| JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE | Jaipur Engineering college and research centre, Shri Ram ki Nangal, via Sitapura RIICO Jaipur- 302 022. | **Academic year- 2020-21** |
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## DEPARTMENT OF ELECTRICAL ENGINEERING

### Syllabus
### Power System Protection

### III Year - VI Semester: B. Tech. (Electrical Engineering)

1. Introduction: Objective, scope and outcome of the course.

2. Introduction and Components of a Protection System: Principles of Power System Protection, Relays, Instrument transformers, Circuit Breakers.

3. Faults and Over-Current Protection: Review of Fault Analysis, Sequence Networks. Introduction to over current Protection and over current relay co-ordination.

4. Equipment Protection Schemes: Directional, Distance, Differential protection. Transformer and Generator protection. Bus bar Protection, Bus Bar arrangement schemes.

5. Digital Protection: Computer-aided protection, Fourier analysis and estimation of Phasors from DFT. Sampling, aliasing issues.

6. Modeling and Simulation of Protection Schemes: CT/PT modeling and standards, Simulation of transients using Electro-Magnetic Transients (EMT) programs. Relay Testing.

7. System Protection: Effect of Power Swings on Distance Relaying. System Protection Schemes. Under-frequency, under-voltage and df/dt relays, Out-of- step protection, Synchro-phasors, Phasor Measurement Units and Wide-Area Measurement Systems (WAMS). Application of WAMS for improving protection systems.

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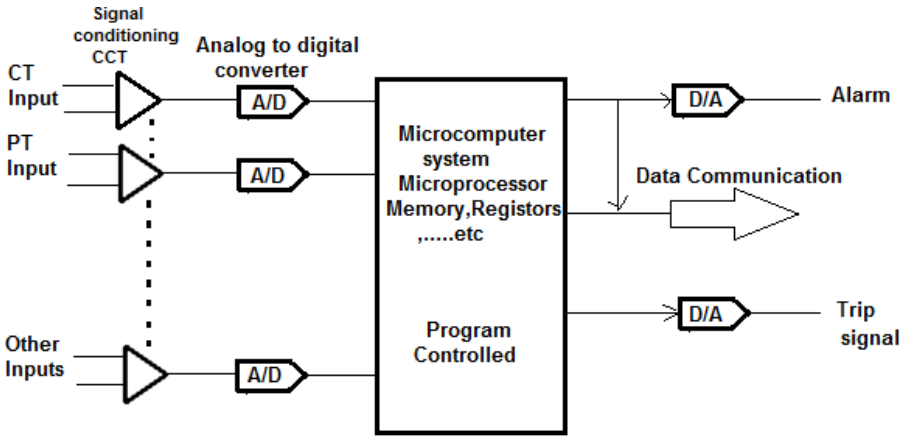
# Power System Protection

## Unit-V

## Digital Protection:

A **digital protective relay** is a microcomputer controlled relay. The data acquisition system collects the transducers information and converts it to the proper form for use by the microcomputer. Information from CT and PT and other systems is amplified and sampled at several kHz. The sampled signals are digitized with A/D converter and fed to registers in microprocessorsystem. The microprocessor may use some kind of counting technique, or use the Discrete Fourier Transform (DFT) to compare the information with preset limits for over current , over/under voltage…etc, and then send command through D/A converter to alarm or trip signals to the circuitbreakers.



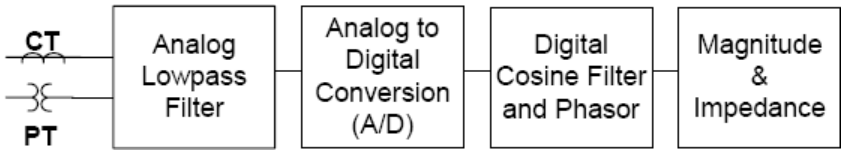

Microcomputer - controlled relay

### Operation:

- The relay applies A/D (analog/digital) conversion processes to the incoming the voltages and currents.
- The relay analyzes the A/D converter output to extract the magnitude of the incoming quantity (RMS value) using Fourier transform concept. Further, the Fourier transform is commonly used to extract the signal's phase angle relative to some reference.
- The digital relay is capable of analyzing whether the relay should trip or restrain from tripping based on current and/or voltage magnitude (and angle in some applications).

