SMART GRID Technologies

PE/PE/HT/324C

Professional Elective Course

Smart Grid Technologies

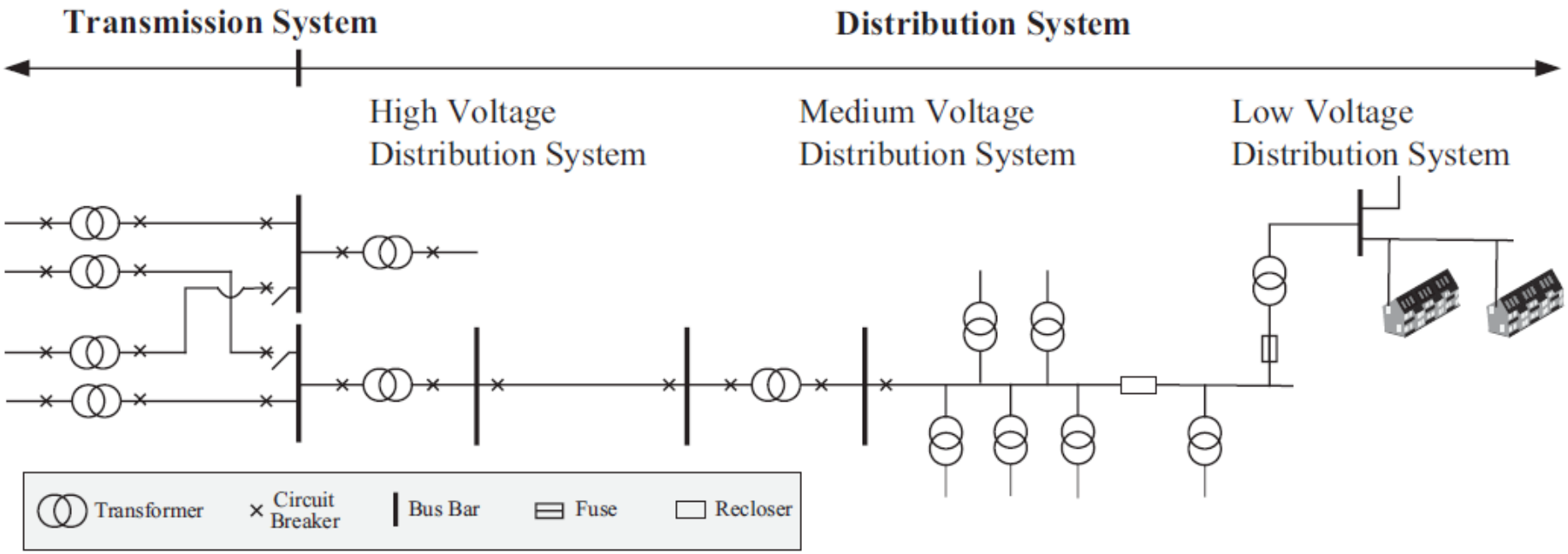
- Automatic Voltage Regulation (AVR)
- Automatic Generation Control (AGC)
- Energy Management System (EMS)
- **Distribution Management Systems (DMS)**
- Demand Side Management (DSM)
- Outage Management System (OMS)
- Wide Area Management System (WAMS)
- Advanced Metering Infrastructure (AMI)
- Meter Data Management (MDM)
- Geographical Information System (GIS)

Distribution Management Systems (DMS)

Electricity distribution networks connect the high-voltage transmission system to users

Conventional distribution networks have been developed over the past 70 years to accept bulk power from the transmission system and distribute it to customers.

Generally they have unidirectional power flows.



Distribution Management Systems (DMS)

The Smart Grid radically augments the function of distribution networks to include:

- integration of Distributed Energy Resources
- active control of load demand
- more effective use of distribution network assets

Distribution systems are extensive and complex and so they are difficult to:

- Monitor
- Control
- Analyse
- Manage

Complexity of distribution systems

Complexity	Source of complexity
Network	• Distribution networks are often built as meshed circuits but operated radially. • Their topology changes frequently during operation, due to faults and maintenance. • The structure of the network changes as the network expands • The three-phases are often unbalanced • The time scales that have to be considered range from milliseconds (protection operation) to years (network expansion) • There is limited communication between elements of the network and most control is local • Comprehensive monitoring of distribution networks would generate a very large amount of data

Complexity of distribution systems

Complexity	Source of complexity
Loads	• The composition of loads is complex and not well known • The pattern of distribution load consumption varies dynamically with time • The trend of the load variation is more difficult to predict than that of a large transmission network • It is not possible to obtain simultaneous measurements of all loads • Load measurements normally are insufficient and may contain large errors and bad data • The correlation between loads is not well understood

