SMART GRID TECHNOLOGY

DIPLOMA WALLAH

EE/EEE

JHARKHAND UNIVERSITY OF TECHNOLOGY (JUT)

UNIT 02 :- SMART GRID ARCHITECTURE

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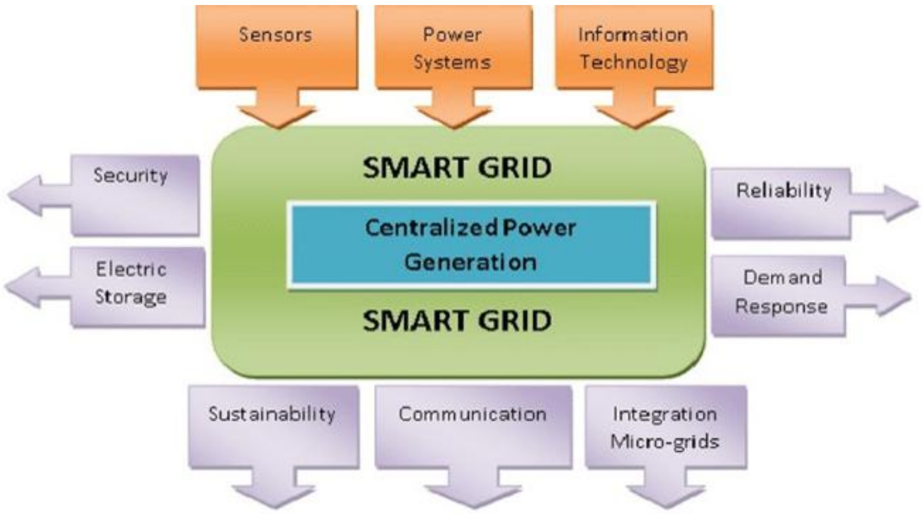
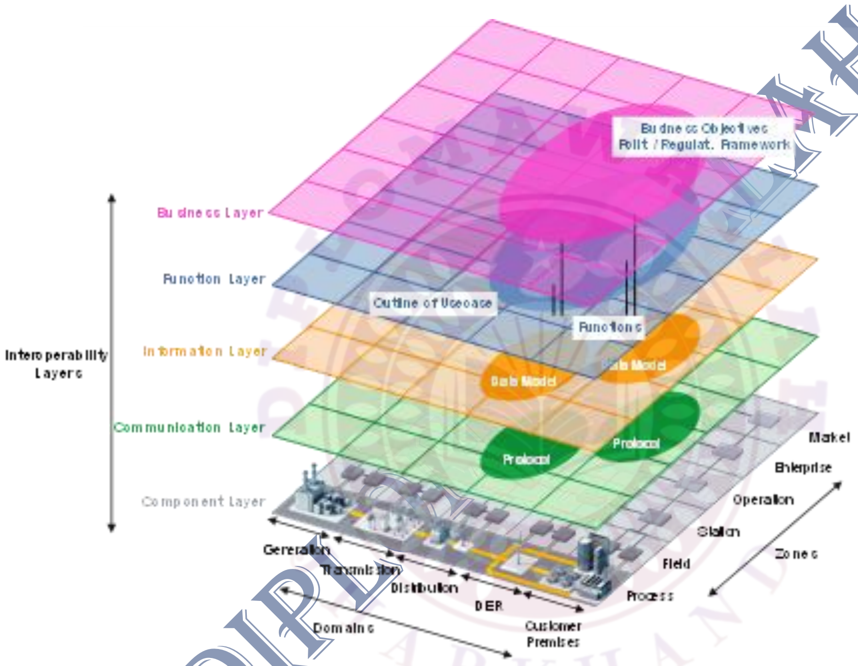
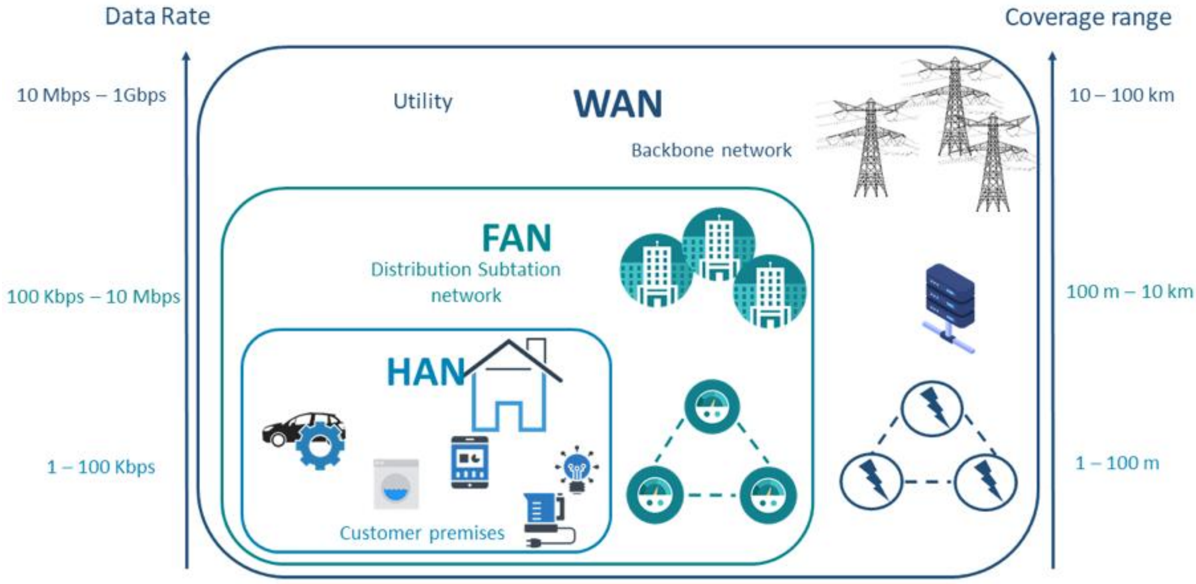
1. Components & Architecture of Smart Grid Design

