication protocols
7	IEC 62351-3:2014+AMD1:2018	This standard specifies how to provide confidentiality, integrity protection, and message level authentication for SCADA and telecontrol protocols that make use of TCP/IP as a message transport layer when cyber-security is required.
11	IEC 62351-7:2017	This standard defines network and system management (NSM) data object models that are specific to power system operations.
12	IEC 62351-8:2011	This standard covers the access control of users and automated agents to data objects in power systems by means of role-based access control.
14	IEC 62351-10:2012	This standard target the description of security architecture guidelines for power systems based on essential security controls, i.e., on security-related components and functions and their interaction.
16	IEC 62351-12:2016	This standard discusses cyber security recommendations and engineering/operational strategies for improving the resilience of power systems with interconnected Distributed Energy Resources (DER) systems.
17	IEC 62351-13:2016	This standard provides guidelines on what security topics could or should be covered in standards and specifications.
18	IEC 62541-2:2016	OPC unified architecture - Part 2: Security Model.

Sl. No	Standard	Description
19	IEC 62541-6 :2015	OPC unified architecture - Part 6: Mappings.
20	IEEE 1686-2013	Standard for Intelligent Electronic Devices Cyber Security Capabilities
21	IEEE 1701-2011(ANSI C12.18)	Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables
22	IEEE 1702-2011(ANSI C12.21)	Standard for Telephone Modem Communication Protocol to Complement the Utility Industry End Device Data Tables
23	IEEE 1815-2012	Standard for Electric Power Systems Communications-Distributed Network Protocol (DNP3)
24	IEEE 2030.5-2013	IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard. It defines the mechanisms for exchanging application messages, the exact messages exchanged including error messages, and the security features used to protect the application messages.
25	MultiSpeak Security-V1.0	A specification for application software integration within the utility operations domain; a candidate for use in an Enterprise Service Bus.
26	NAESB REQ.21	Energy Services Provider Interface Model Business Practices (MBPs)
27	NAESB RMQ.26	The framework supports Distributed Energy Resources that communicate based on a common schematic definition and then can process the data locally for action (control, reporting).
28	NEMA SG-AMI 1-2009 (R2015)	This standard serves as a key set of requirements for smart meter upgradeability. These requirements should be used by smart meter suppliers, utility customers, and key constituents, such as regulators, to guide both development and decision making as related to smart meter upgradeability.
29	NERC Critical Infrastructure Protection (CIP) 002-009	These standards cover organizational, processes, physical, and cybersecurity standards for the bulk power system.
30	NIST SP 800-53-Rev 5-2017	This publication provides a catalogue of security and privacy controls for federal information systems and organizations to protect organizational operations and assets, individuals, other organizations, and the Nation from a diverse set of threats including hostile attacks, natural disasters, structural failures, human errors, and privacy risks.
31	NISTIR 7628	Guidelines for Smart Grid Cyber Security: Vol. 1, Smart Grid Cybersecurity Strategy, Architecture, and High-Level Requirements
32	Security Profile for Advanced Metering Infrastructure, v 1.0	The scope of this work extends from the meter data management system (MDMS) up to and including the home area network (HAN) interface of the smart meter. Informative security guidance may be provided for systems and components relevant but beyond the explicitly designated scope. In developing this guidance, the task force examined community-established AMI use cases, evaluated risk for AMI, and utilized a security service domain analysis.

Relevant security guidelines and some international standards useful for Indian context:

1. **National Institute of Standards and Technology (NIST) Cyber Security Framework (CSF)**

The NIST CSF is a framework that can be used to assess an organizations cybersecurity maturity against a set of functions, categories, and underlying controls which then form recommendations within those functions for improvement.

2. **Centre for Internet Security (CIS) Critical Security Controls (CSC)**
   The CIS CSC is a recommended set of actions for cyber defence that provide specific and actionable ways to stop today's most pervasive and dangerous attacks.

3. **ISO/IEC 27001:2013**
   ISO/IEC 27001:2013 is an international standard on how to manage information security.