### Signal Path for Microprocessor Relays

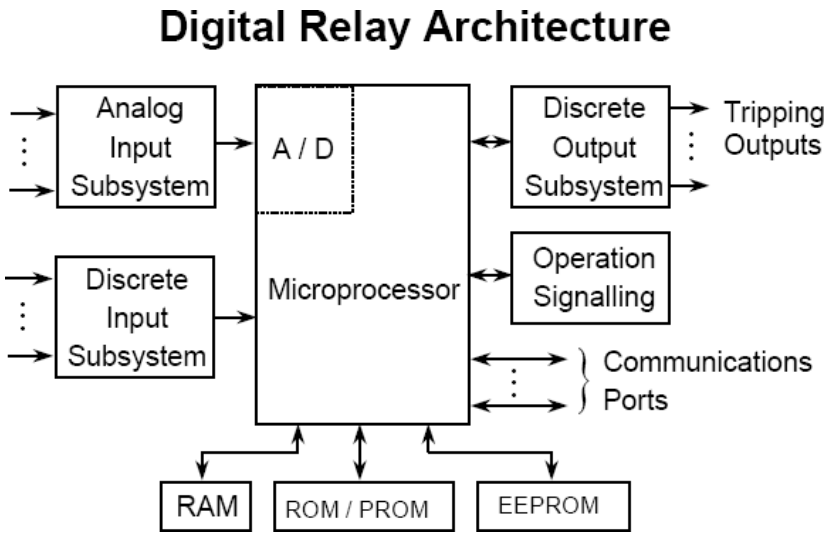
The signal path for voltage and current input signals are shown in Fig.




- After the currents and voltages are reduced to acceptable levels by theinstrument transformers, the signals are filtered with an analog filter
- The signal then digitized and re-filtered with a digital filter.
- Numerical operating quantities are then calculated from the processedwaveforms.

**Digital Relay Construction**

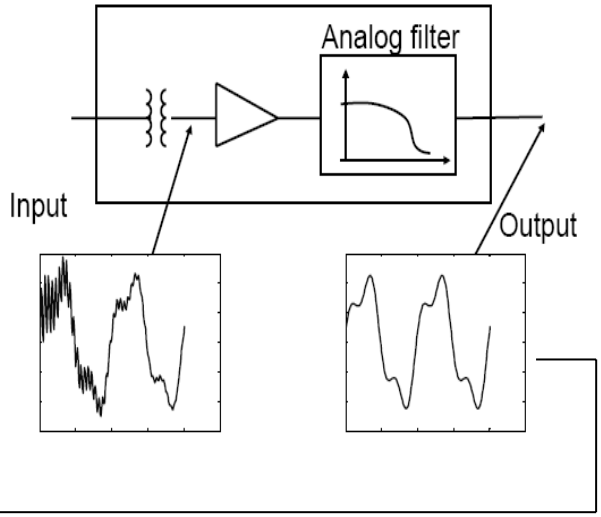
- Analog Input Subsystem
- Discrete Input Subsystem
- A/D Converter
- Microprocessor
- Discrete output Subsystem
- Operating signaling and communication subsystems



