DIGITAL TECHNOLOGIES IN ELECTRIC POWER SECTOR

PRAVEEN KUMAR AGARWAL

FORMER DIRECTOR & CISO, GRID CONTROLLER OF INDIA

Profile

Independent Consultant
Former Director & CISO
POSOCO Ltd.

Brief Job Profile:

Jun-2020 to Mar-2009 Power System Operation Corporation Ltd.
Director of Market Operations & Chief Information Security Officer (CISO). Executive Director – Head of Northern Region Grid Control System.

Mar-2009 to Oct-1993 Power Grid Corporation of India Ltd.
Posts Held- AGM, DGM, Chief Manager, Manager, Dy. Manager

Sep-1981 to Oct-1993 National Thermal power Corporation Ltd (NTPC Ltd)
Post held – Dy. Manager, Sr Engineer, Engineer, Executive Trainee.

Professional Expertise:

An accomplished professional with 43+ yrs. of experience in diverse areas of power sector. Expert on electricity market design, digital & automation strategy, large SCADA integration, and OT cyber security.

Currently: Advising at International Level for Tetra tech / USAID / MCC as expert in following areas:

1. **SCADA/EMS/WAMS.**
2. **Power System Cyber Security**
3. **Utility Digitalization Strategy**
4. **Electricity market design & Operations**

LinkedIn: ~pkagar
X: @pkagar

OUTLINE

- Introduction
- Distribution and Consumers
- Transmission and Operations
- Renewables & DERs
- Benefits and Challenges

INTRODUCTION

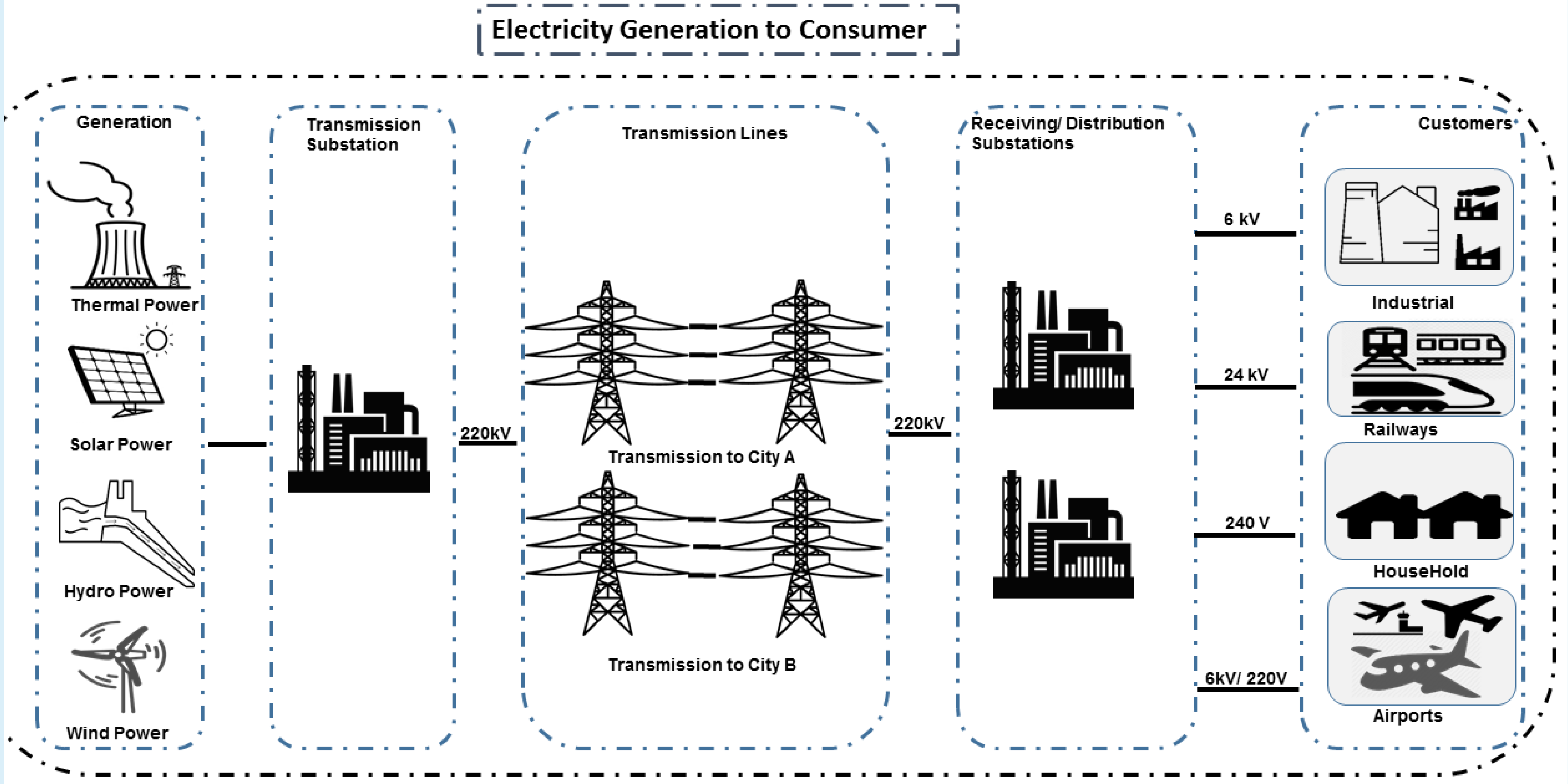
TRANSFORMATION OF POWER GRID

- There is a fundamental shift in the global energy landscape.
- Time has added many dimensions since the birth of power supply grid in 19881.

