A Quick Review of Substation Automation

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Presented by
Steve Mackay PhD
Dean of Engineering

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INTRODUCTION

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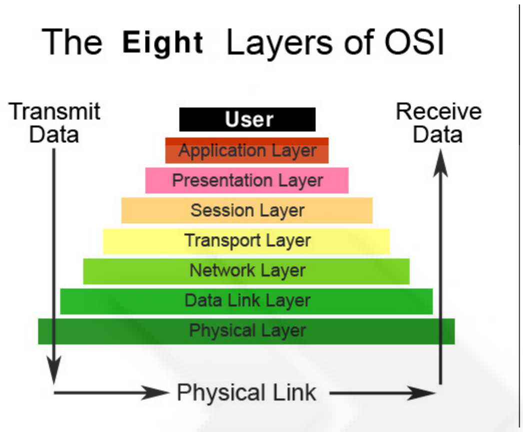
Open Systems Interconnection



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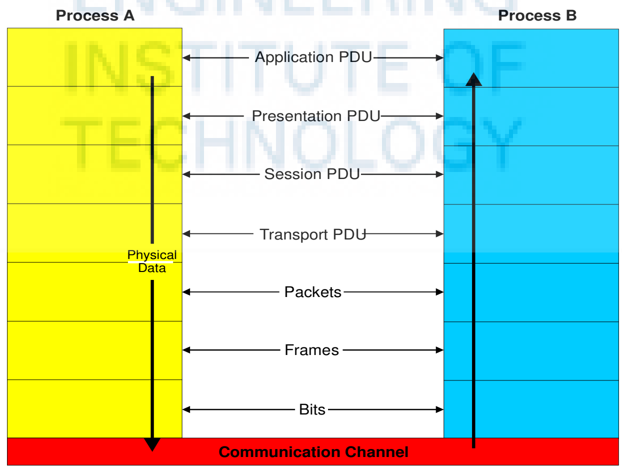
Open Systems Interconnection



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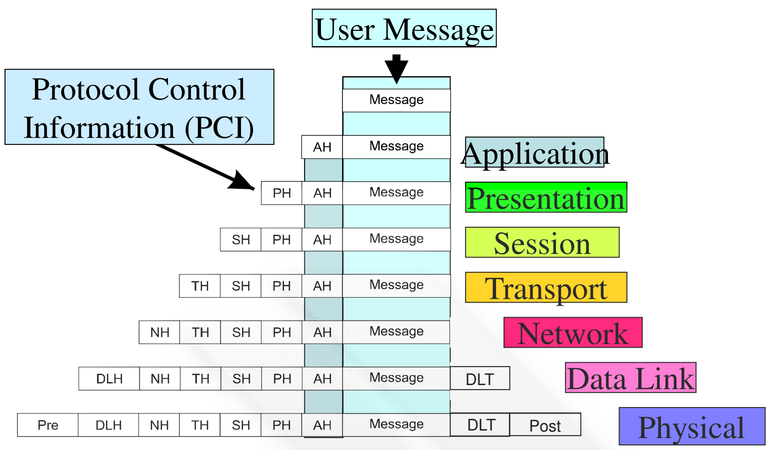
OSI Message Passing



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User Layer (8)

- Defines the way of accessing information within Fieldbus devices to distribute to other devices or nodes in network
- This is a fundamental attribute for process-control applications
- Architecture of Fieldbus device is based on Function Blocks
- Function Block parameters are addressed by TAG.PARAMETER-NAME

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Application Layer (7)

- Give user applications access to the lower layers of the stack. Supports applications such as:
  - File transfer
  - Electronic mail
  - Network management
  - Web browsing

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Presentation Layer (6)

- Can provide data translation i.e
  - Code conversion
  - Text compression
  - Data encryption
- Rarely appears in 'pure' form

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Session Layer (5)