Need for DMS

Real-time monitoring and remote control are very limited in today's electricity distribution systems and so there is a need for intervention by the system operators particularly during widespread faults and system emergencies

However, it is difficult to deal with such a complex system through manual procedures

Here comes the concept of DMS, that makes use of advanced sensing, measurement, communication, analysis, and control features of the smart grid for efficient performance of the distribution network

Definition of DMS

A Distribution Management System (DMS) is a collection of applications used by the Distribution Network Operators (DNO) to monitor, control and optimize the performance of the distribution system and is an attempt to manage its complexity

The ultimate goal of a DMS is to enable a smart, self-healing distribution system and to provide improvements in:

- supply reliability and quality
- efficiency and effectiveness of system operation
- better asset management
- provisions of new services
- greater customer satisfaction

Development of DMS

The first generation of Distribution Management Systems integrated a number of simple applications into a computer system

An interactive graphical user interface was then added to visualize the network being managed

The subsequent use of large relational databases allowed the management of more complicated distribution networks and a large volume of data

However, as more and more Applications were added, managing the information exchange and maintaining the DMS became a challenge

Standardized models such as the Common Information Model (CIM) were developed to aid information management

For the Smart Grid future, the DMS will use higher-performance ICT hardware, be equipped with greater intelligence, and be deployed in a decentralized manner

DMS for Smart Grid

The following functions are implemented as part of the software infrastructure of DMS in Smart Grid

Distribution system power flow (DSPF):

- Real-time DSPF (RT-DSPF) computes the voltage phasors at the network nodes from the knowledge of the grid parameters and power injections, representing generation and loads.

Short-term prosumer forecasting (STPF):

- In the smart grid context, the prosumer can be either a producer or a consumer of power. STPF uses historical load profiles, weather related information, energy values from automatic meter readings (AMR), and the newer advanced metering infrastructure (AMI).
- The forecasted energy values are computed using probabilistic modeling techniques or neural networks

DMS for Smart Grid

Distribution System State Estimation (DSSE):

- State estimation is a digital processing scheme which provides a real-time database for many of the control and dispatch functions in a power system
- The estimator processes the imperfect information available and produces the best possible estimate of the true state of the system
- DSSE estimates the state vector of distribution networks by applying a weighted least-squares approach on a redundant set of measurements
- A current or power balancing method is commonly adopted in industrial implementations to achieve high-performance computation
- Given that many of the measurements originate from STPF, i.e., pseudo measurements, DSSE is also referred to as load estimation

DMS for Smart Grid

System Monitoring (SM)

- Real-time distribution system monitoring can bring a number of benefits to system operation
- For example, it can lead to better information of nodal voltages and circuit loading conditions which allows alarms to be sent to the system operators before serious problems occur
- System monitoring compares the measured data against their normal values or limits
- Any abnormal change in the real-time measurements generates an event that triggers automatic control functions or notify the Distribution Network Operators (DNOs)

DMS for Smart Grid

Distribution Network Reconfiguration (DNR)

- Distribution networks are normally constructed as a meshed network but are operated in a radial manner with normally open points
- The network configuration can be varied through changing the open/close status of switchgear, manually or automatically
- The main objectives of network reconfiguration are:
  - Supply restoration: This optimally restores electricity to customers using alternative sources following fault location, isolation and supply restoration function
  - Active power loss minimization at a given time or energy loss minimization over a period of time
  - Load balancing between different feeders or transformers and equalizing voltages

DMS for Smart Grid

Distribution Network Reconfiguration (DNR)

- The methods used for network reconfiguration include:
  - practical experience
  - mathematical methods
  - computational intelligence-based methods
    - artificial neural networks
    - genetic algorithm
    - fuzzy logic
    - hybrid methods which combine two or more methods

DMS for Smart Grid

Relay Protection Re-coordination (RPR)

- This application adjusts relay protection settings in real time based on predetermined rules
- This is accomplished through analysis of relay protection settings and operational modes of circuit breakers (that is, whether the circuit breaker is in a single-shot or recloser mode), while considering the real-time network connectivity, co-ordination with DER and Micro Grids, and weather conditions
- This Application is called into use after feeder reconfiguration or when the bad weather is expected

Distribution System Short-Circuit Computation (DSSCC):

- DSSCC runs short-circuit calculation screening to check the capability of a circuit breaker or fuse in the maximal current mode and then check the relay sensitivity under the minimal current

DMS for Smart Grid

Volt/Var control (VVC):