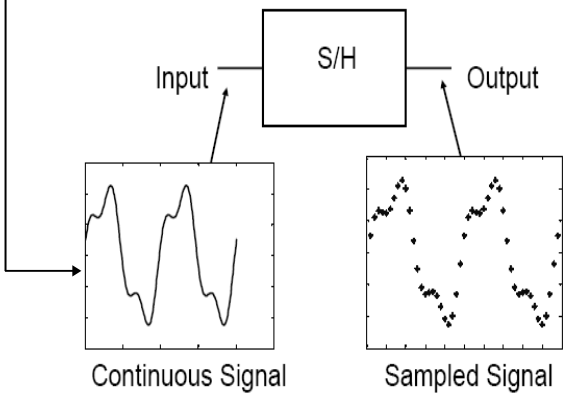
## Analog Input System

**Discrete Input Subsy**

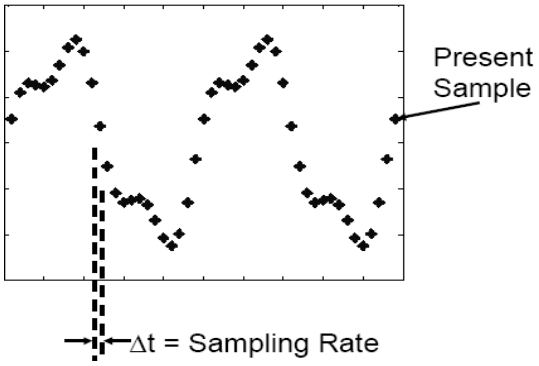
- Surge S
- Signal




## Sampling of Analog Signals

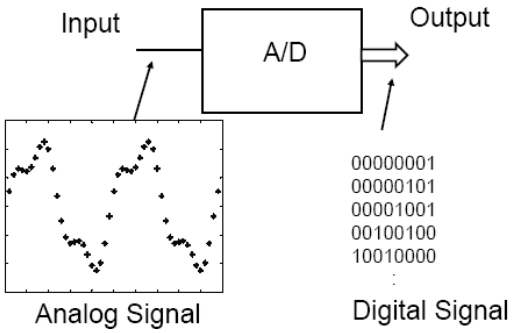


## Sampled Signal

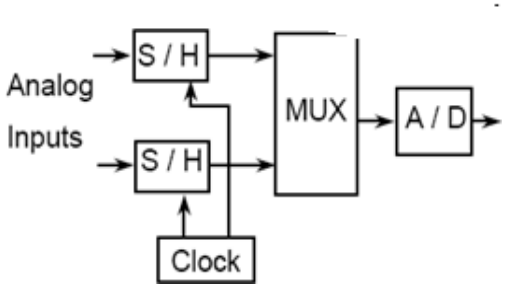



Sampling frequency is the inverse of sampling rate.