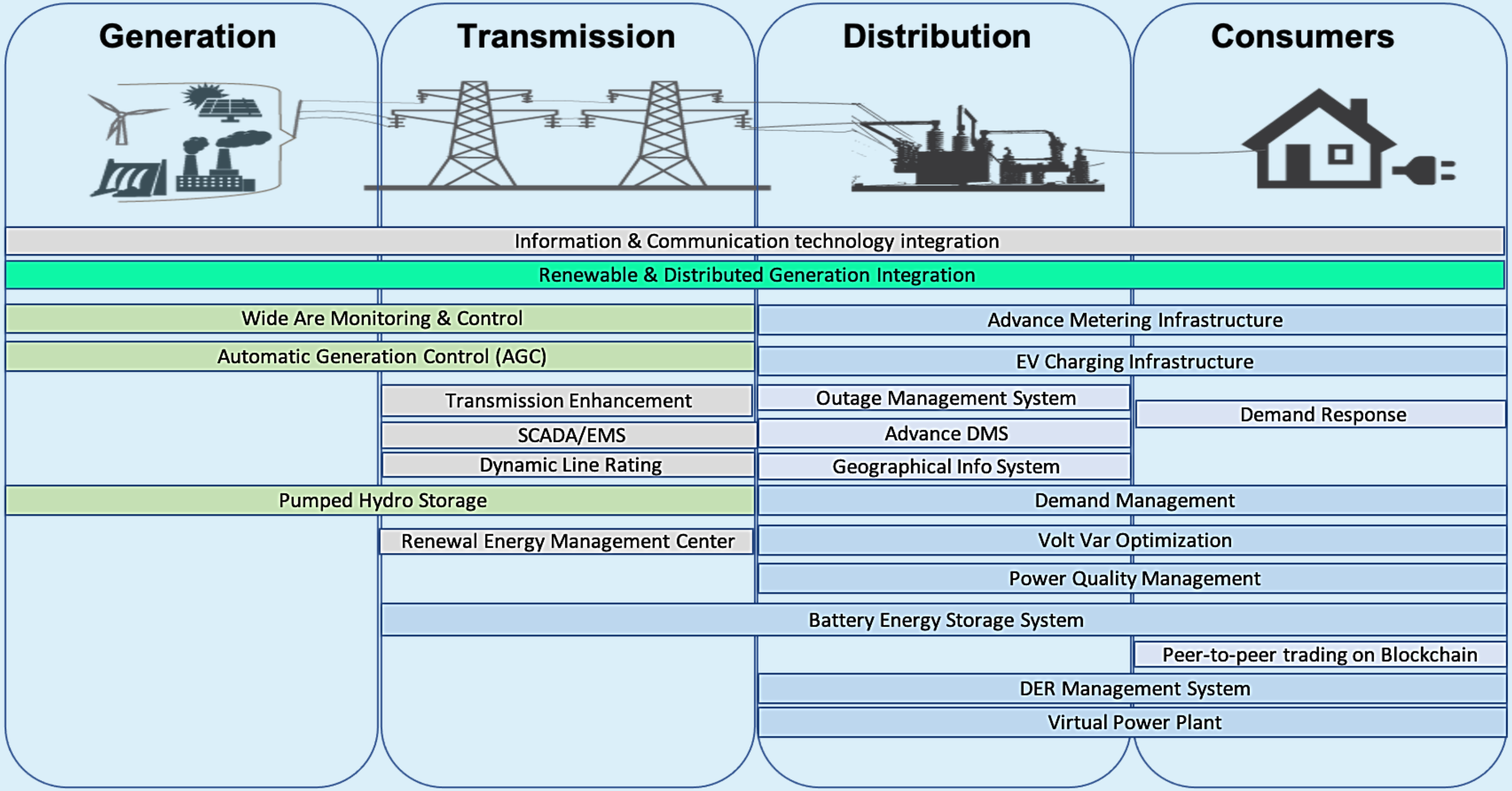
- The modern grid is transitioning to its fourth phase.
  - **Grid 1.0**– Localized generation and distribution – **Local Grid**.
  - **Grid 2.0**– Networked & inter-connected resources - **Interconnected Grid**.
  - **Grid 3.0**– Converged physical and cyber network - **Smart Grid.**
  - **Grid 4.0**– Decarbonized, Distributed, and Digitalized – **Digital Grid**.

- World over policy makers, planners, engineers are striving to keep grid resiliency, minimizing cost to consumer, and environment friendly infrastructure.
- Decarbonization efforts have introduced a new dimension of resources variability and granularity.
- Digitalisation has yet added another dimension of cyber security.

ELECTRICITY SECTOR VALUE CHAIN



TECHNOLOGIES ACROSS VALUE CHAIN



DIGITAL TECHNOLOGIES

- AMI, ADMS, GIS, Distribution Automation
- Customer services
- Prosumers & P2P trading

Distribution & Consumers

- SCADA / EMS / WAMS / REMC
- Ancillary Services, AGC & Reserves
- FACTS devices

Transmission & Operations

- Grid Edge Technologies
- Virtual Power Plants
- Microgrids & Inverters

Renewables & DERs

DISTRIBUTION AND CONSUMERS

DIGITAL TECHNOLOGIES IN DISTRIBUTION

Advanced Metering Infrastructure

An integrated systems of Smart meters, communication network and data management systems.
It provide real time data on consumption, connect-disconnect.

Benefits:
- Energy auditing & reduction in commercial loss.
- Remote detection of meter tempering.
- Remote disconnection.

Geographical Information System

GIS is representation of an on-field infrastructure on computer system. All the grid stations, transformers, lines, and cables are maintained I GIS.

Benefits:
- Situational awareness.
- Visualization of of field devices.
- Help managing outages.
- Reduced restoration time

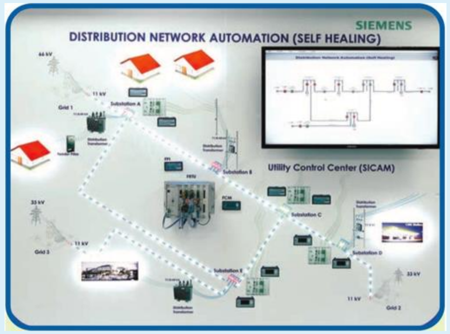
Advanced Distribution Management System

ADMS unifies SCADA, DMS and OMS in single system.

Collects field data from DCUs, RTUs and interface to GIS, SAP, etc.

Benefits:
- Quick decision capability.
- Reduction of technical losses.
- Automatic load shedding.
- Historical data for planning & analysis.