- VVC solves an optimization problem that controls the load tap changer (LTC) installed on substation transformers and step voltage regulators, switched capacitors, and the reactive power from DERs
- The goal of VVC is mainly to lessen voltage violations that occur due to load and renewable power variations
- The VVC optimization problem is part of an active distribution management system (ADMS)

Fault Location (FLOC):

- FLOC the uses the statuses of fault locators that are telemetered to the distribution management center to determine the fault branch in a network, followed by impedance-based methods to localize the fault on the line accurately

DMS for Smart Grid

Fault Isolation (FISO):

- FISO is a procedure for opening circuit breakers to isolate the fault. Ideally, FISO isolates the smallest possible part of the system by opening switches upstream and downstream of the fault

System Restore (SRES):

- SRES restores power to load nodes affected by FISO by transferring energy to them via alternative feeders
- SRES is essentially an optimization problem whose solution reconfigures the network to serve as many loads as possible within the feeder loading limits while undertaking a minimum number of switching operations

DMS Applications (Apps)

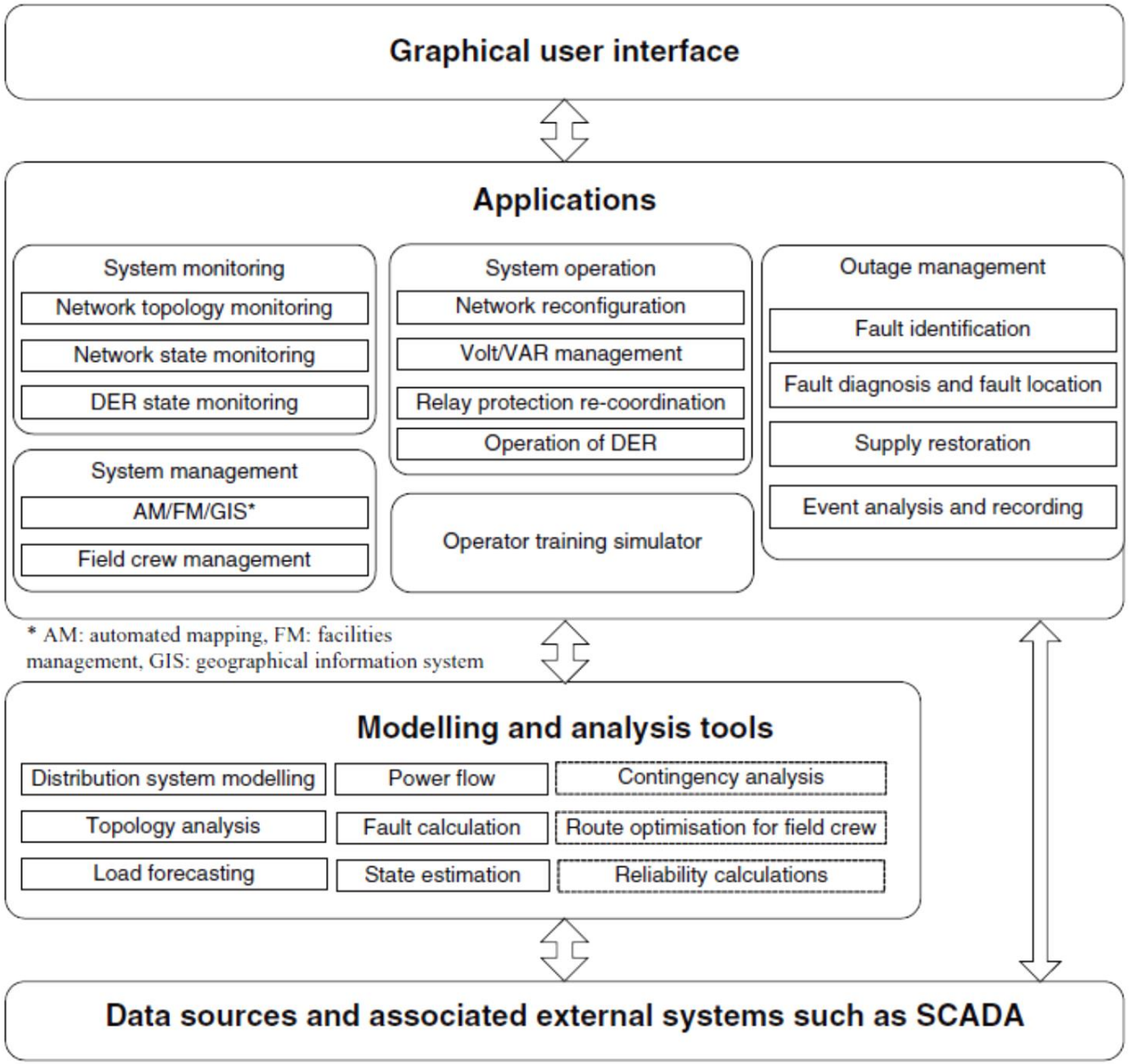
A DMS includes a number of Applications that use modelling and analysis tools together with data sources and interfaces to external systems