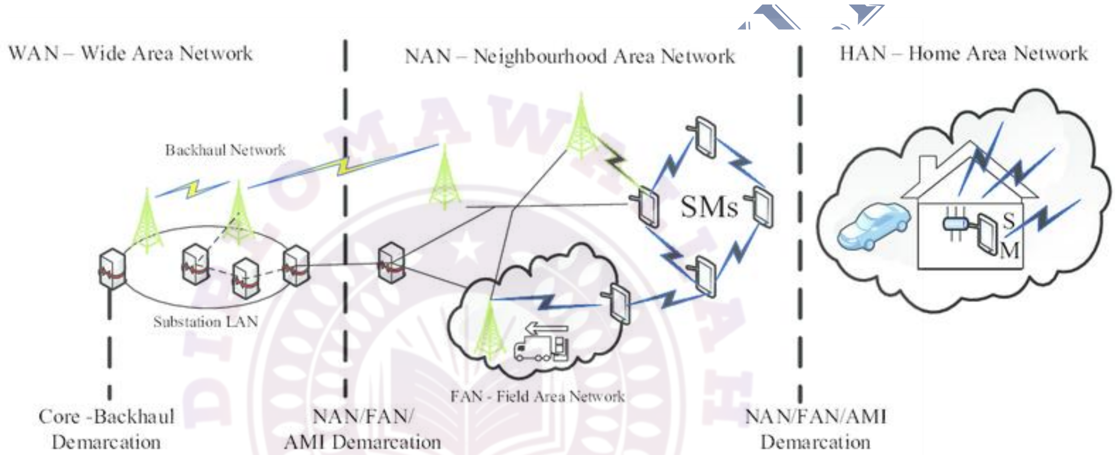
1.1 Architecture Overview

- The architecture of a smart grid integrates the traditional power system (generation → transmission → distribution → consumption) with an **information, communication and control** overlay. (RF Wireless World)
- One widely used modelling framework is the Smart Grid Architecture Model (SGAM) which represents domains (generation, transmission, distribution, DERs, customer) and zones (from process, field, station, operation, enterprise, market) to structure smart-grid architecture descriptions. (ScienceDirect)
- Key architectural layers:
  - Physical power infrastructure: equipment, lines, substations, DERs.
  - Communication/ICT layer: sensors, smart meters, networks (WAN, NAN, HAN) for two-way data. (TutorialsPoint)
  - Control & management layer: grid management systems (SCADA, DMS/ADMS), analytics, automation.
  - Customer (end-user) layer: smart appliances, prosumers, home energy management.
- The architecture should enable: two-way flows of electricity and information, high visibility of the grid, automated monitoring/control, integration of renewables/storage, active consumer participation. (The Department of Energy's Energy.gov)


Sensors
Power Systems
Information Technology
SMART GRID
Centralized Power Generation
SMART GRID
Security
Electric Storage
Reliability
Demand Response
Sustainability
Communication
Integration Micro-grids


Business Objectives
Polit. / Regulat. Framework
Business Layer
Function Layer
Information Layer
Communication Layer
Component Layer
Interoperability Layers
Outline of Usecase
Functions
Data Model
Protocol
Market
Enterprise
Operation
Station
Field
Process
Zones
Generation
Transmission
Distribution
DER
Customer Premises
Domains





1.2 Components of Smart Grid Design

Some of the major components (technological building blocks) of smart grid design include:

- Smart meters & Advanced Metering Infrastructure (AMI) – collect data, enable two-way communication. (Genus Power Infrastructures Ltd)
- Sensors and automated controls in transmission/distribution (PMUs, IEDs, relays) – for real-time grid monitoring and control. (Huawei Enterprise)
- Communication networks – e.g., WAN (Wide Area Network), NAN (Neighbourhood Area Network), HAN (Home Area Network) – enable connectivity between grid devices, utilities and consumers. (TutorialsPoint)
- Distributed Energy Resources (DERs) & renewable generation – solar, wind, battery storage added into the grid. (Meegle)
- Grid management systems (SCADA, DMS/ADMS), data analytics, control centres – manage operations, optimize flows, detect faults. (NREL)

- Energy storage and microgrids – to provide flexibility, buffer variability from renewables. (Huawei Enterprise)
- Consumer-side systems – smart appliances, demand response, home energy management that engage the end user. (RF Wireless World)

1.3 Review of Proposed Architectures for Smart Grid

- Generic block diagrams show smart meters at consumer sites communicating (via HAN/NAN) with utilities, with data concentrators, communication networks, control centres. (RF Wireless World)
- Communication architecture focuses on network layers: WAN connects major transmission/substation nodes; NAN connects neighbourhoods; HAN connects within home/building. (TutorialsPoint)
- Frameworks such as SGAM provide standardized way to model architectures, identify gaps in interoperability and standardization. (Wikipedia)
- Recent reviews emphasise architectures that integrate IoT/edge computing/fog computing to support smart grid monitoring & control at distribution/edge level. (arXiv)

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2. Advanced Metering Infrastructure (AMI)

2.1 Definition & Role

- Advanced Metering Infrastructure (AMI) is a set of integrated systems comprising smart meters, communications networks, data management systems allowing two-way communication between utilities and consumers. (IBM)
- It enables collection of interval consumption data (hourly or less), remote reading, remote connect/disconnect, outage detection, consumer information, demand response. (Genus Power Infrastructures Ltd)

2.2 Architecture & Components of AMI

Key components:

- Smart meters at end-user premises (electricity, gas, water) which record usage and communicate data. (Genus Power Infrastructures Ltd)
- Communication network connecting meters to data concentrators and then to utility head-end systems; may use wireless, power-line communications (PLC), cellular, broadband. (TutorialsPoint)

- Data management systems (Meter Data Management System – MDMS) for storing, analysing data and presenting actionable insights. (Genus Power Infrastructures Ltd)
- Consumer interface/home area network, demand response modules, and utility backend systems.

2.3 Benefits & Applications of AMI

- Enables utilities to more accurately monitor consumption, detect outages or theft, reduce manual meter reading. (Genus Power Infrastructures Ltd)
- Supports demand response programs, dynamic/tracking tariffs, and empowers consumers with real-time usage data. (Integrity Energy)
- Plays a critical role in integrating renewables/DERs because it gives visibility and communication necessary to handle two-way flows of energy and data. (Energy → Sustainability Directory)
- Helps improve reliability, reduce losses, optimise grid operations.

2.4 Challenges of AMI

- Requires significant investment in meters, communications and IT infrastructure.
- Data volume and security/privacy issues – handling large datasets, ensuring cybersecurity. (ScienceDirect)
- Interoperability, device standards, consumer acceptance.