Distribution Network Automation



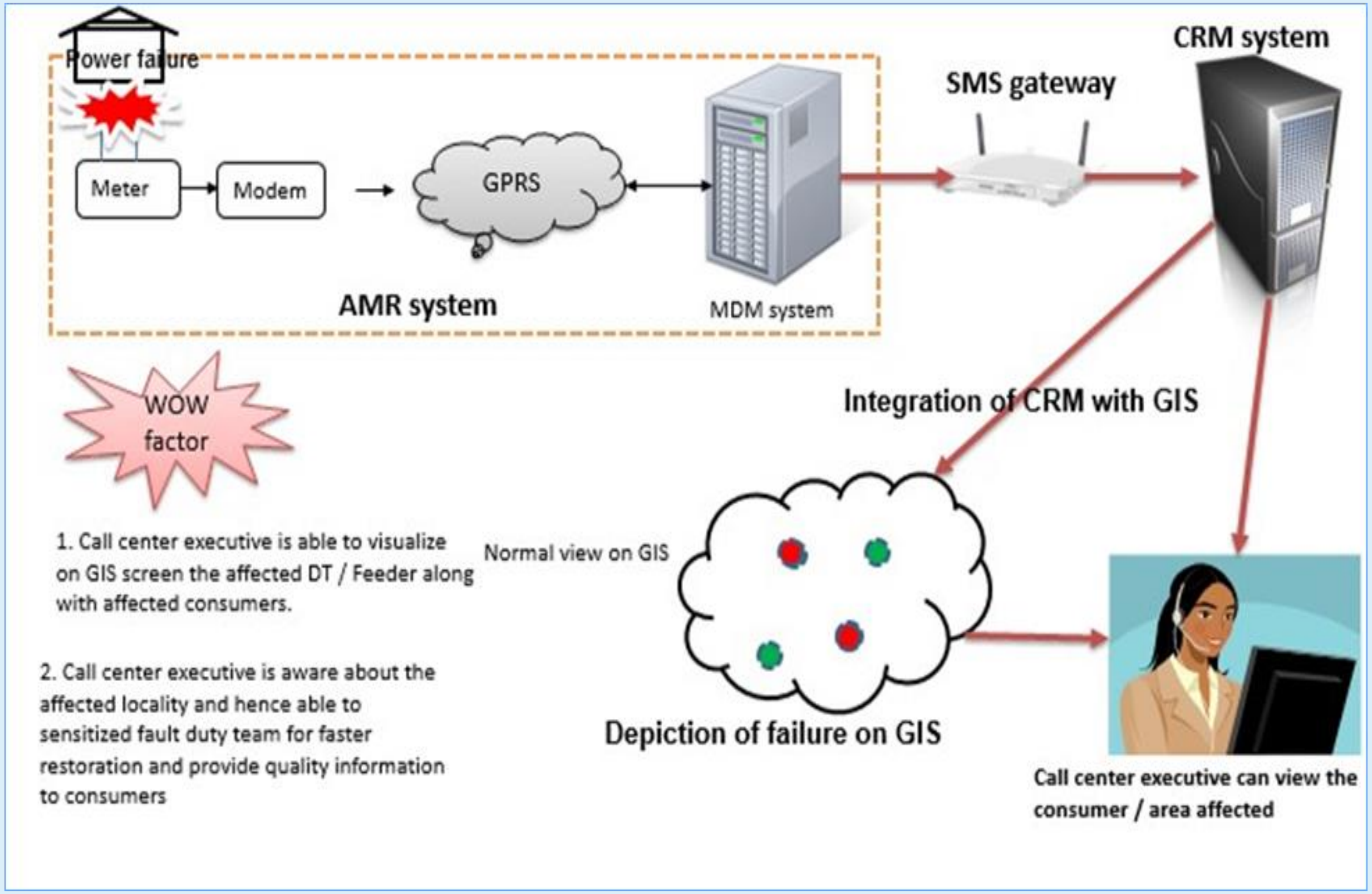
A self-healing system for reliable system.

The task of DNA is manifold which guarantee safe and secure operation.

Benefits:
- Minimal outage time.
- Quick isolation of faulty section.
- Improved customer service.
- Self healing network.

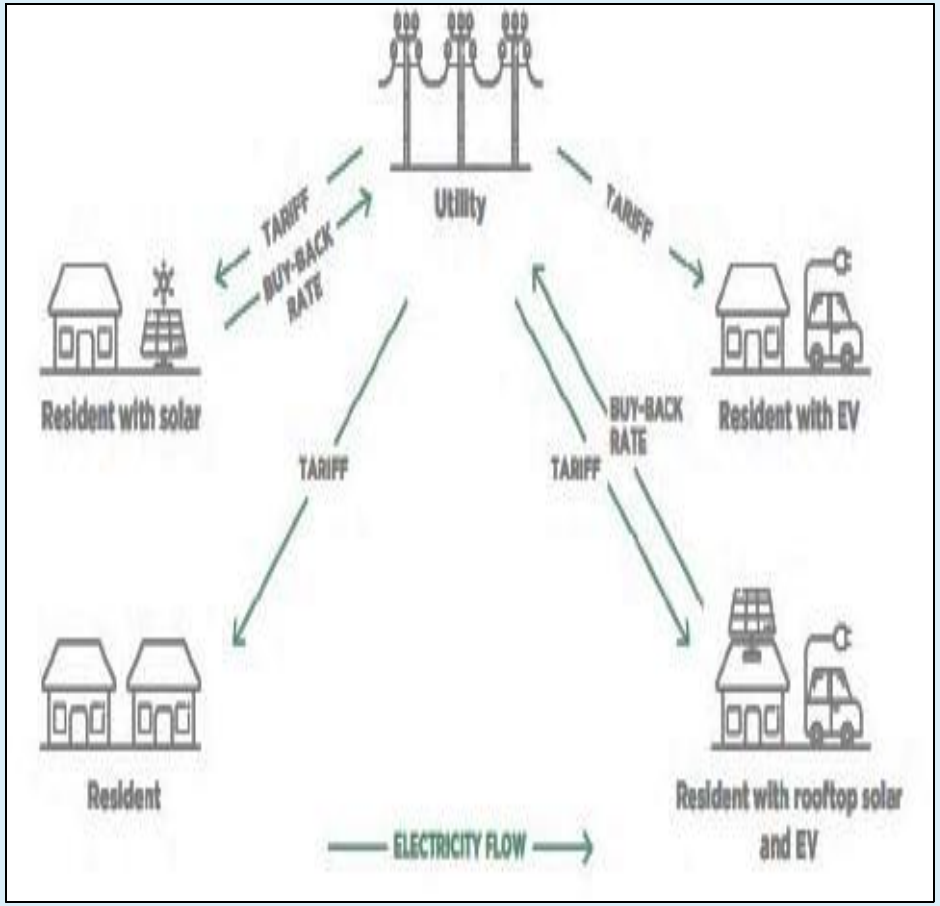
IMPROVING CUSTOMER SERVICES

- *In case of power failure, meters send an SMS to CRM System.*
- *CRM system generates and assigns the ticket to maintenance Team automatically.*
- *he the consumer is not required to log any power failure complaint.*
- *Executive can view the affected area / consumers.*
- *Call centre have prior knowledge of fault and approximate time for restoration.*
- *Improved customer service and complaint handling.*