DMS includes Applications:

- For system monitoring, operation and outage management
  - These are the Applications responsible for the daily running of the network with the primary object of maintaining continuity of supply
- To help manage the assets of the utility, such as inventory control, construction, plant records, drawings, and mapping
  - These include the automated mapping system, the facilities management system, and the geographical information system (GIS)
- Apps associated with design and planning for network extensions
  - These Applications are used for audits of system operation to determine short-term solutions and optimal expansion planning to achieve system reinforcement at minimum cost

All these Applications require modelling and analysis tools for which network parameters, customer information, and network status data are used as inputs

Structure and main components of DMS



SCADA for DMS

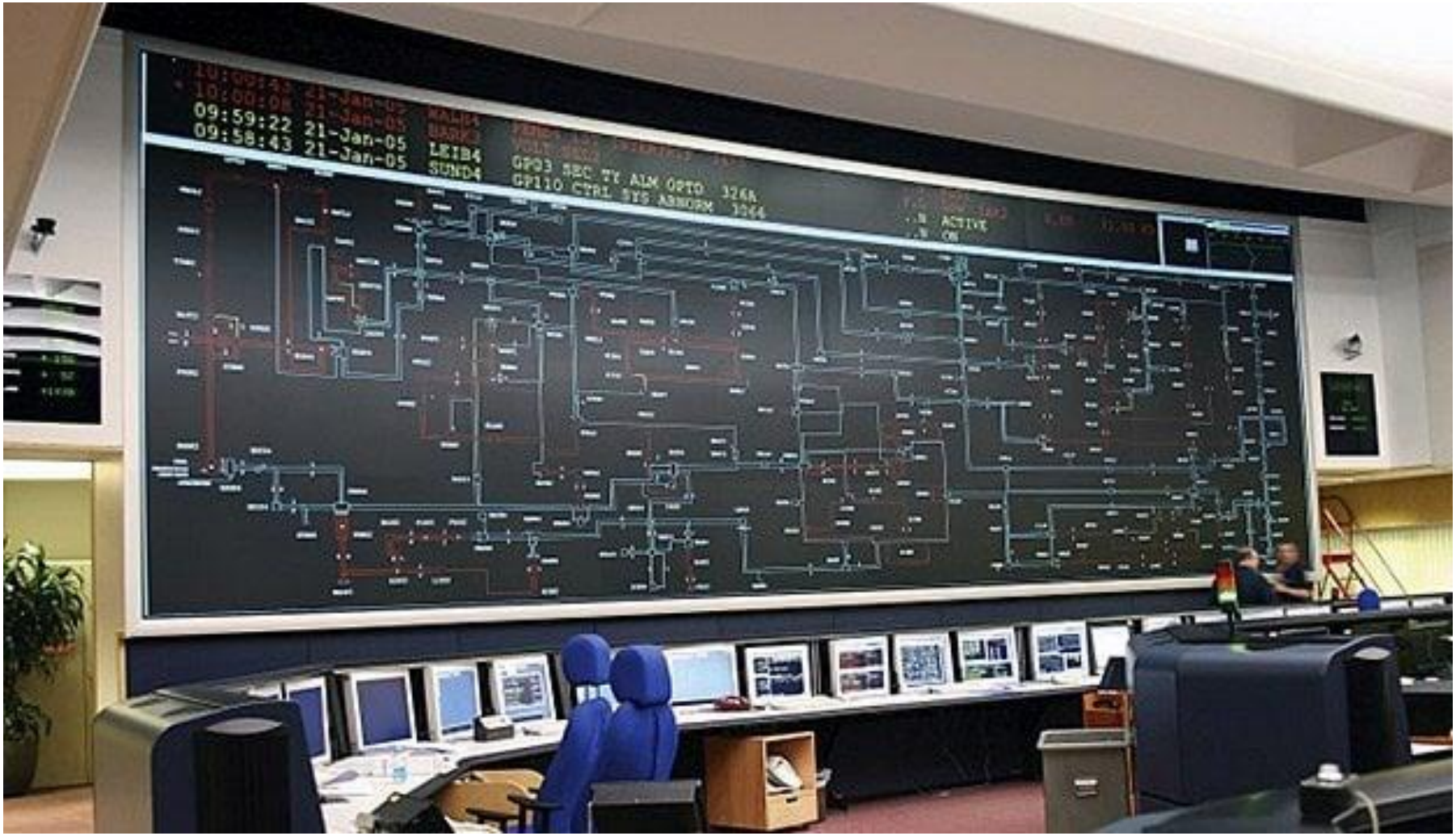
SCADA (Supervisory Control And Data Acquisition) is the heart of DMS