- Users interface through here
- Synchronizes the dialogue between users
- Provides transparent recovery
- Provides name functions and security
- Provides database integrity

Transport Layer (4)

- Is the first layer for a source - destination (end-to-end) conversation
- Provides data transfer at an agreed level of service
  - Transmission speed
  - Error rates
  - Reliability of service
- Provides sequencing and flow control
- Can perform data segmentation

Network Layer (3)

- Can perform data fragmentation if required
- Provides message routing through intermediate nodes from source to destination
- Provides routing related services such as address resolution

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Data Link Layer (2)

- Provides point-to-point error free binary transmission i.e. creates, transmits and receives data packets (frames) between each of the connecting points
- Transforms the transmission facility into a line free of errors to the network layer above
- Can provide error detection and request retransmission
- May implement flow control

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Physical Layer (1)

- Defines, but does not include the media (e.g. copper, optical, wireless)
- Defines electrical & mechanical aspects of the signaling hardware
- Is responsible for:
  - Modulation
  - Multiplexing
  - Activating, maintaining & deactivating the physical connection
  - Ensuring ‘1’ transmitted = ‘1’ received

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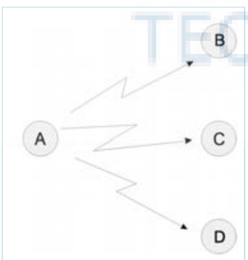
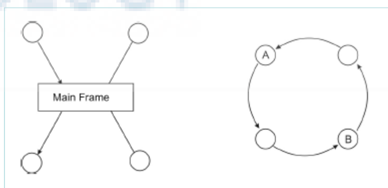
Network Topologies

- **Broadcast and point-to-point topologies :**



Broadcast topology



Point-to-point topologies

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Physical Topologies

- Three structures......
  - Bus
  - Star
  - Ring
- Hybrids are possible
- The logical topology may not reflect the physical!

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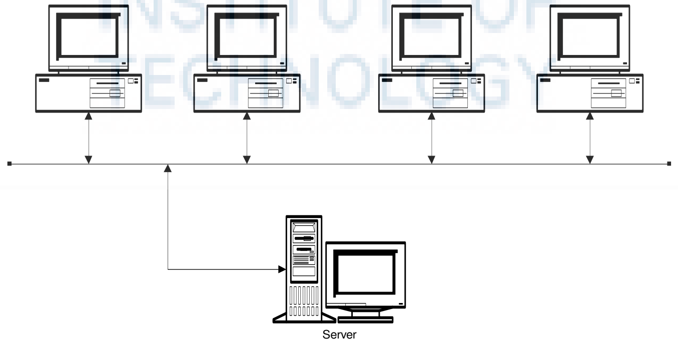
Bus Topology



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Bus Topology….

- Advantages:
  - Uses relatively little cable compared to other topologies
  - Easy to add or remove nodes
  - Simple & flexible architecture
  - Broadcast messages are easy
  - Failure of node does not affect network
  - Inexpensive cable and connectors

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Bus Topology….

- Disadvantages:
  - Security problem - every node ‘hears’ every message
  - Fault diagnosis can be difficult

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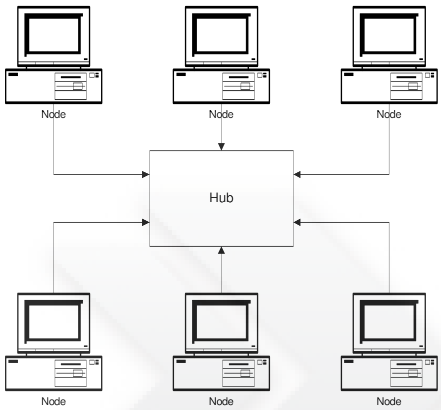
Star Topology



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Star Topology….

- Advantages:
  - Troubleshooting & fault isolation are easy
  - Easy to add / remove nodes & modify cable layout
  - Failure of a node does not isolate any other
  - Central hub allows monitoring for management purposes

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Star Topology….