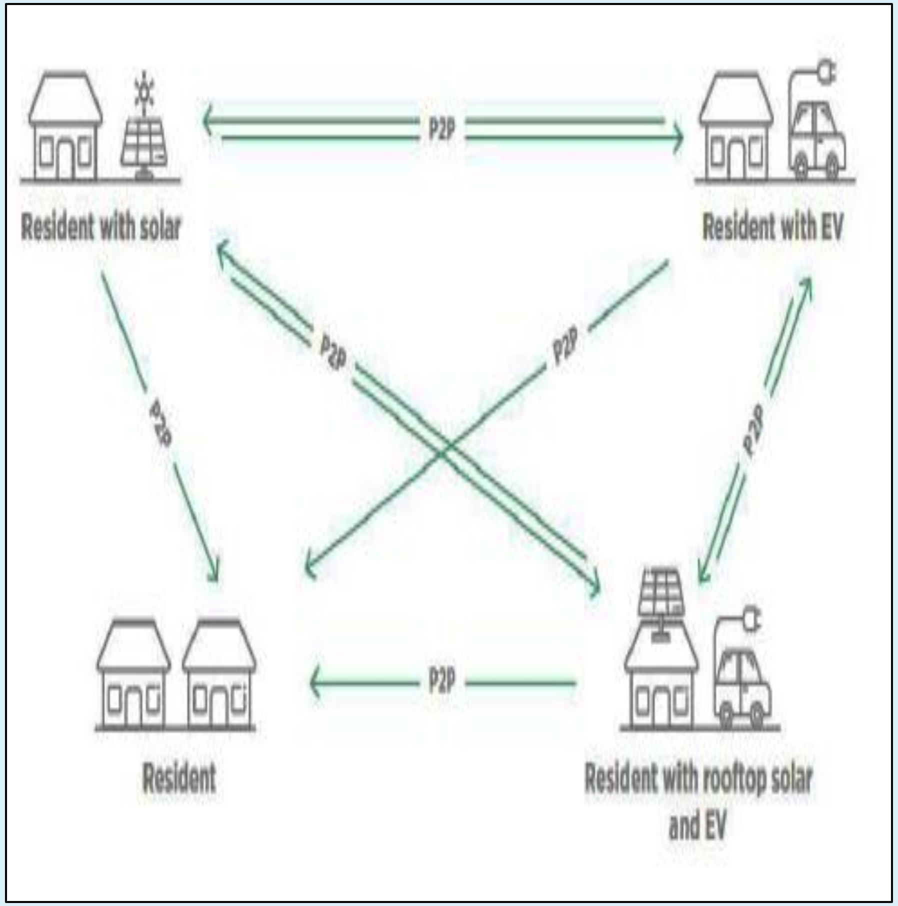


PEER-TO-PEER TRADING ON BLOCKCHAIN

Traditional Model



Peer to Peer (P2P) Model



Enablers

1. Rooftop Solar.
2. Digitalisation.
3. Blockchain Tech.
4. Conducive regulatory framework

Implementation

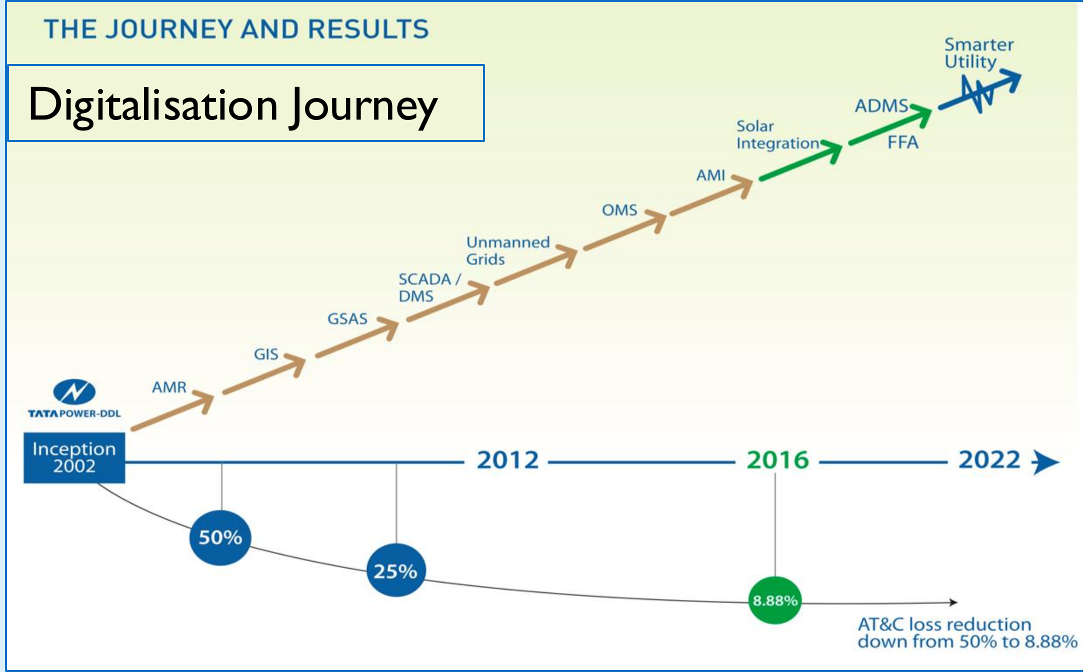
- Pilot projects were conducted in UP and Delhi.
- Karnataka has recently published regulations on P2P trading.
- Other countries have already started.

CASE EXAMPLE

Company: Tata Power Delhi Distribution Ltd

- A joint stock company with Delhi Government.
- Took over Government company in 2002.
- Licensed for distributing electricity in North & Northwest of Delhi (Capital of India).