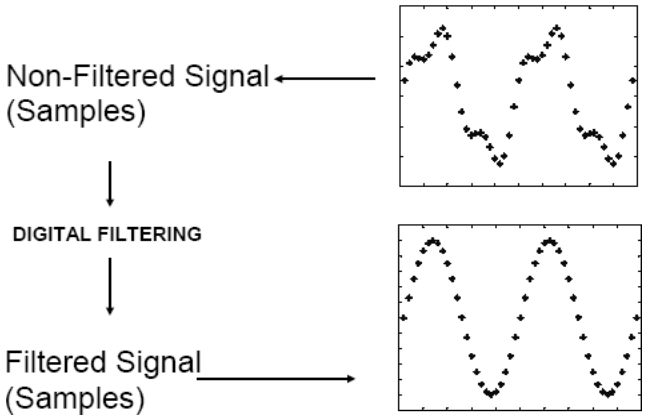
## Analog to Digital (A/D) Conversion




## Sampling and Hold system

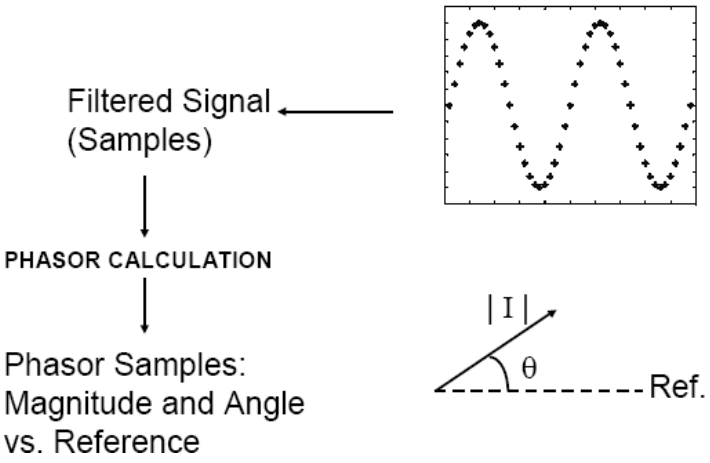


## Digital Filtering

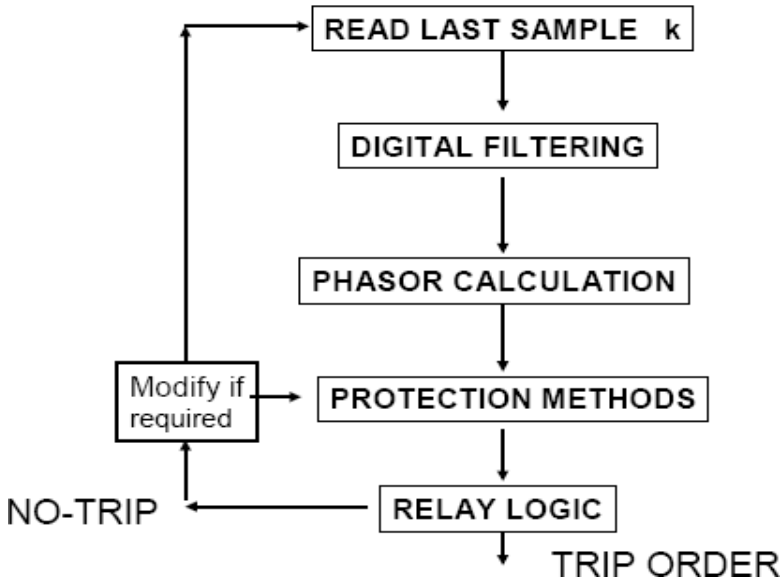



The digital filter smoothes the signal by eliminating DC and frequenciescomponents those are different than the fundamental (when required).

## Phasor Calculation

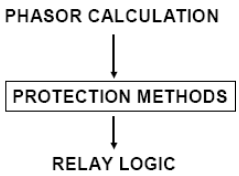


# Digital Relay Algorithm




## Protection Methods

- Overcurrent (50, 51)
- Voltage (59, 27)
- Directional (67)
- Distance (21)
- Differential (87)
- Frequency (81)




These routines implement the protection function:over current, directional, distance, differential, etc.

**Other Features:**

- The relay has some form of advanced event recording. The event recording would include some means for the user to see the timing of key logic decisions, relay I/O (input/output) changes, and see in an oscilloscope fashion at least the fundamental frequency component of the incoming AC waveform.
- The relay has an extensive collection of settings, beyond what can be entered via front panel knobs and dials, and these settings are transferred to the relay via an interface with a PC (personal computer),and this same PC interface is used to collect event reports from the relay.
- The more modern versions of the digital relay will contain advanced metering and communication protocol ports, allowing the relay to become a focal point in a SCADA system.

**Advantages of Digital Relays**

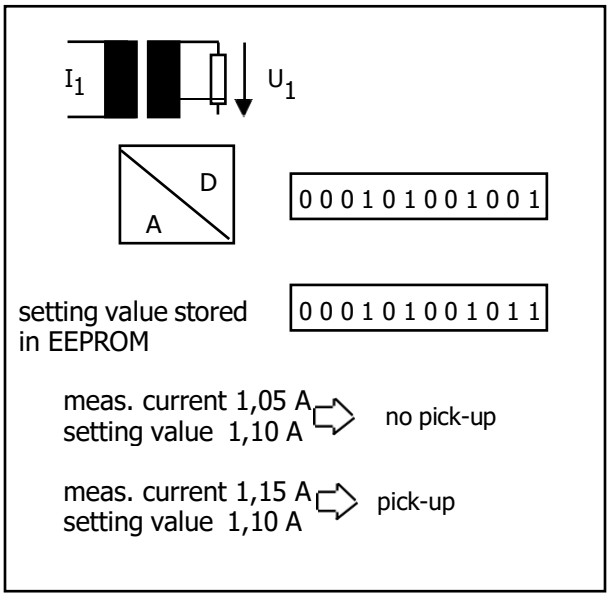
- Low Cost
- Multi functionality
- Protection and control
- Measurement
- Fault recording
- Communications capability
- Compatibility with Digital Integrated Systems
- High Reliability
- Relays (integration, self-testing)
- Protection system (supervised by the relays)
- Sensitivity and Selectivity
- New Protection Principles
- New Relay Operating Characteristics
- Maintenance-Free
- Reduced Burden on CTs and VTs
- Adaptive Protection