TELEPHONE
NETWORK
INTERFACE
AEP-NMD06
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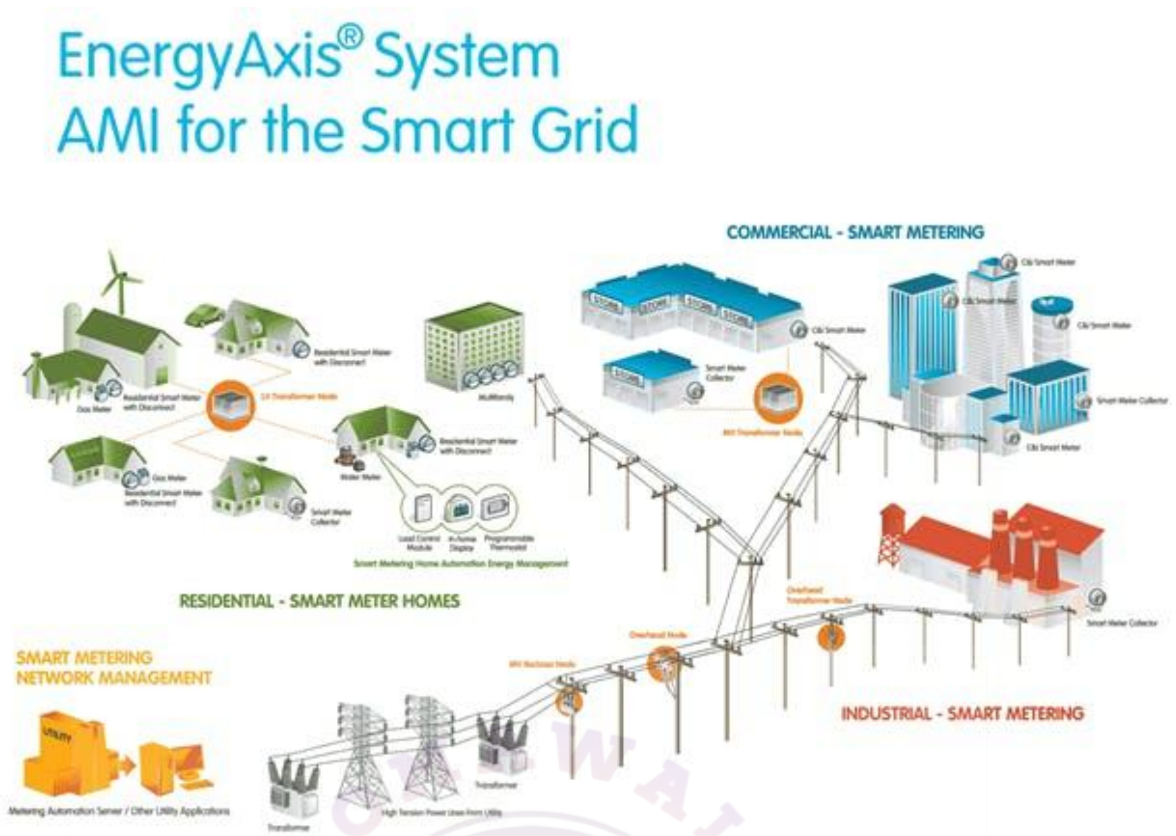
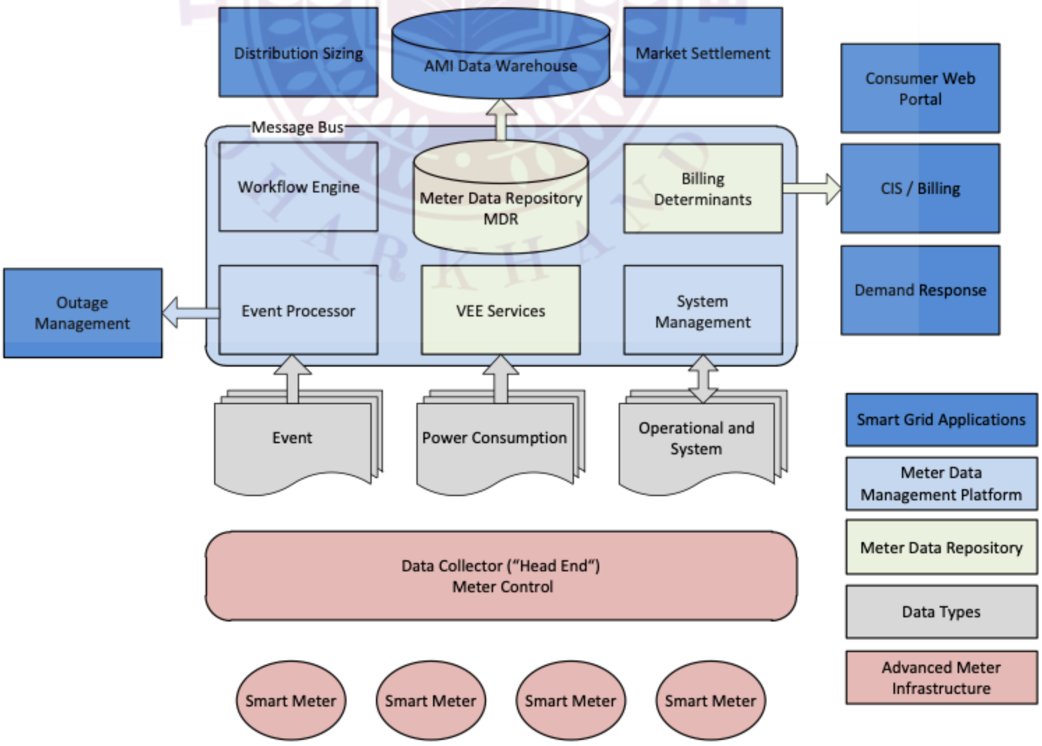

EnergyAxis® System
AMI for the Smart Grid
COMMERCIAL - SMART METERING
RESIDENTIAL - SMART METER HOMES
SMART METERING
NETWORK MANAGEMENT
INDUSTRIAL - SMART METERING


Distribution Sizing
AMI Data Warehouse
Market Settlement
Consumer Web Portal
Message Bus
Workflow Engine
Meter Data Repository MDR
Billing Determinants
CIS / Billing
Demand Response
Outage Management
Event Processor
VEE Services
System Management
Event
Power Consumption
Operational and System
Smart Grid Applications
Meter Data Management Platform
Meter Data Repository
Data Types
Data Collector ("Head End")
Meter Control
Advanced Meter Infrastructure
Smart Meter
Smart Meter
Smart Meter
Smart Meter