- Disadvantages:
  - Hub fails - network fails!
  - Requires a lot of cabling

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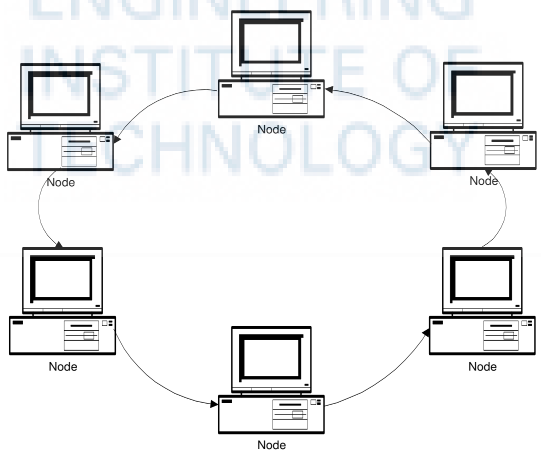
Ring Topology



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Ring Topology….

- Advantages:
  - Physical ring has minimal cable requirements
  - Sometimes implemented with wiring center (physical star) e.g. IBM Token Ring
  - Message can be automatically acknowledged
  - Each node can regenerate the signal

Ring Topology….

- Disadvantages:
  - If a node fails, the ring fails
  - Diagnosis & fault finding is difficult
  - Adding /removing nodes disrupts network

Utility Communication Architecture (UCA)

- The Electric Power Research Institute (EPRI) developed the suite of protocols known as Utilities Communication Architecture, Version 2 (UCA 2.0)
- This protocol is based on:
  - Ethernet physical and link layers,
  - incorporates the TCP/IP collection of protocols, and
  - utilizes the MMS protocol for the application layer

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UCA (Cont...)

- UCA offers interconnectivity and interoperability
- UCA is based on various international protocols and standards
- The first version (1991)
  - Provided the necessary communication requirements and guidelines for use
- UCA Version 2, (1998)
  - provides additional communication profiles, application services, and device models for interoperability among various equipment

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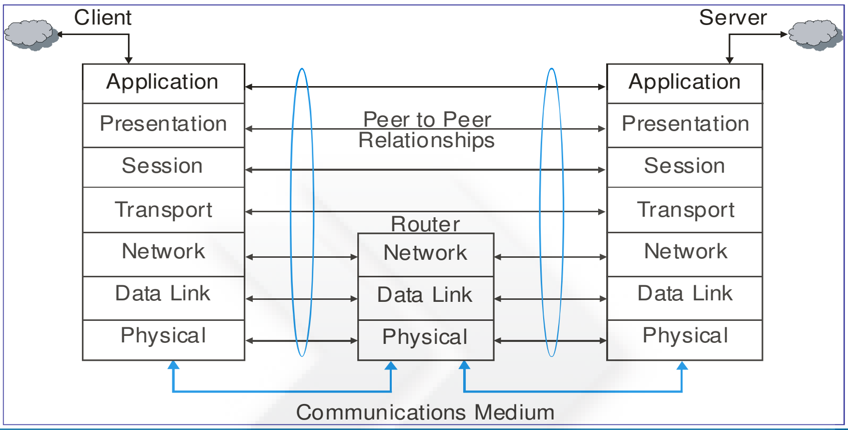
The Client/Server paradigm

- *Client/Server communication*



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Publish/Subscribe Concept

- Applications that communicate through a publish and subscribe paradigm require
  - Sending applications (publishers) to publish messages without explicitly specifying recipients
  - Receiving applications (subscribers) must receive only those messages that the subscriber has registered