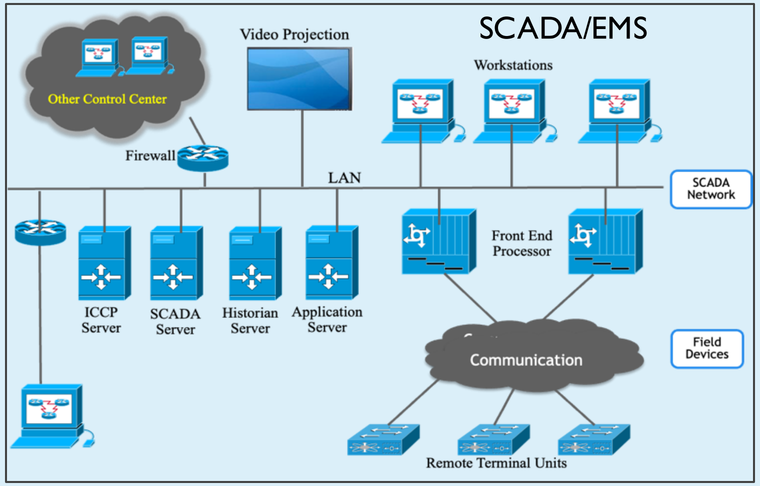
Digitalisation Journey

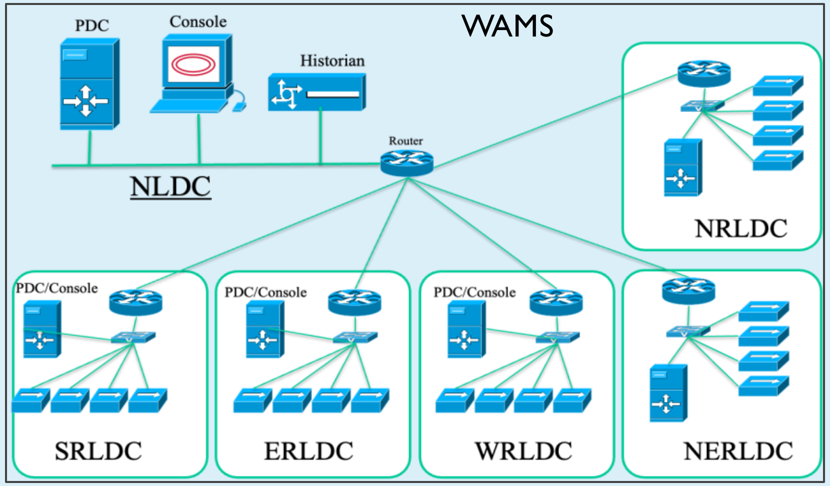


Parameter	Unit	July '02	March'19
OPERATIONAL PERFORMANCE			
AT&C Losses	%	53.1	7.92
System Reliability – ASAI -Availability Index	%	70	99.57
Transformer Failure Rate	%	11	0.87
Peak Load	MW	930	1967
Length of Network	Ckt. Km	6750	12634
Street Light Functionality	%	40	99.2
CONSUMER RELATED PERFORMANCE			
New Connection Energization Time	Days	51.8	2
Meter Replacement Time	Days	25	2.79
Provisional Billing	%	15	0.49
Defective Bills	%	6	0.2
Bill Complaint Resolution	Days	45	2
Mean Time to Repair Faults	Hours	11	0.95
Call Center Performance - Service Level	%	-	85
Consumer Satisfaction Index	%	-	94

TRANSMISSION AND OPERATIONS

SCADA / EMS / WAMS / REMC

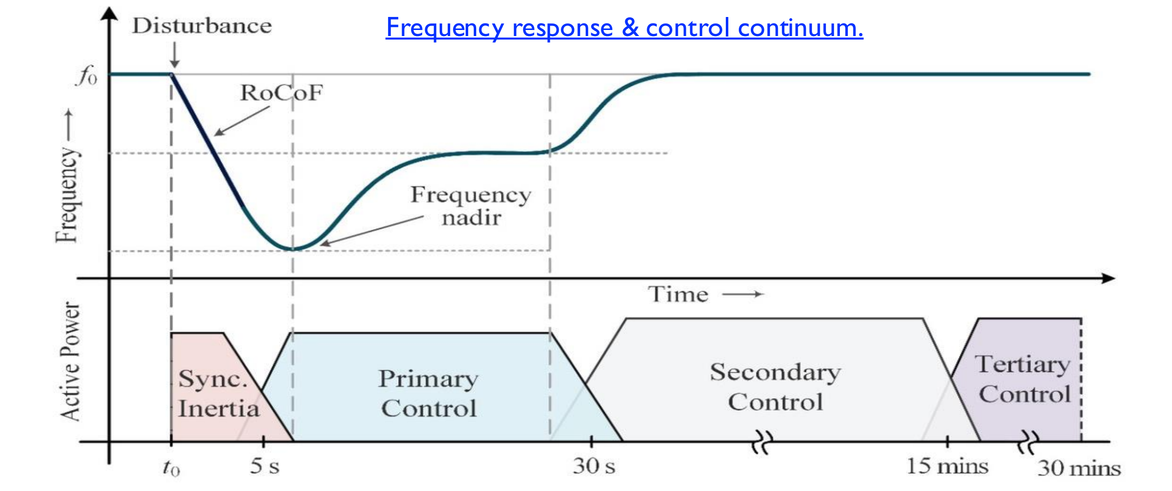




Features	SCADA/EMS	WAMS	Advantages
Data Reporting & Measurement	4-10 seconds Unsynchronized	40 millisecond Synchronized	Accurate System representation for pinpointed problems detection
Angle Measurement	Not possible	Possible	Improved Power Flow for maintaining automatic Load/Generation balance
Oscillation Monitoring	Not possible	Possible	Power System Oscillations monitoring and action to achieve greater Grid Stability
Post fault analysis	Not in Real Time	Possible in Real Time.	Accurate & Fast Fault Analysis for suitable remedial actions
Visibility of dynamic behavior.	Not possible	Possible	Corrective measures possible to achieve greater Grid Stability and resilience.

- India started its WAMS journey in 2009.
- First pilot projects were implemented.
- Pilot projects were upgraded to a national level pilot project.
- Indian grid operators are using WAMS data for:
    - Real time fault identification
    - Oscillation Monitoring.
    - Enhanced Situation awareness.
- Subsequently, India has implemented a full fledge WAMS project known as URTDSM (Unified Real Time Dynamic State Measurement).
- URTDSM consists of
    - 1700 OMUs
    - 32 PDCs at various levels
    - Analytics
- Renewable Energy Management Centers (REMCs) are SCADA control room for RE

ANCILLARY SERVICES AND RESERVES



- Reserves are deployable capacity in the grid in operation.
- Reserves are managed by grid operators.
- They are either mandated or incentivize by regulation or procured by system operators.
- Reserves are dispatched through different Ancillary Services.