4. **Purdue Enterprise Reference Architecture (PERA)**
   PERA is a commonly accepted concept-based model used in OT/ICS network segmentation. The model segments devices and equipment into hierarchical functions that show the interconnections and independencies of the main components of a typical OT/ICS. The PERA delineates security boundaries between users, ICS networks, and business networks. It also shows how these boundaries have been blurred in recent years as IT/OT convergence gained importance.

Annexure 10 – IT-OT integration framework

A DISCOM may have a few or several IT-OT use cases enabled based on the maturity level. As the Indian distribution industry focuses more on the integrated operation of the IT-OT systems, the convergence initiatives allow a range of new applications/ systems to be implemented on top of the existing infrastructure along with enablement of new use cases.
The eventual goal of IT-OT integration is to build an integration solution wherein all the existing applications and future system upgrades may easily be converged to enable use cases which meet the business requirements/goals.

The IT-OT integration framework aims to demonstrate how various applications and systems (already in place or to be established) may be integrated. It also aims to establish the data flows and the working principles of the system. The below sections provide an overview of the IT-OT integration solution followed by further detailing the flow of data among various systems (internal or external) and applications.

Data flow framework

An IT-OT integrated distribution operation needs to handle real time data from various ground level devices, sensors as well as from external applications. The integration layer between various IT-OT systems is the Level 3 of the architecture, as per the ISA-95 standard. This layer can be subdivided into three sections:

- ***OT system Integrator:*** This comprises of the adaptors, and the OT data interfaces which interpret real time data and push this data to the common data layer.
- ***Common data layer:*** This is the data storing system which captures real time data from various devices and internal, external applications (weather data applications, CRM etc.). This layer consists of historian and relational databases. The primary function of the common data layer is to store, cast, and send data to the appropriate applications in the right format and structure for further execution.
- ***IT infrastructure integrator:*** This is the interface between the common data layer and existing applications such as billing, CRM, SCADA etc. There are various systems such as OLEDB, JDBC, ODBC, middleware programs, API interfaces, and so on for integrating the common data layer to any individual application or data base.

The Common data layer is the most important part of any IT-OT integration system. The common data layer should have the following features:

- Should be easily scalable and integrable with multiple types of field devices and applications
- Should have high flexibility to handle any data type/format
- Should support hosting on cloud
- Should be able to accommodate analytical engines for the analysis of the stored data

Many integration solutions in the Indian distribution industry employ MDM or OMS as a historian solution for smart meters. To examine the structure of data flow, one key use case (i.e., Planned Outage Management System) from the point of view of Indian distribution has been used. The system is depicted below.

***Overview & assumptions*:**

- The study takes into account a distribution circle with four substations.
- Consumer end meter readings are collected at the substation level at a 3-minute interval.
- The distribution circle also has distributed energy resources, and DER generation meter data which is collected on an hourly basis.
- The common data layer, which is deployed on the cloud, has the capability of supporting various meters and the implemented IT application communication protocols.
- External applications of the integrated system include weather and market data (to sell or buy surplus/deficit in the open market) whereas, internal applications comprise of CRM (Customer Relationship management, Load scheduling, Analytical decision support along with control and monitoring systems.

The following section summarizes how the data from multiple internal and external sources/systems flows, interacts, or is absorbed by the Common Data Layer:

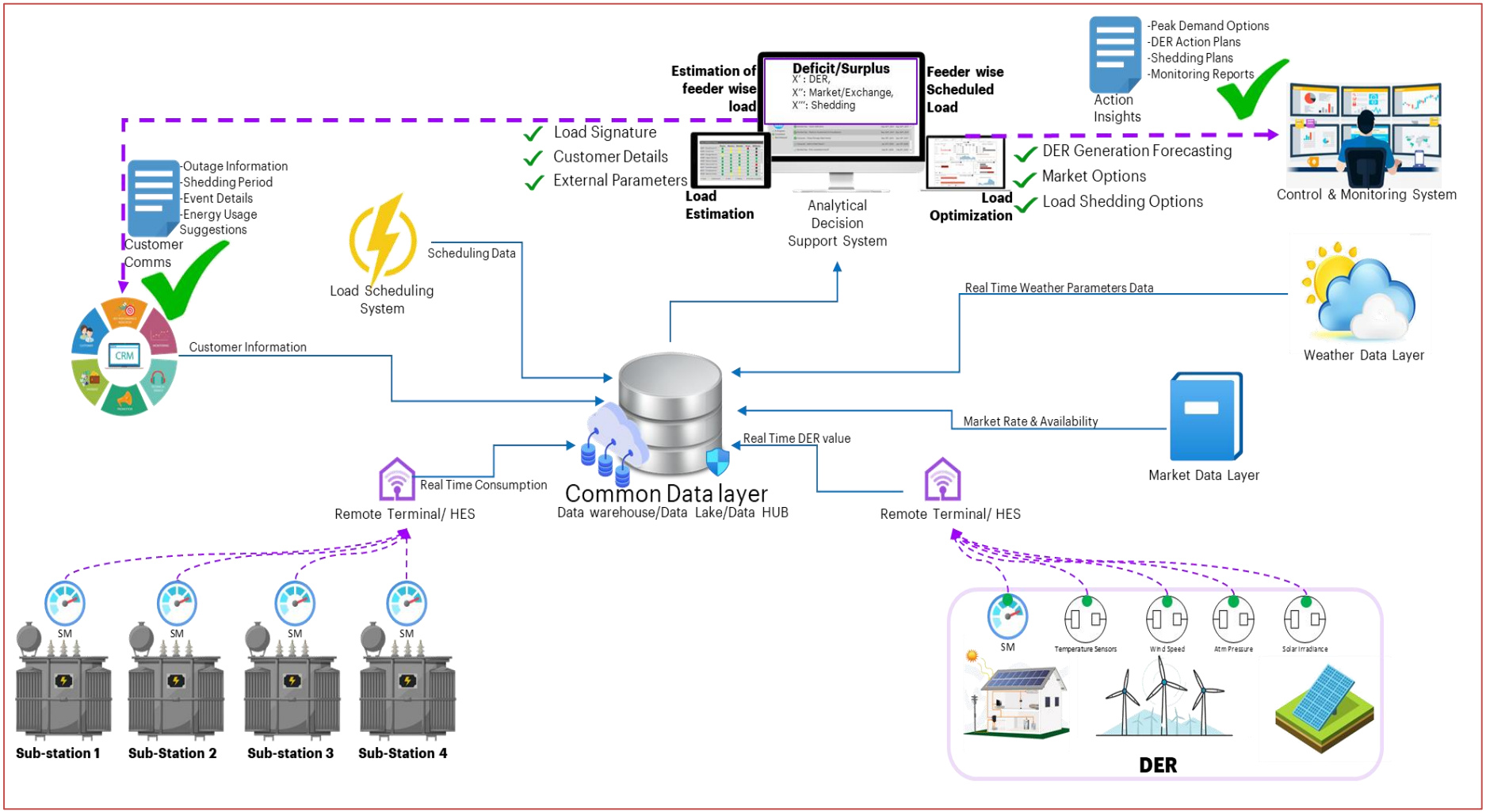
Data Flow Structure:

- As a first step, the respective substation meter data is sent to the HES system, where the data is concentrated and sent to the common data location of the system.
- The respective generation meter readings (DER readings) are also captured and provided to the HES for data consolidation. The consolidated data from HES is then pushed to the Common Data Layer which is deployed on the cloud.
- The CRM application pushes the customer/ substation details to the Common Data Layer to map the meter data against the respective customer/substation.
- Scheduling, weather, and market data applications deliver hourly data on forthcoming planned loads, real-time weather conditions, market rate, and available alternatives on an hourly basis to the central data location.
- After all the relevant data are received by the Central Data Location, the next step is to CAST and transfer the data. Thus, all data from relevant IT applications (CRM, weather data applications, market data applications, scheduling system) and OT applications are received by the Common Data Layer and CASTed (clean, augment, shape, and transform) & converted into relational data sets. The data layer provides the data in a manner that can be supported by an analytical decision support system and any other enterprise IT applications. The formatted data is then transferred to the analytical engine via the corresponding middleware system.
- The situation might result in a load surplus or deficit. In both the circumstances, the analytical engine will generate action insights based on the available mitigation plan and provide these insights to the control and monitoring applications, which will execute the action on time without system downtime. Additionally, the analytical engine will enable customer communication to keep the end user up to date.