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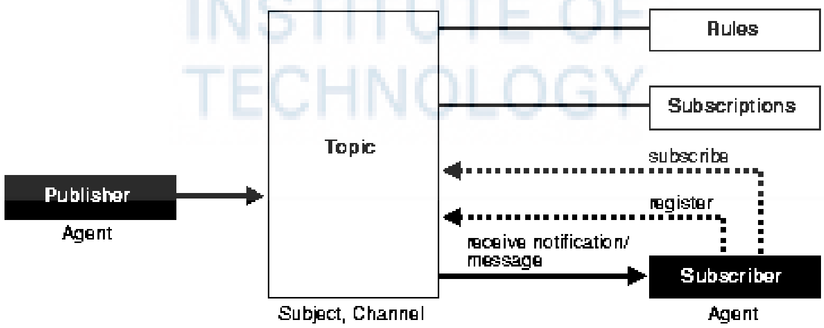
Publish/Subscribe Concept…

- Intervening entity between the publisher and the subscriber serves is a queue that represents a subject or channel
- The queue delivers messages that match the various subscriptions to the subscribers

Publish/Subscribe Concept…



Publish/Subscribe Communication

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Basic features of IEC 61850

- Support the communication for all functions being performed in substation
- Interoperability
- Free allocation of functions to devices (IEDs)
- Access to all the data is provided in a standardized way by the services of the standard
- Limitation to the non-deterministic behaviour of Ethernet

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IEC 61850 vs. DNP3

- DNP3 addressed North American requirements from IEC60870-5 work.
- IEC61850 addressed European requirements from UCA2.0 work.
- UCA2.0 was developed for LAN/WAN and profiles added for serial links.
- DNP3 was developed for serial links and profiles were added for LAN/WAN

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IEC 61850 vs. DNP3

- DNP3 has roots in the RTU world where byte efficiency for low-speed links was important
- IEC61850 has roots in the LAN/WAN world where independence from the organization and storage of “bytes” was important.

IEC 61850 vs. DNP3

- DNP3 is very byte efficient optimized for low-bandwidth applications.
- IEC61850 is feature rich with capabilities optimized for LAN/WAN based systems

IEC 61850 vs. DNP3

- DNP3 consists of:
  - Protocol specification that defines the bytes sent/received, data formats, and timing (the “Basic 4”)
  - DNP3 subset specifications for specific devices
- IEC61850 consists of:
  - Definition of architecture and requirements.
  - Abstract definition of objects and services.
  - Mapping of these abstracts to a specific profile (MMS and Ethernet).

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IEC 61850 vs. DNP3

- The DNP3 specifications look simpler.
- IEC61850 defines more externally visible behavior for a device.

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IEC 60870

- This standard defines the systems used for telecontrol
- Such systems are used for
  - Controlling electric power transmission grids
  - Geographically wide spread control systems.

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IEC 60870...

- IEC standard 60870 has six parts
- It defines general information related to
  - The standard
  - Operating conditions
  - Electrical interfaces
  - Performance requirements, and
  - Data transmission protocols.

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Purpose and Scope of IEC 61850

- Scope:
  – To support the communication for all functions being performed in substation.
- Goal is interoperability

Purpose and Scope...

- The 61850 standard was developed to:
  – Address the need for a more structured approach to design of Substation Automation Systems
  – Separate Data model from method of communication
  – Utilize new technologies (Ethernet, TCP/IP)
  – Enable vendor independence
  – Simplify system configuration
  – Enable sharing of measurement among devices

Purpose and Scope...