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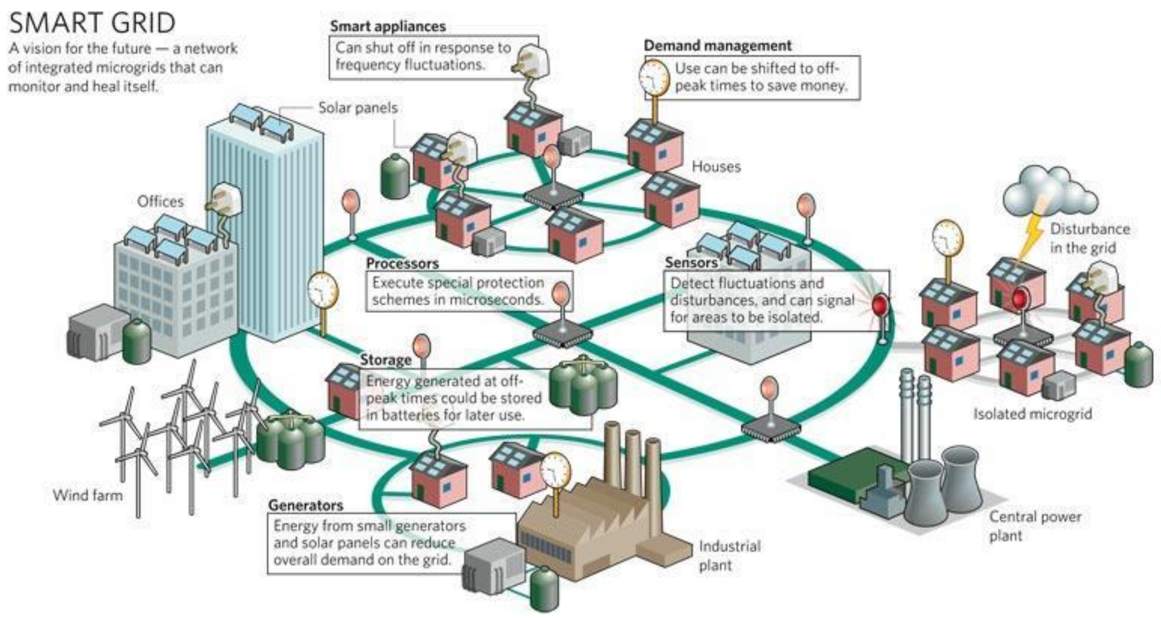
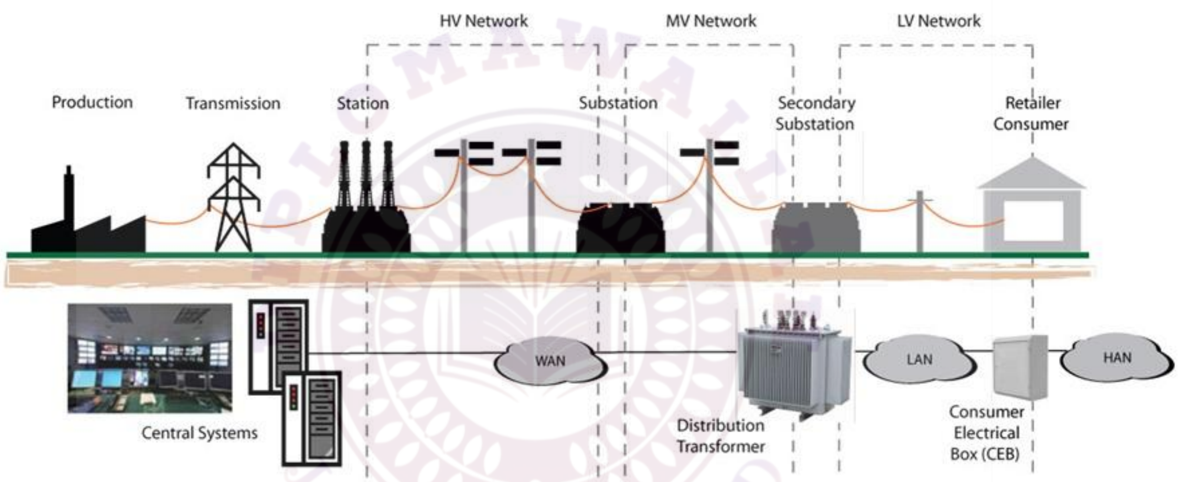
3. Fundamental Components of Smart-Grid Designs

Here we address three major foundational components: Transmission Automation, Distribution Automation, and Renewable Integration.

3.1 Transmission Automation

- Transmission Automation refers to the automation of high-voltage network equipment and control systems in the transmission domain — substations, lines, large generation sources. (TutorialsPoint)
- Key technologies include: substation automation (IEDs, SCADA), wide-area measurement systems (Phasor Measurement Units – PMUs), fault detection & isolation, automated switching, real-time monitoring of grid stability. (The Department of Energy's Energy.gov)
- Benefits: faster fault detection, faster restoration, improved reliability and better integration of grid scale renewable generation. (TutorialsPoint)