SCADA provides real-time system information to the modelling and analysis tools of DMS

A DMS SCADA system's primary functions are:

- distribution operations telemetry
- alarming
- event recording
- remote control of field equipment

SCADA for DMS

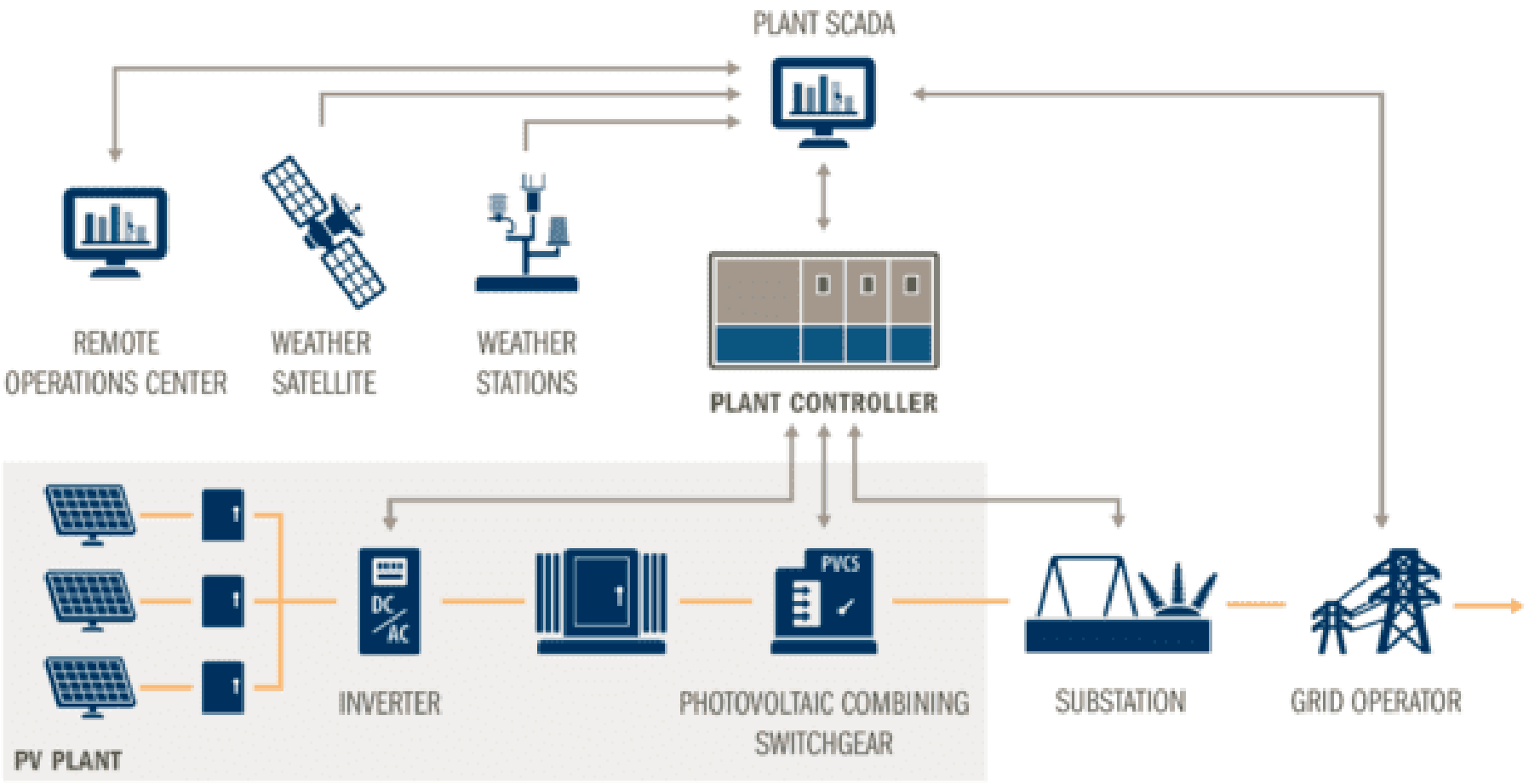


Attributes of SCADA for DMS

Data acquisition:

- Information describing the system operating state is collected automatically by Remote Terminal Units (RTUs)
- This includes the status of switching devices as well as alarms and measured values of voltages and currents
- This information is passed to the control center in real-time