- Model information about the real world
  - Status, measurements, settings
  - Configuration of system
- Single-line diagram
- Function related information
- Defines when to exchange values
  - Configuration of IED
- Defines how to exchange values
  - Configuration of IED
- Describe the recipient of the values
  - Configuration of IED
- Describe who to receive values from
  - Configuration of IED

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Introducing IEC 61850

Standard	Status, Year	Title
IEC 61850-1	TR, 2003	Introduction and overview
IEC 61850-2	CDV, 2002	Glossary
IEC 61850-3	IS, 2002	General requirements
IEC 61850-4	IS, 2002	System and project management
IEC 61850-5	IS, 2003	Communication requirements for functions and device models
IEC 61850-6	FDIS, 2003	Configuration description language for communication in electrical substations related to IEDs
IEC 61850-7-1	IS, 2003	Basic communication structure for substations and feeder equipment – Principles and models
IEC 61850-7-2	IS, 2003	Basic communication structure for substations and feeder equipment – Abstract communication service interface (ACSI)
IEC 61850-7-3	IS, 2003	Basic communication structure for substations and feeder equipment – Common data classes
IEC 61850-7-4	IS, 2003	Basic communication structure for substations and feeder equipment – Compatible logical node classes and data classes
IEC 61850-8-1	FDIS, 2003	Specific communication service mapping (SCSM) – Mapping to MMS (ISO/IEC 9506 Part 1 and Part 2) and to ISO/IEC 8802-3
IEC 61850-9-1	IS, 2003	Specific communication service mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link
IEC 61850-9-2	FDIS, 2003	Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3
IEC 61850-10	CD, 2003	Conformance testing
IEC 61850-7-401	NP, 2002	Power Quality Monitoring Addendum to IEC 61850 - Logical nodes, data objects and definitions for exchanging information about power quality.

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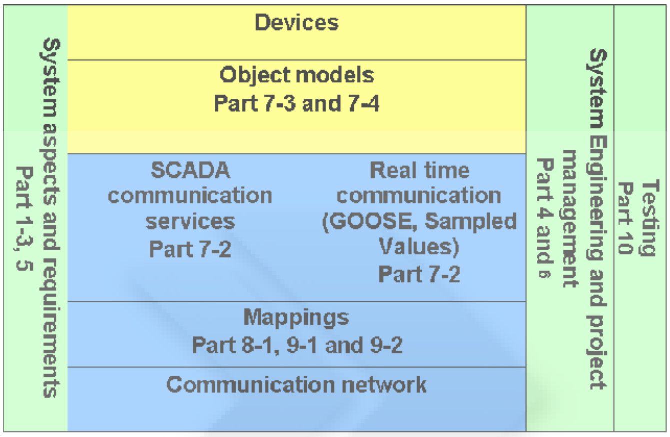
Parts of IEC 61850



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General functional requirements

- Parts 3, 4, and 5 of the standard
  - Identify the general and specific functional requirements for communications in a substation

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Abstract Services

- Part 7.2 of the standard
  - Basic communication structure for substations and feeder equipment – ACSI

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Common Data Classes

- Part 7.3 of the standard
  - Basic communication structure for substations and feeder equipment – Common data classes (CDC)

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Abstraction of Data Objects

- Part 7.4 of the standard
  - Basic communication structure for substations and feeder equipment – Compatible logical node classes and data classes

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Mapping of Abstract Data Objects and Services...

- IEC 61850-8-1 specifies,
  - Mapping of the objects and services of the ACSI to MMS and ISO/IEC 8802-3 frames
  - MMS (Manufacturing Message Specification, ISO 9506)
  - It provides specifications to the mechanisms and rules required
    - To implement the services, objects, and algorithms specified in IEC 61850-7-2,7-3 and 7-4
    - By using ISO 9506 MMS, SNTP, other protocols

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SUBSTATION AUTOMATION FUNCTIONS

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Remote Substation Access

- Remote Terminal Unit (RTU)
- Programmable Logic Controller (PLC)
- Protection Relays
- Intelligent Electronic Device (IED)