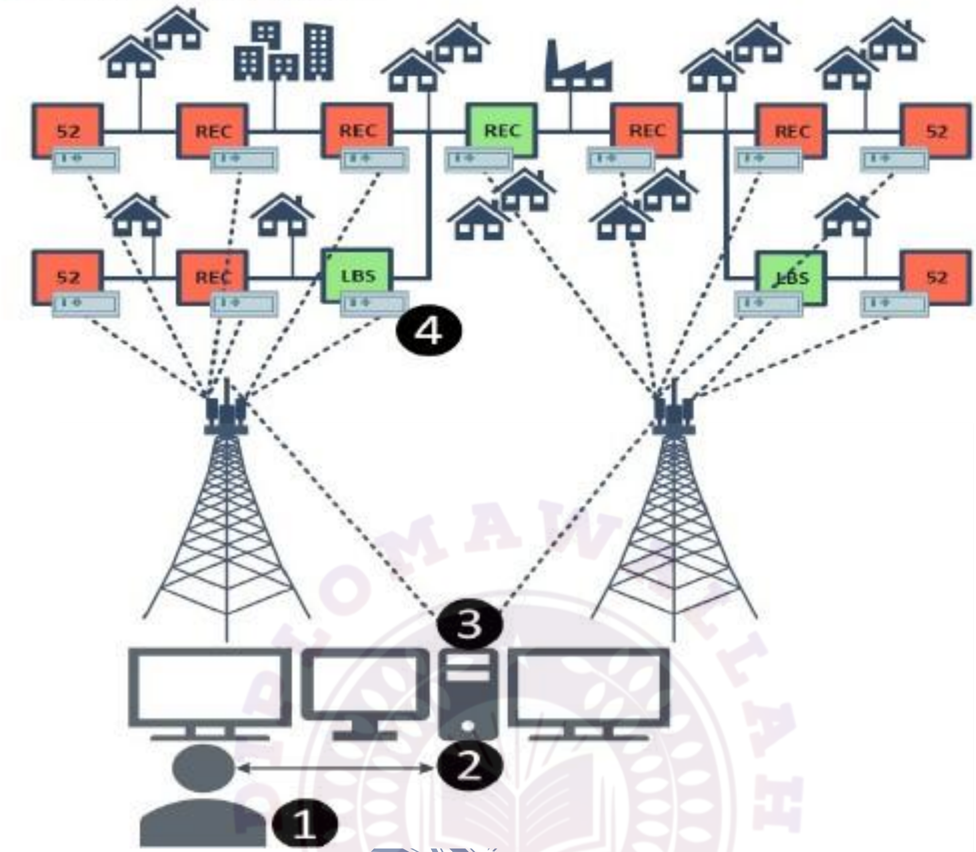


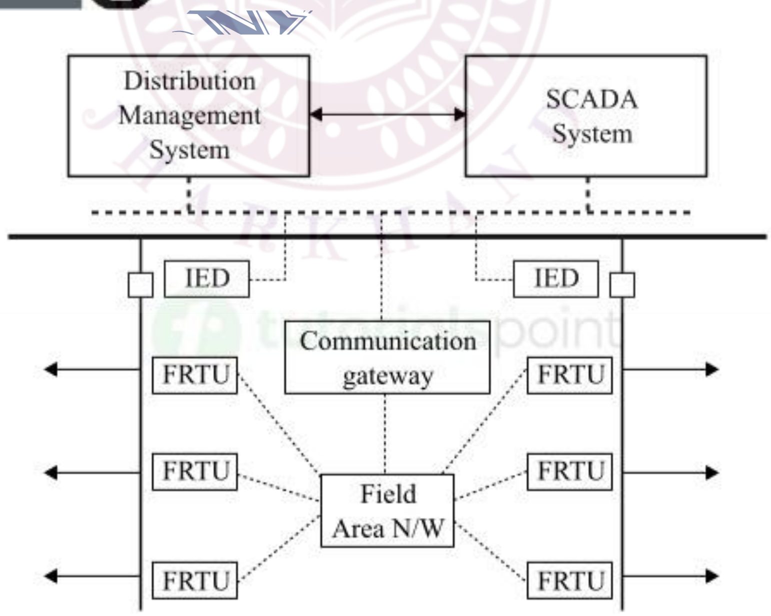
3.2 Distribution Automation

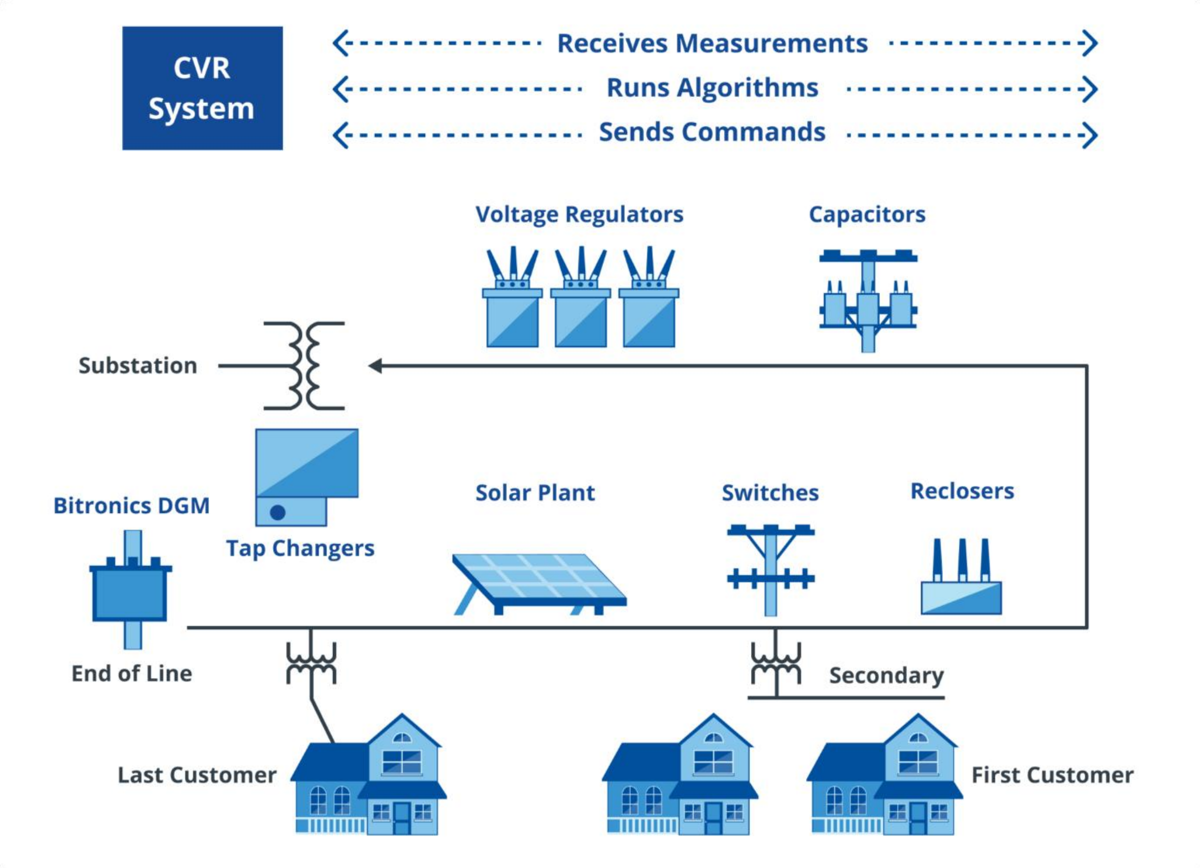
- Distribution Automation (DA) refers to automation at the medium/low-voltage distribution network: feeders, transformers, reclosers, capacitors, regulators, sensors across the distribution network. (grouper.ieee.org)
- DA enables remote monitoring and control of distribution system – e.g., feeder fault isolation and restoration, voltage/VAR optimisation, integration of DERs at distribution level. (TutorialsPoint)
- Architectural note: As distribution becomes more "smart", the communication and control infrastructure resembles that of the transmission domain (more sensors, SCADA/ADMS, expanded visibility). (grouper.ieee.org)

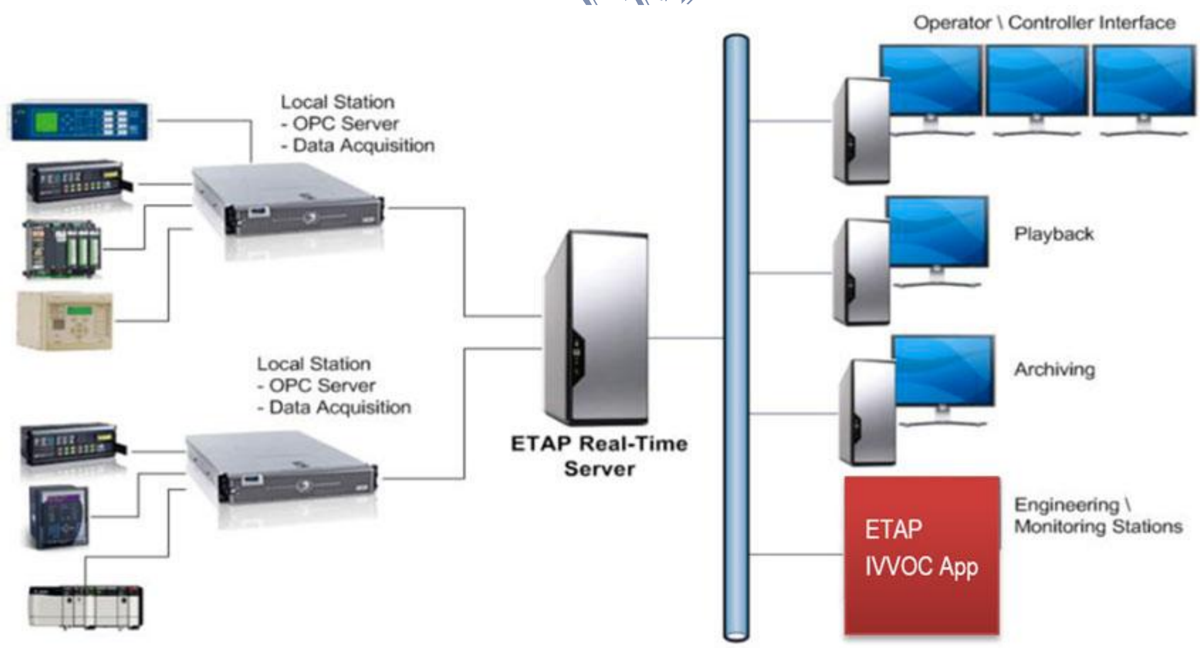
- The adoption of an Advanced Distribution Management System (ADMS) is a key trend: combining network modelling, real-time data from AMI, sensors, DERs, and control of edge devices. (NREL)