Outcome:

- Real time data from generation and distribution is used to reduce downtime
- An analytical decision support system that can generate effective action insights to be executed automatically to decrease downtime
- The solution facilitates effective consumer communication about system updates

Figure 53 : Detailed IT-OT integration framework and data flow structure



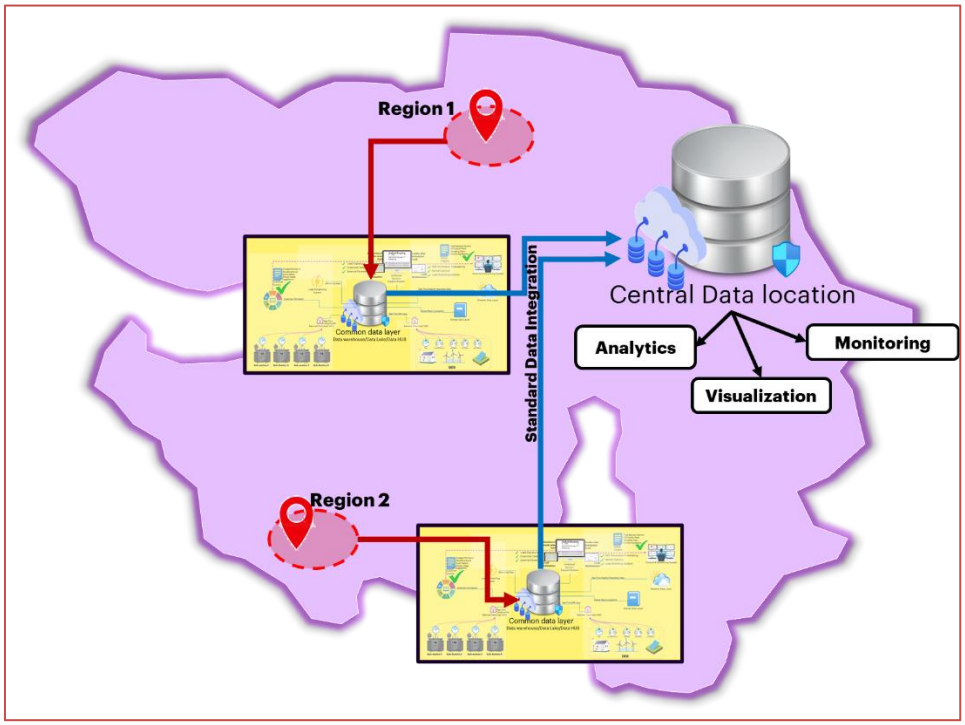
Centralized common data layer

The study (as per the best practices) recommends that the Common Data Layer be connected to the centralized relational data server. In the Indian context, a centralized data server provides the business users the visibility into the system's data (such as - SCADA, AMI, OMS, etc.) via standard data integration methodologies with common data layers. Thus, a DISCOM functioning in multiple geographies using IT-OT solutions (SCADA, AMI, OMS etc.), can have the Common Data Layer of each regional solution connected via a peer-to-peer connection through cloud or standard business network with the centralized data location.

The below image shows a DISCOM's operation spread over two regions, with separate planned outage management systems. The Common Data Layers of both regions are connected via standard integration protocols (TCP/IP or other business network integrations) to a centralized relational data base (Central data location). The users or business decision makers can access the data for the systems and the regional common data layers from the central data location remotely. The DISCOM can configure any analytical or visualization tool on top of the centralized relational data server, as per the requirement.

Note: The study recommends a centralized Common Data Layer. The centralized data server may be implemented either on-premises or on the cloud without impacting the centralized data handling procedures.