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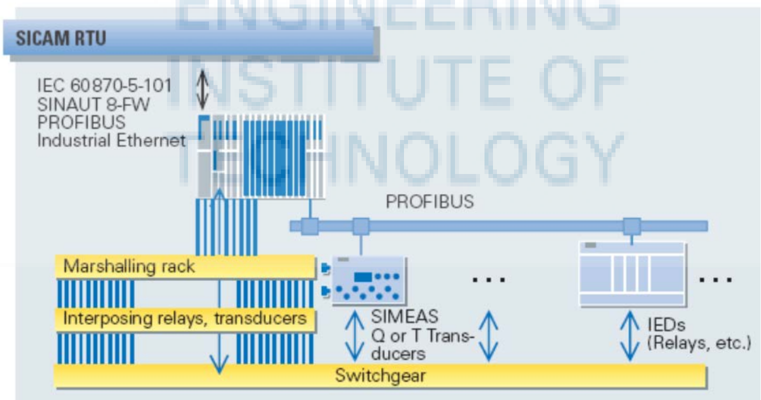
Remote Terminal Unit

- Alarm acquisition and processing
- Measured value acquisition and processing
- Fail safe command output
- Communication with SCADA master
- Time synchronisation diagnostics

Example



Source : SIEMENS SICAM brochure

PLC

- **P**rogrammable **L**ogic **C**ontroller is a special purpose control computer.
- It directly replaces electromechanical relays with logic elements, substitutes a solid-state digital computer with a stored program,
- Is able to emulate the interconnection of many relays to perform certain logical tasks.
- Performs relay switching tasks.

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PLC

- It offers flexibility to modify the control logic.
- Response time to changes in input parameters is within fraction of seconds.
- Overall control system reliability is improved.
- Input / Output configuration can be easily changed
- It is cost effective for controlling complex systems.
- Trouble shooting is simpler and faster.

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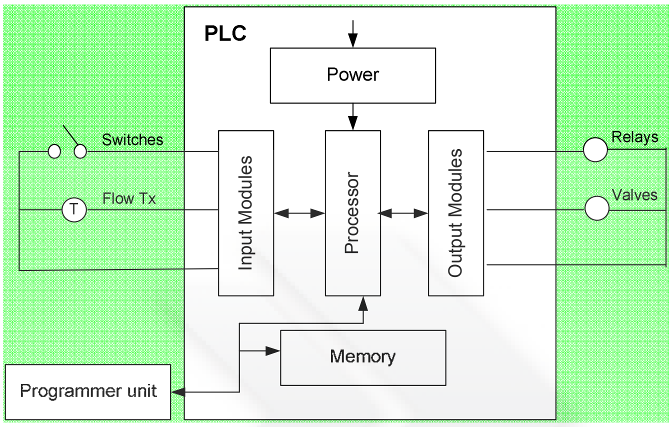
PLC block diagram



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Protection relays - functions

- Overcurrent
  - Overload
  - Fault current
- Earth Fault
- Differential Protection
  - Machine differential protection
  - Feeder differential protection
- Voltage Regulation
- Frequency Regulation
- Distance Protection
- Negative Sequence Protection

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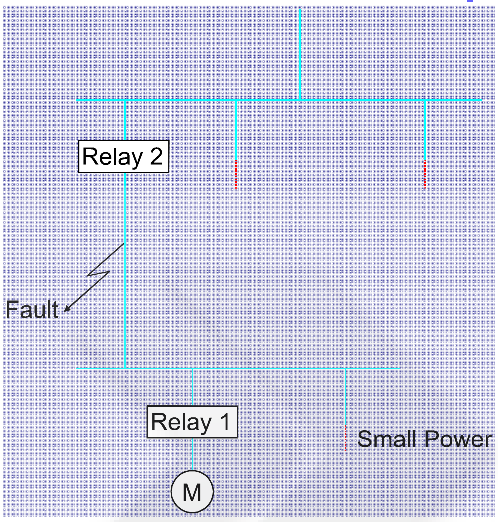
Protection Example