Ancillary Service	Reserves	Motivation	Start of Activation	Full Deployment	Ability to Sustain
Primary - FGMO	Primary Reserve	Mandated	Instantaneous	< = 30 sec	Up to 15 minutes
Secondary - AGC	Secondary Reserve	Regulated	>= 30 Sec	< = 15 min	Up to 30 minutes or till replaced by TR
Tertiary - Dispatch	Tertiary Reserve	Procured	Usually, > 15 Min to 1 hour		

OTHER ANCILLARY SERVICES

Ancillary services are functions that help grid operators maintain a reliable electricity system. They include:

•**Synchronized regulation**: Corrects for short-term changes in electrical imbalances

•**Contingency reserves**: Responds to unexpected failures or outages

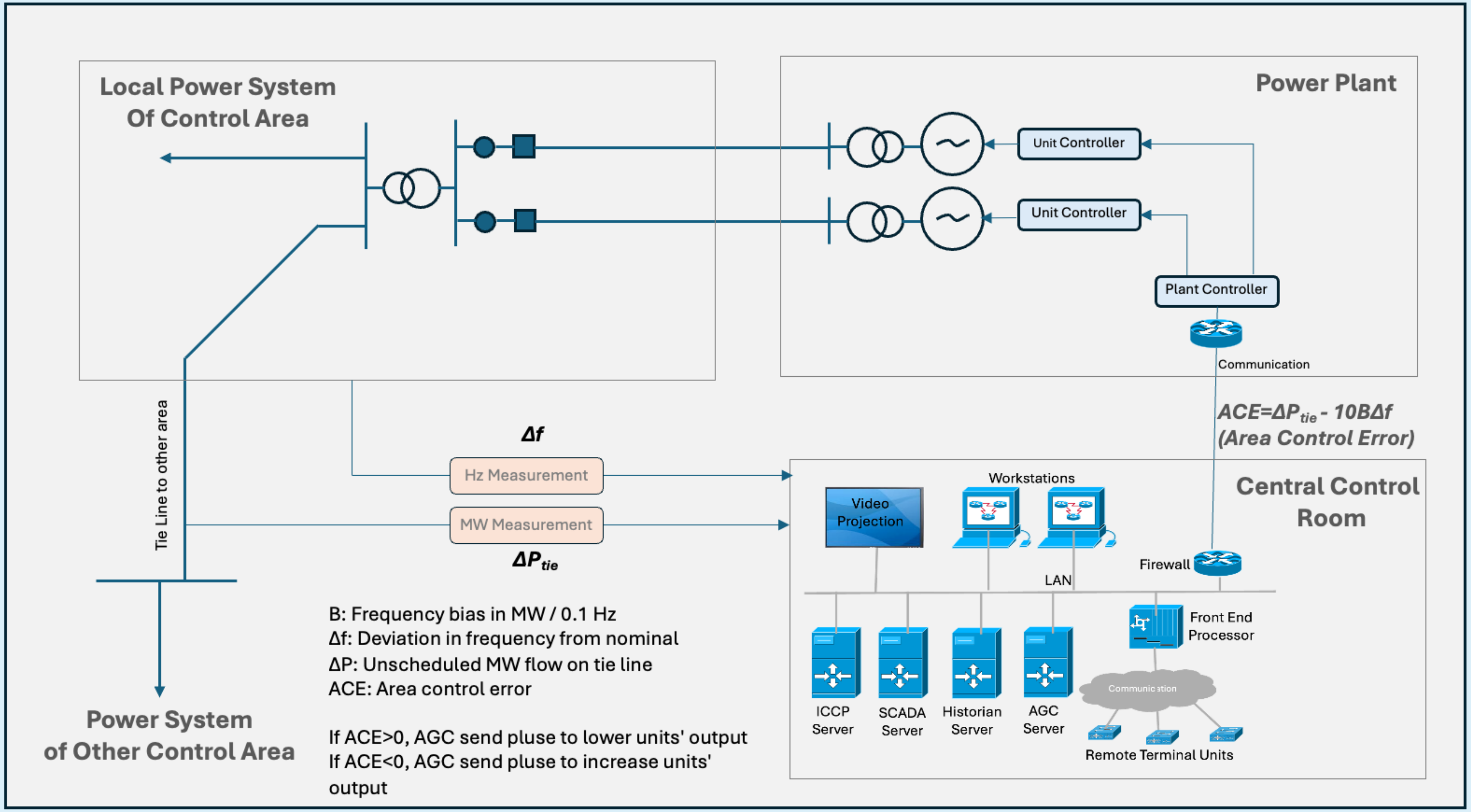
•**Black-start regulation**: Supplies electricity to restore the system if the entire grid loses power

•**Flexibility reserves**: Addresses variability and uncertainty on longer timescales

•**Frequency regulation**: Maintains grid stability

•**Voltage control**: Maintains grid stability

SECONDARY CONTROL
AUTOMATIC GENERATION CONTROL



FACTS TECHNOLOGY (FLEXIBLE AC TRANSMISSION SYSTEM)

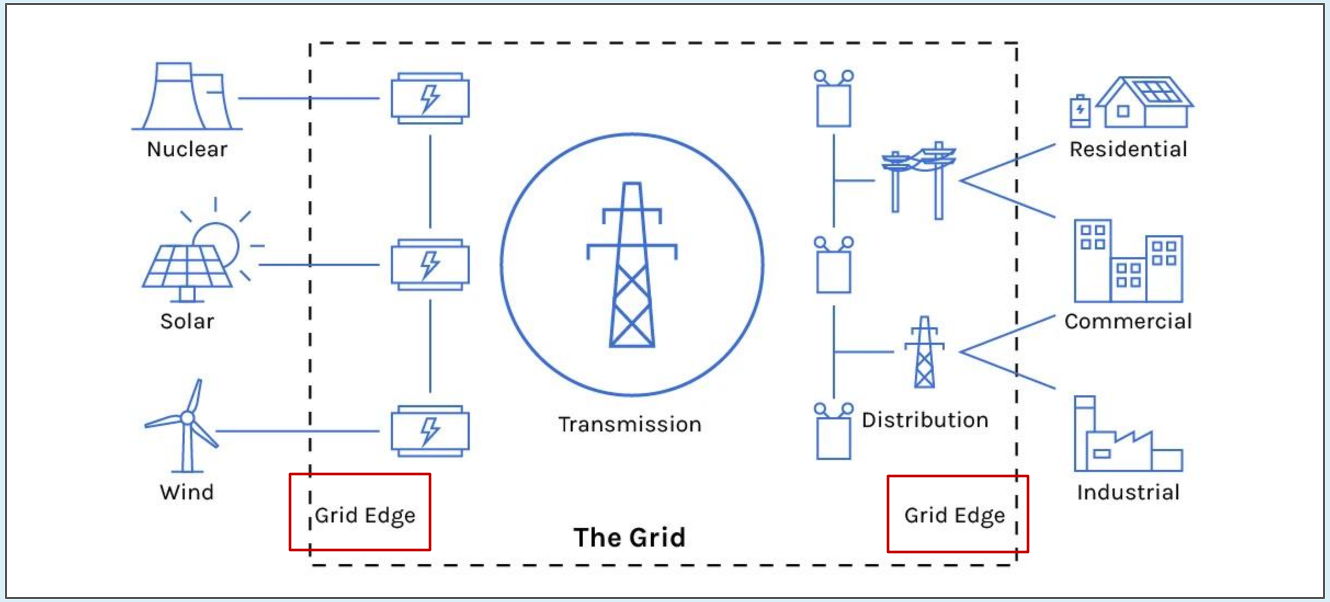
- The cost of transmission lines and losses, as well as difficulties encountered in building new transmission lines, would often limit the available transmission capacity.
- There are many cases where economic energy or reserve sharing is constrained by transmission capacity
- Added to this is the problem that it is very difficult to acquire new rights of way.
- many transmission facilities confront one or more limiting network parameters plus the inability to direct power flow at will.
- many transmission facilities confront one or more limiting network parameters plus the inability to direct power flow at will.
- FACTS technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded, lines
- By providing added flexibility, FACTS Controllers can enable a line to carry power closer to its thermal rating.
- It is based on power electronics with the thyristor or high-power transistor is the basic element for a variety of high-power electronic Controllers.