Attributes of SCADA for DMS



Attributes of SCADA for DMS

Monitoring, event processing and alarms:

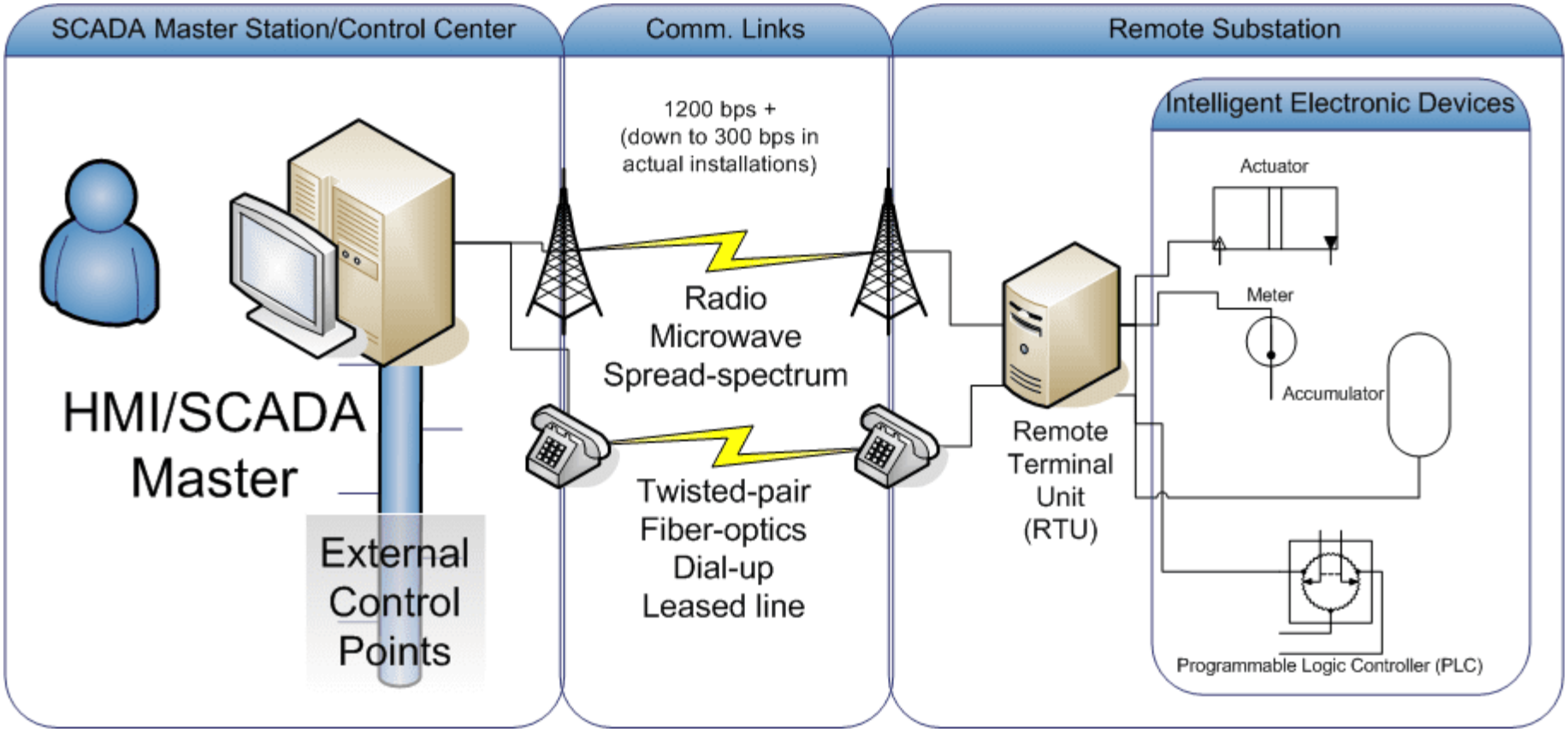
- An important function of SCADA is to compare the measured data to normal values and limits
- It also detects the change of status of switchgear and operation of protection relays
- An event is generated if there is change of switchgear status or violation of circuit limits
- All events generated by the monitoring function are processed by the event processing function, which classifies and groups events and delivers appropriate information to the system operators through the Human–Machine Interface (HMI)
- Most critical events will be sent to the operators as alarms, for example, flashing color presentation or audible signals