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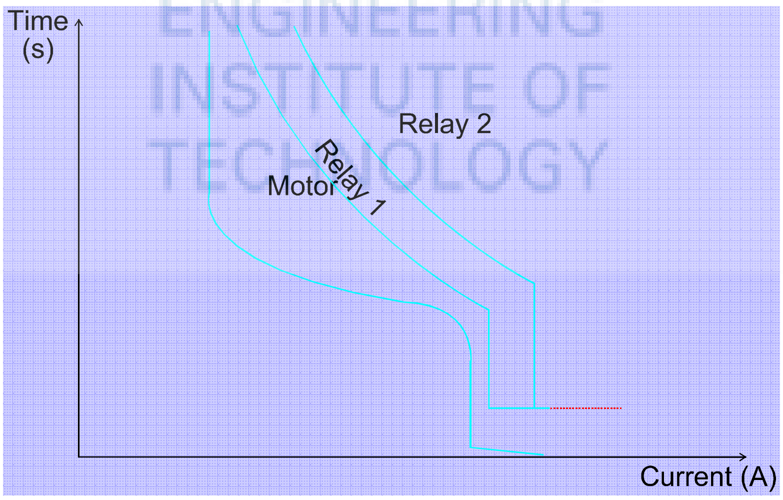
Protection Example



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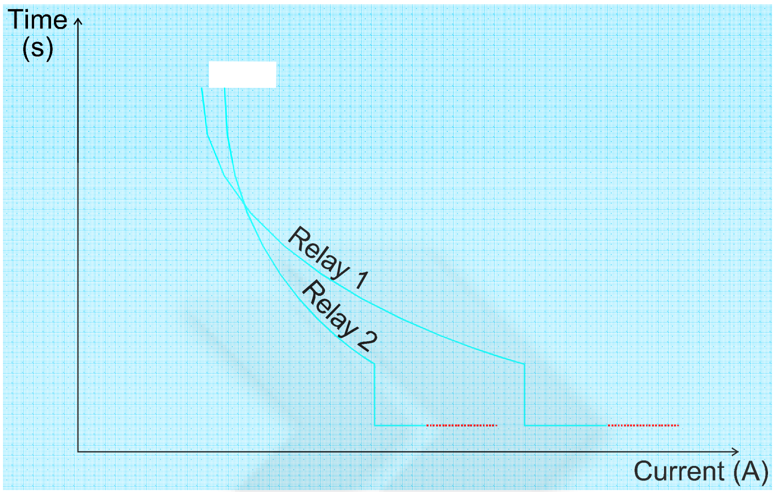
Protection Example



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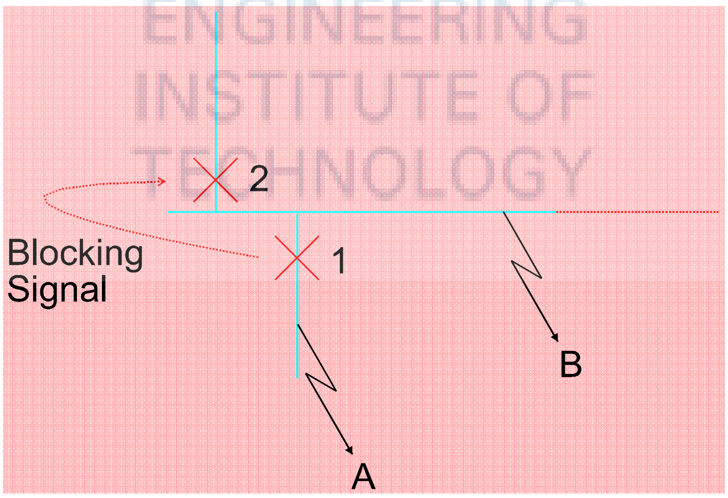
Blocking Principle



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Intelligent electronic device

- Protection
- Control
- Monitoring
- Metering
- Communication

SIEMENS 9700 Power Meter

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IED – Protection Functions

- Non-directional three-phase overcurrent
- Non-directional earth fault protection
- Directional three-phase overcurrent
- Directional earth fault protection
- Phase discontinuity protection
- Three-phase overvoltage protection
- Residual overvoltage protection
- Three-phase undervoltage protection
- Three-phase transformer inrush / motor start-up current detector