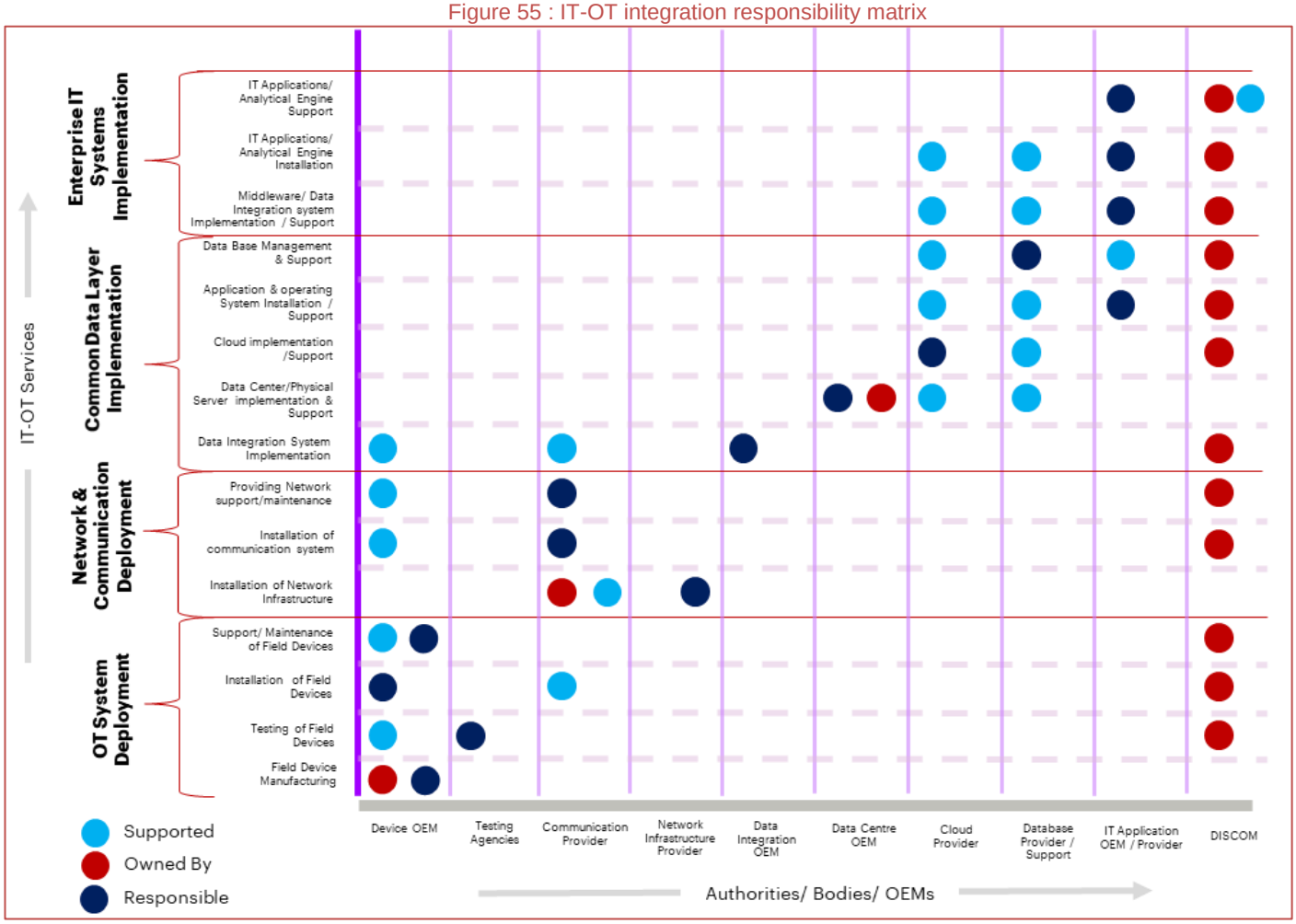
Figure 54 : Interconnection between DISCOM's operations in two regions



Annexure 11 – IT-OT integration responsibility matrix

The responsibility matrix is to depict different activities & the corresponding stakeholders involved to implement IT-OT integration for a DISCOM. The activities are broadly divided into four broad services OT system deployment, network & communication deployment, common data layer implementation, enterprise IT system implementation. The below diagram illustrates an indicative responsibility matrix of different stakeholders during the implementation phase.

Figure 55 : IT-OT integration responsibility matrix



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