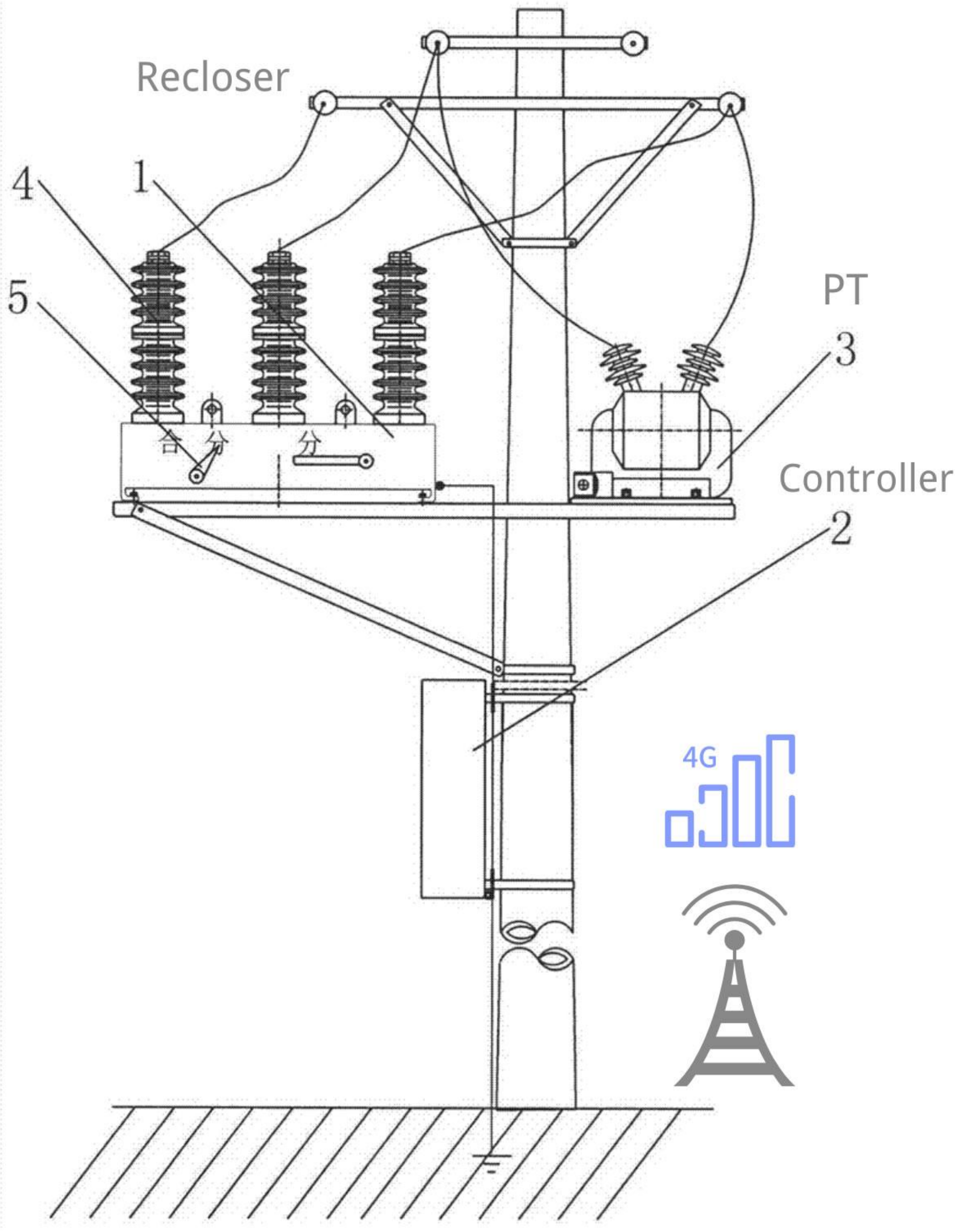
1 DFA Architecture






CVR System
Receives Measurements
Runs Algorithms
Sends Commands
Voltage Regulators
Capacitors
Substation
Bitronics DGM
Tap Changers
Solar Plant
Switches
Reclosers
End of Line
Secondary
Last Customer
First Customer


Operator \ Controller Interface
Local Station
- OPC Server
- Data Acquisition
Playback
Archiving
Local Station
- OPC Server
- Data Acquisition
ETAP Real-Time Server
Engineering \ Monitoring Stations
ETAP IVVOC App