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IED – Control Functions

- Local and remote control of up to twelve switching objects
- Control sequencing
- Bay level interlocking 1 of the controlled devices
- HMI panel on device

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IED – Monitoring Functions

- Circuit-breaker condition monitoring
- Trip circuit supervision
- Internal self-supervision
- Gas density monitoring (for SF_6 switchgear)
- Event recording
- Other monitoring functions, like auxiliary power, relay temperature, etc.

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IED – Metering Functions

- Three-phase currents
- Neutral current
- Three-phase voltages
- Residual voltage
- Frequency
- Active Power
- Reactive Power
- Power Factor
- Energy
- Harmonics

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Typical IED Functions

- Protection
- Control
- Monitoring
- Metering
- Data Communications

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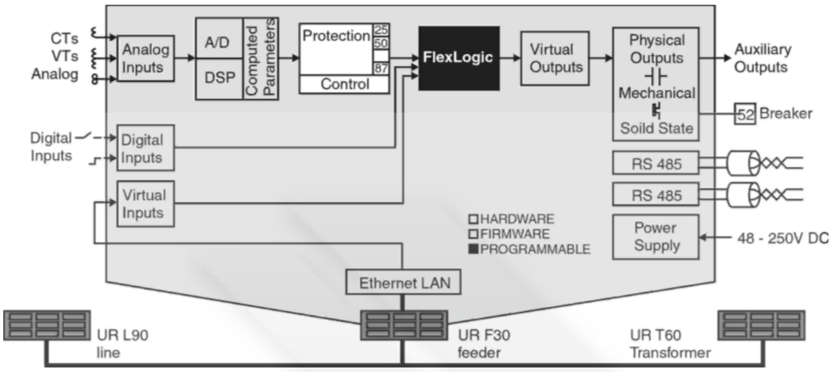
Typical IED Functionality



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Comparison of Relay Types

No	Feature	Electromechanical	Digital
1	Reliability	Moderate	High
2	Stability	High	High
3	Sensitivity / Accuracy	Low	High
4	Speed of operation	Moderate	High
5	Discrimination capability	Moderate	High
6	Multi-function	No	Yes
7	Versatile (can be used for different applications)	No	Yes
8	Flexible (multiple curves, selectable setting groups)	No	Yes
9	Maintenance intensive	High	Low
10	Self-diagnostics	No	Yes
11	Trip circuit supervision	No	Yes
12	Condition monitoring	No	Yes
13	Data communications	No	Yes
14	Control functions	No	Yes
15	Metering	No	Yes
16	Disturbance recordings	No	Yes
17	Remote operation	No	Yes
18	CT Burden	High	Very low
19	Cost	Low	Depend on application

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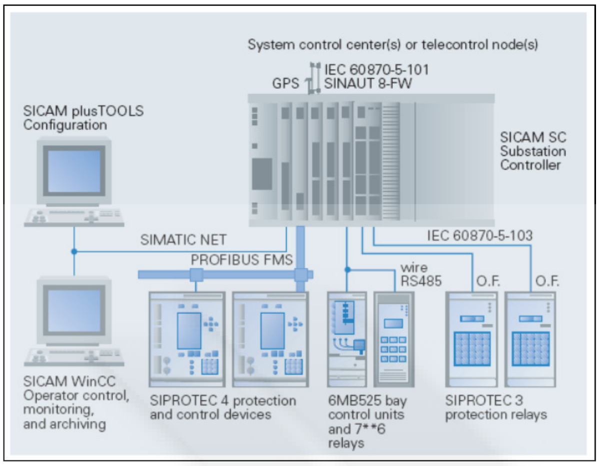
Example



Source : SIEMENS brochure

A typical configuration of a SICAM substation automation system

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