Attributes of SCADA for DMS

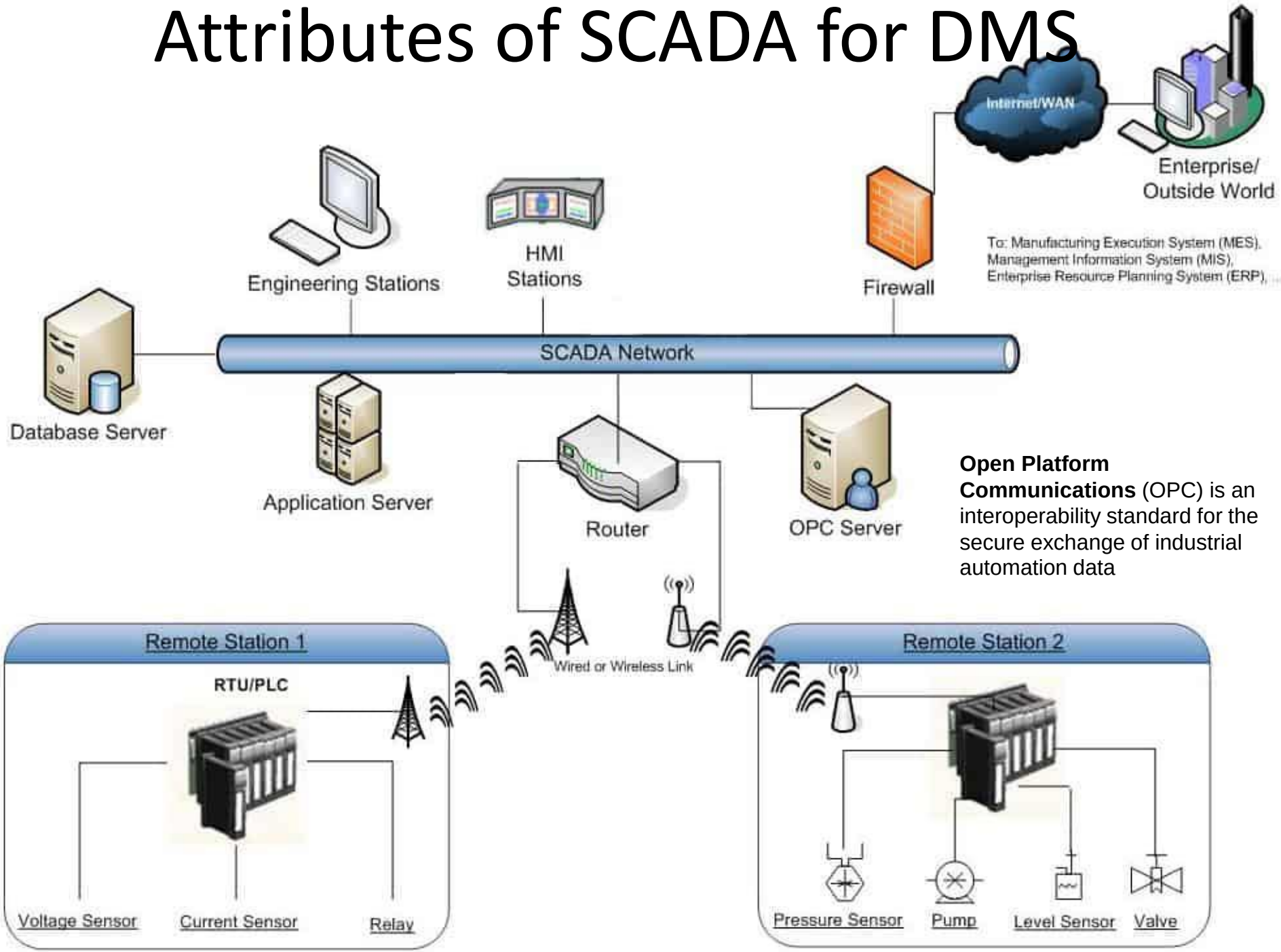
Control:

- Control through a SCADA system can be initiated manually or automatically
- Some functions are initiated manually by the control room operator
- Control initiated manually can be the direct control of a particular device (for example, a circuit breaker or tap-changer)
- Automatic controllers include programmable Logic Controller (PLC) or Intelligent Electronic Device (IED) that communicate with Remote Terminal Unit (RTUs) in substations to initiate data gathering and control actions