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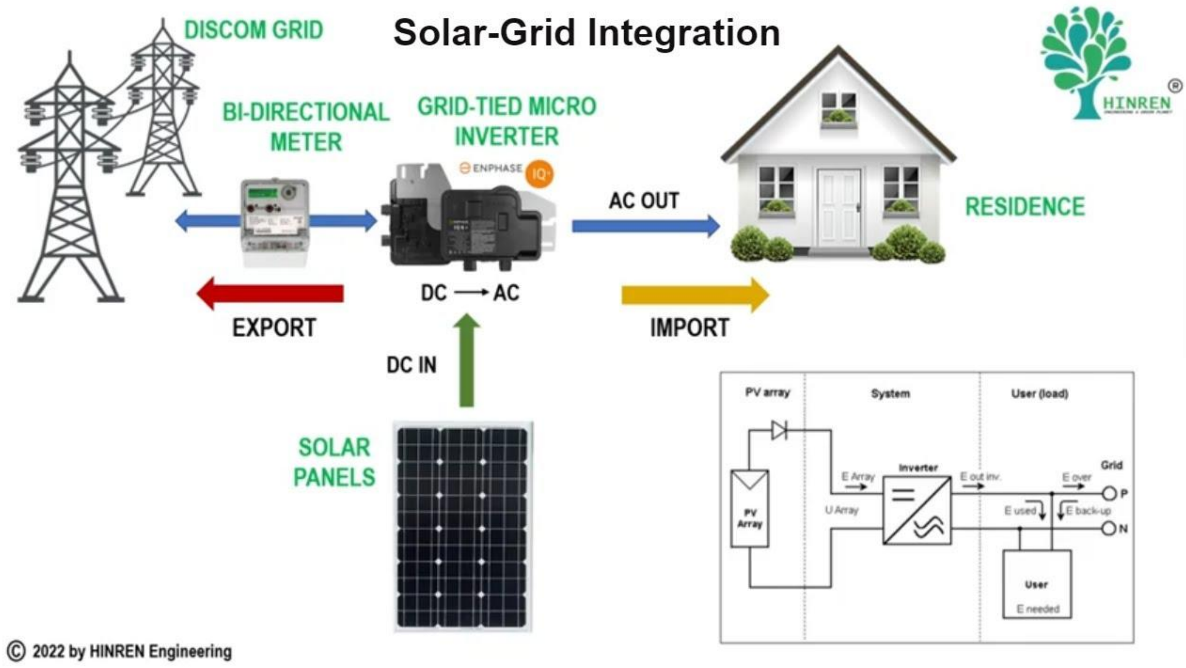
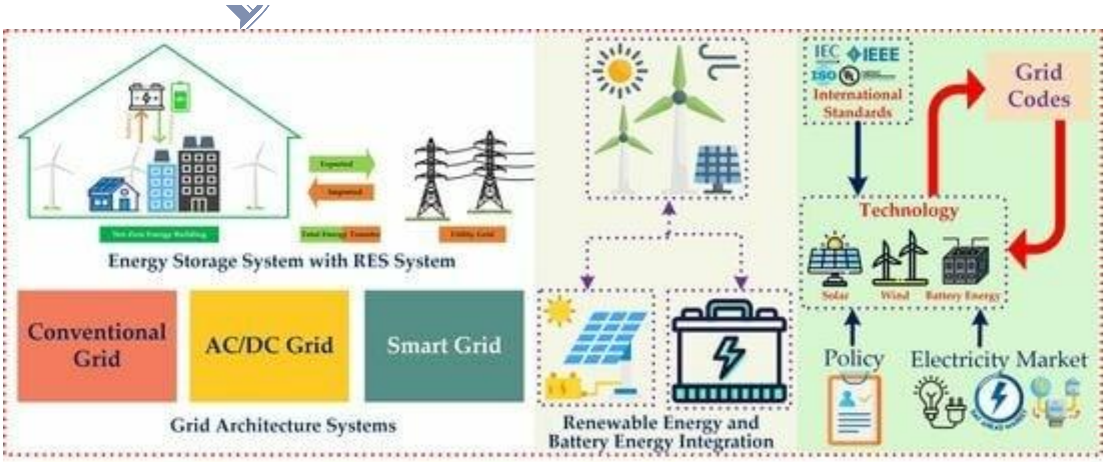
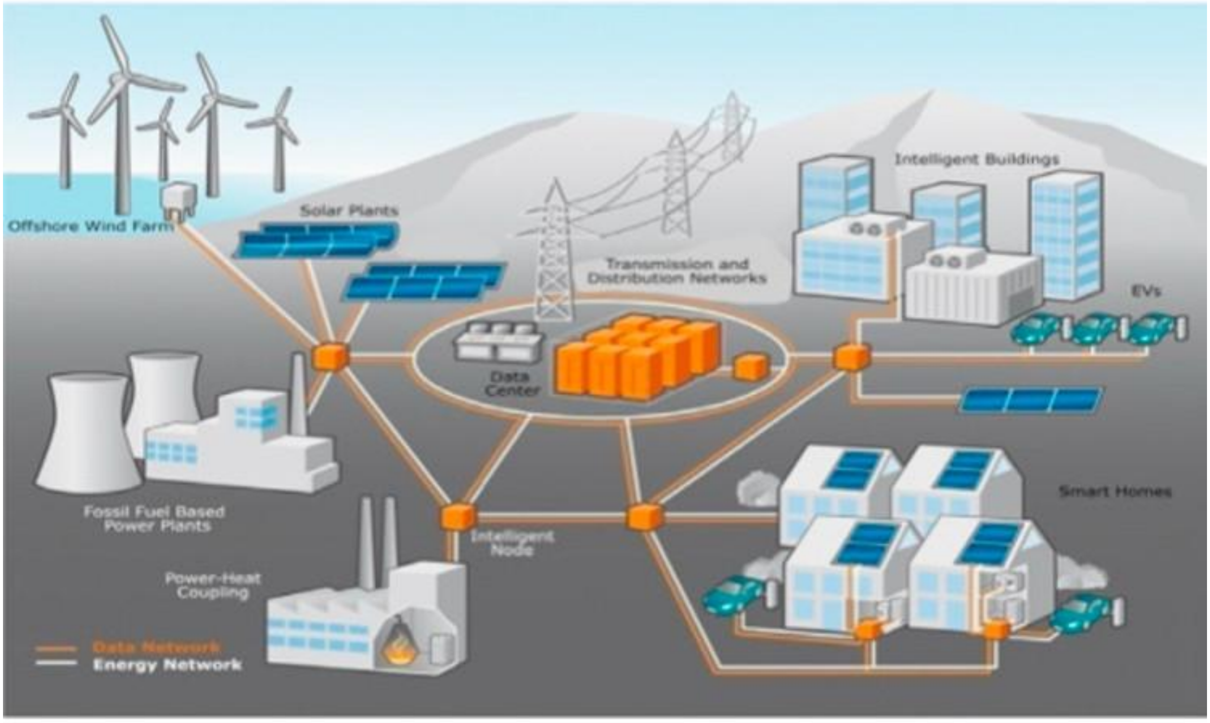
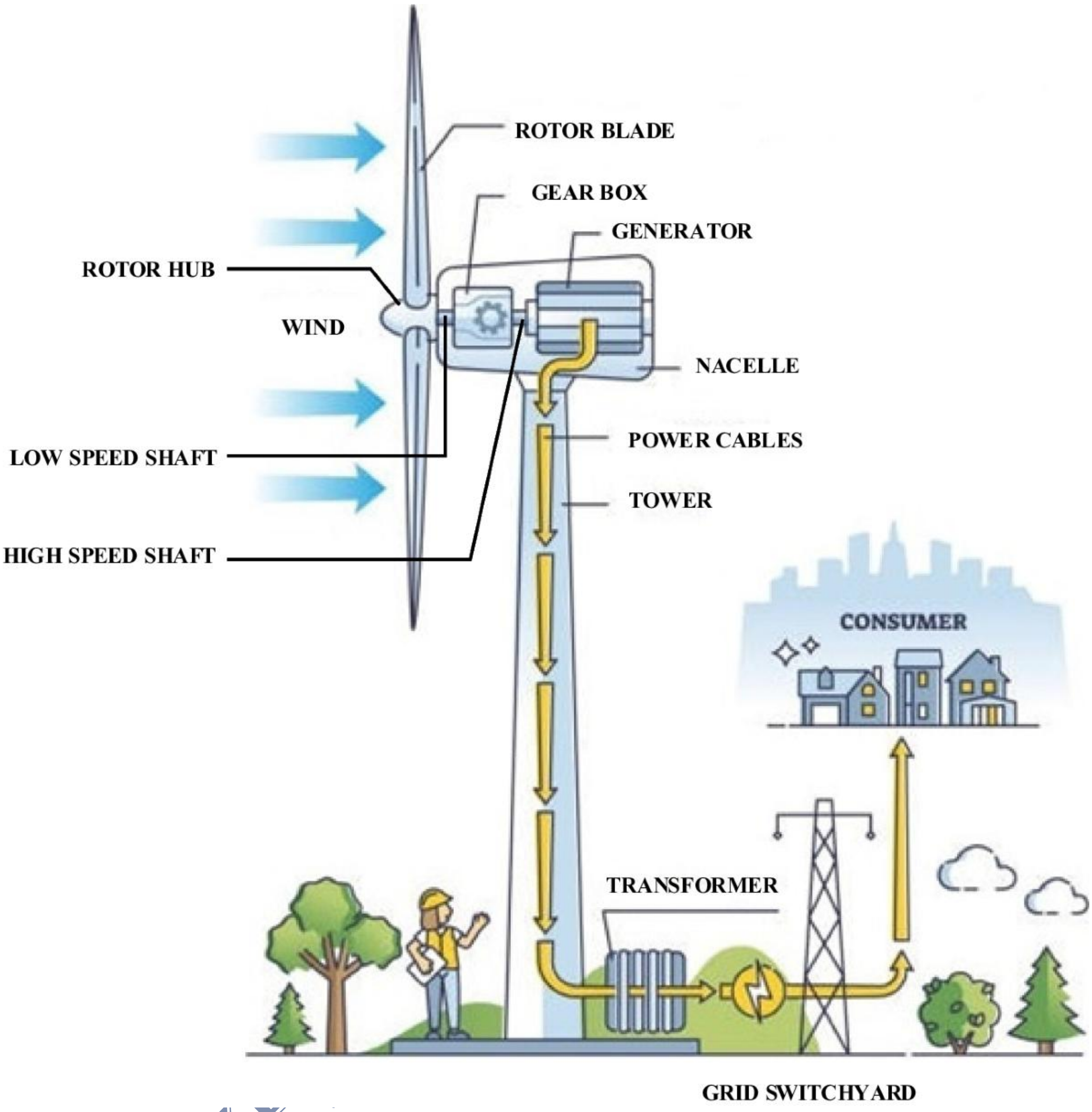
3.3 Renewable Integration