- **Flexible AC Transmission System** (FACTS), Alternating current transmission system incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.
- **Static Synchronous Compensator (STATCOM**): A Static synchronous generator operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage.
- **Static Var Compensator (SVC):** A shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage).
- **Thyristor Controlled Series Capacitor (TCSC):** A capacitive reactance compensator which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance.

RENEWABLES AND DER

GRID EDGE TECHNOLOGIES

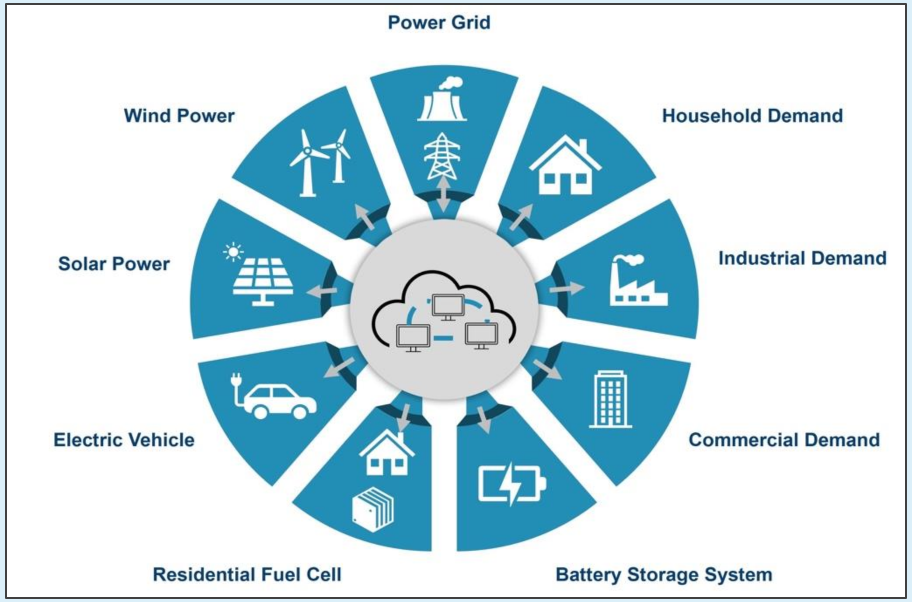
- The **Grid Edge** is where the wires meet the power plant or the load.
- **Grid Edge Technologies** integrates power generation sources or integrates loads. Like:
  - Inverters that convert rooftop solar or EVs to grid compliant power.
  - Smart meters that measure consumption and interact with central system.
  - Smart circuit breakers or other management systems that may have control of the systems and appliances behind the meter.



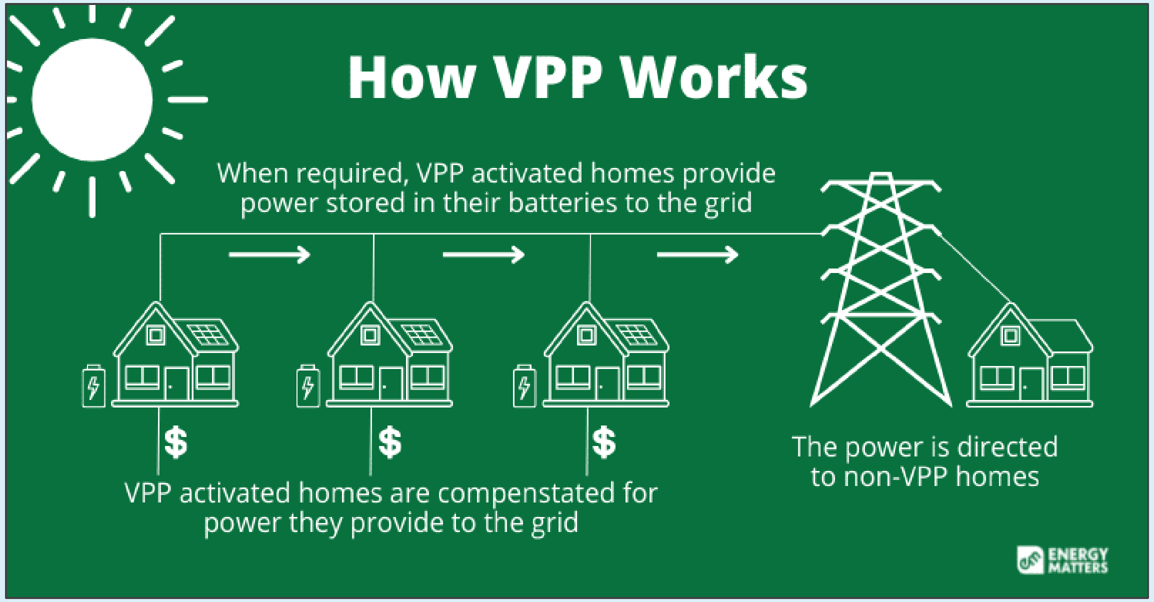
VIRTUAL POWER PLANTS

- VPP is a cloud-based software system that
    - aggregates and flexibly orchestrated distributed energy resources such as solar, wind, combined heat & power units, and storage systems. .