Attributes of SCADA for DMS



Attributes of SCADA for DMS



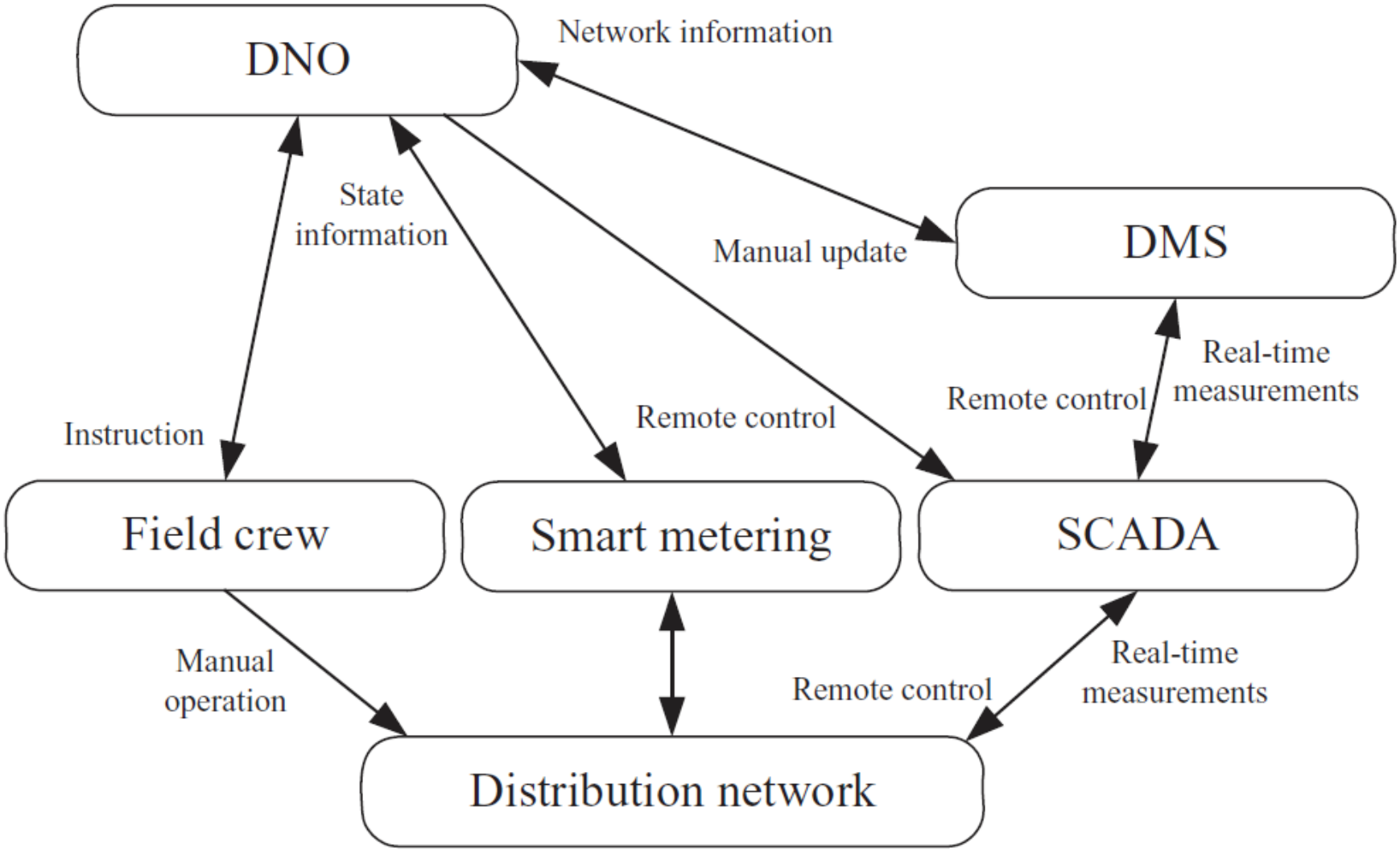
Open Platform Communications (OPC) is an interoperability standard for the secure exchange of industrial automation data

Attributes of SCADA for DMS

Data storage, event log, analysis and reporting:

- Real-time measurements are stored in the real-time database of the SCADA system at the time received
- Because the data update overwrites old values with new ones, the time-tagged data is stored in the historical database at periodic intervals, for example, every 5 minutes or every hour, for future use
- In order to analyze system disturbances correctly, an accurate time-stamped event log is necessary
- Some equipment (for example, RTUs) is capable of recording events with millisecond precision and then delivering time-stamped information to the SCADA system
- The sequence of events formed by time-stamped information is useful for the system operator to analyze an event to establish the reason for its occurrence

Attributes of SCADA for DMS



DNO – Distribution Network Operator

DER control in SG through DMS

The integration of DER operation to the DMS has a large impact on the performance of a smart distribution network

The presence of DERs in the distribution network can significantly alter the flow of fault currents and change the source of ancillary services

So the operation of DER needs to be integrated to the DMS to guarantee reliable system operation

The integration of DMS and MicroGrids/ SmartGrids can be implemented through setting up the links between the DMS and the MicroGrid Central Controllers (MGCC)

DER control in SG through DMS