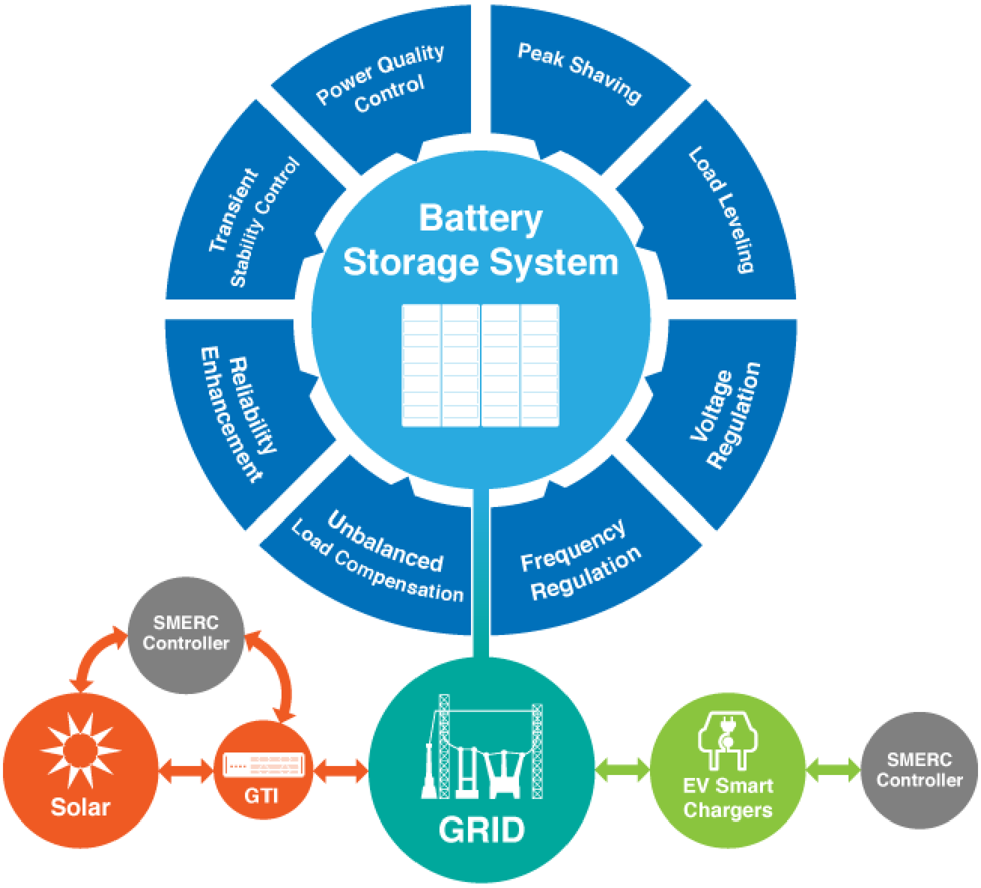
- Integration of Renewable Energy Sources (RES) — solar PV, wind, small hydro, biomass — and energy storage into the grid is a core function of smart grids. (IRENA)
- Smart grid technologies support renewables by providing flexibility, monitoring, control, storage integration, two-way communication, variable generation forecasting. (IRENA)
- The architecture to integrate renewables needs communication and control from DERs, storage, and grid edge to main grid; it also needs grid infrastructure that can accommodate two-way flows and variable supply. (EEP - Electrical Engineering Portal)
- At lower penetration levels, conventional grid may suffice; as renewable penetration grows (>15-30 %), more advanced smart grid technologies (smart inverters, storage, microgrids, advanced control) become essential. (IRENA)






Offshore Wind Farm
Solar Plants
Transmission and Distribution Networks
Intelligent Buildings
EVs
Data Center
Fossil Fuel Based Power Plants
Intelligent Node
Smart Homes
Power-Heat Coupling
Data Network
Energy Network


ROTOR BLADE
GEAR BOX
GENERATOR
ROTOR HUB
WIND
NACELLE
POWER CABLES
LOW SPEED SHAFT
TOWER
HIGH SPEED SHAFT
CONSUMER
TRANSFORMER
GRID SWITCHYARD



4. Summary

- The architecture of a smart grid — how the physical power infrastructure is overlaid with ICT/communication/control layers, and how the domains/zones model (SGAM) helps organise this.
- The components of smart grid design — smart meters/AMI, sensors & controls, communications networks, DERs, storage, consumer side, grid management systems.
- A review of proposed architectures (generic diagrams, communication architecture, layered frameworks, IoT/edge enhancements).
- A focused discussion on Advanced Metering Infrastructure (AMI): definition, architecture, benefits, applications, role in smart grid.
- The fundamental components of smart-grid designs: Transmission Automation, Distribution Automation, and Renewable Integration — their definitions, roles, benefits and architectural implications.

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