- VPPs can bring many and varied benefits to the grid.
    - increasing the utilization of current grid assets,
    - reducing the need for capital intensive grid upgrades.
    - providing needed resources for grid resiliency,



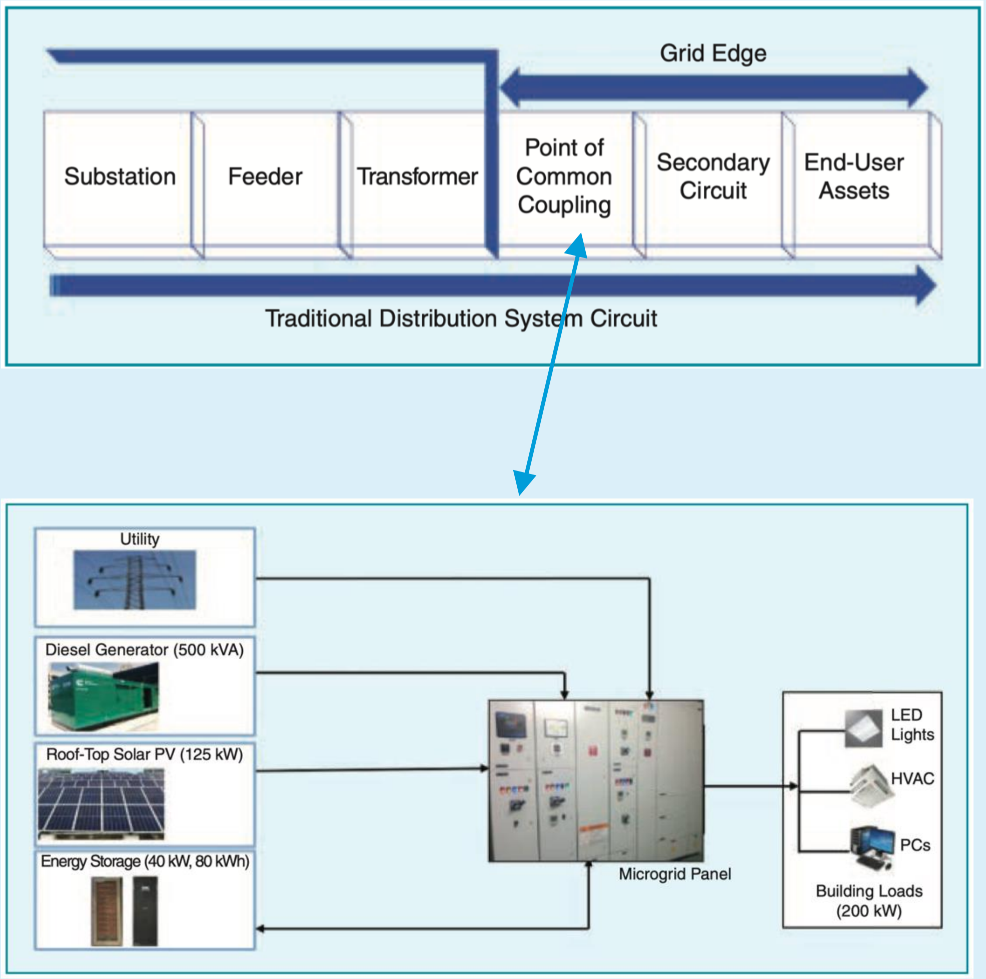
https://www.aranca.com/knowledge-library/articles/business-research/veterinary-virtual-power-plants-the-way-forward-an-emerging-segment-1



https://solarunitedneighbors.org/resources/rooftop-solar-distributed-power-plants-a-better-way-to-generate-electricity/

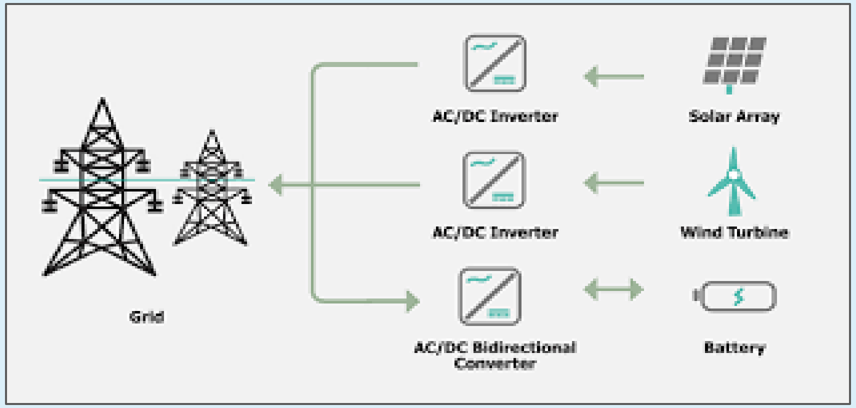
GRID EDGE TECHNOLOGIES - MICROGRIDS

- Microgrid:
  - A group of interconnected loads and DER
  - Within clearly defined electrical boundaries
  - That act as a single controllable entity with respect to the grid.
  - Enable multiple grid edge assets to participate together at the secondary circuit level behind the Point of Common Coupling.



GRID EDGE TECHNOLOGIES - IBR

- RE resources as connected to the grid through power inverters are known as IBRs.
- Inverters are of two types
  - **The grid-following inverters**
    - Follow the desirable set points for its real power under normal conditions.
    - Can change its real power for power sharing purposes upon a disturbance but and within the maximum power limit.
  - **A grid-forming inverter**
    - Have bidirectional power-transfer capability
    - Connects battery or microgrid system to the grid.



- IBRs can provide short-term ancillary services helping in reliability electricity system:
  - **Rapid I Q injection**: IBRs can quickly respond to commands to inject I and Q in the grid.
  - **Controlled inertial response**: IBRs can provide a controlled inertial response to the grid.

BENEFITS AND CHALLENGES

POTENTIAL BENEFITS

Generation	Transmission & System Operations	Distribution	Consumers
• Increase revenue & reduce cost with digital twin and condition monitoring: • Higher reliability with Automatic Load Control • Lower cost of grid integration of VRE	• Improve utilization of assets, increase return on investment • Defer or avoid CAPEX • Reduce congestion • Integrate higher amount of VRE • Lower reserve requirement by faster and more accurate dispatching • Higher reliability through better situational awareness	• Loss reduction • Reduce cost by automating meter reading, billing, customer service • Higher quality service—outage mgmt., voltage mgmt. • Reduce high-cost purchase of power with Demand response (DR) • Superior customer service	• Reduce bill through DR—time-of-use tariff and other means • Faster service • Advanced services to prosumers, rooftop solar, EV • Integrate with Smart devices • Increased reliability of power supply

CHALLENGES

- Digital technologies and automation software enables remote operation of the critical parts of the system. Adversaries may exploit this capability.
- Risk of cyber attack increases with digitalization.
- Vendor lock in and lack of interoperability may result in the high TCO.
- Modern power electronics devices like inverters are controlled by firmware. Bug or mis operation of firmware may lead to the controller mis behavior leading to pattern less oscillations.
- Intentional backdoor in firmware may provide control of critical infrastructure to the enemy nation.
- Tendency of over automation poses difficulty in troubleshooting of out of process task genuinely needed.

THANKS

?