**NUMERICAL RELAYS**

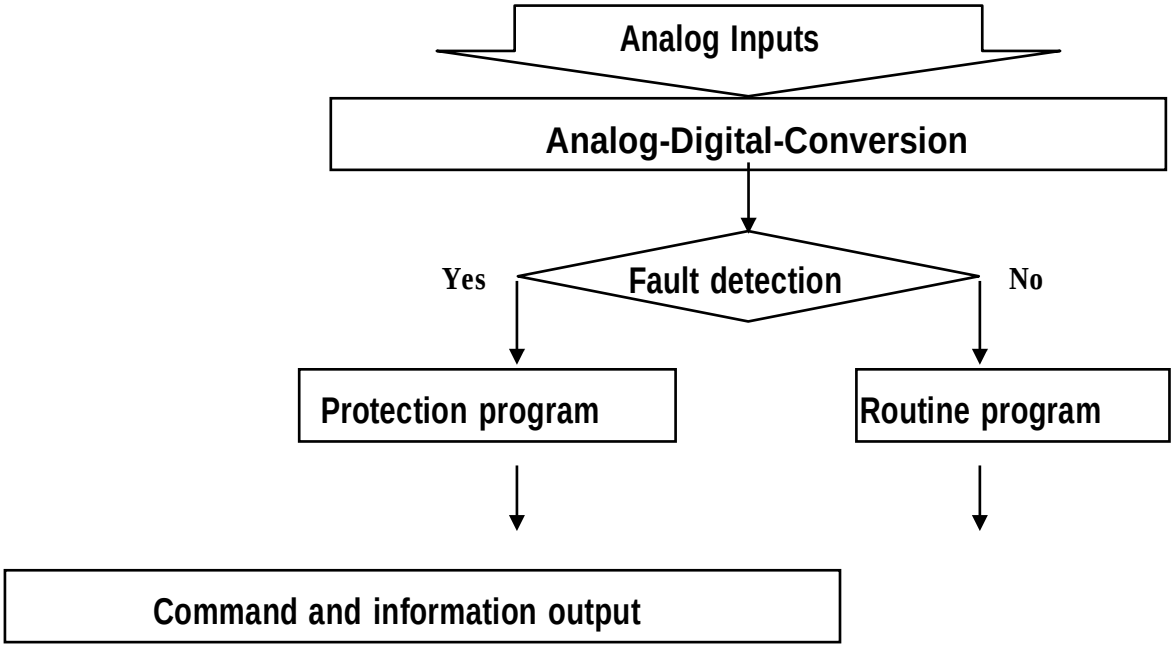
The distinction between digital and numerical relay rests on points of fine technical detail, and is rarely found in areas other than Protection. They can be viewed as natural developments of digital relays as a result of advances in technology. Typically, they use a specialized digital signal processor (DSP) as the computational hardware, together with the associated software tools.

**Numerical measurement treatment**

Numerically the measurementvalue is converted into a logical digit and then compared with another digit stored in a memory.



**Mode of operation**




**Advantages of numerical technology**

- **Comprehensive information supply**
- **clear representation of the fault sequence**

**Fault sequence of event and disturbance recording indicate**

- **What actually happened?**
- **What did the current and voltage signals look like (CTsaturation)?**
- **When did the protection issue a trip signal?**
- **How long did the circuit breaker need to operate?**
- **What was the magnitude of the interrupted current?**
- **How did the system behave after the circuit breakertripped?**

**Electromagnetic vs. Computerized**

## Comparison between Electromagnetic Relay and Computerized Relay

| Characteristic | Electromagnetic Relay | Computerized Relay | |
|---|---|---|---|
| | | Digital Relay | Numerical Relay |
| **Relay Size** | Bulky | Small | Compact |
| **Speed of Response** | Slow | Fast | Very fast |
| **Timing function** | Mechanical clock works, dashpot | Counter | Counter |
| **Time of Accuracy** | Temp. dependent | Stable | Stable |
| **Reliability** | High | High | High |
| **Vibration Proof** | No | Yes | Yes |
| **Characteristics** | Limited | Wide | Wide |
| **CT Burden** | High<br>8 to 10 VA | Low<br>< 0.5 VA | Low<br>< 0.5 VA |
| **Reset Time** | Very High | Less | Less |
| **Auxiliary supply** | Required | Required | Required |
| **Range of settings** | Limited | Wide | Wide |
| **Function** | Single function | Multi-function | Single function |
| **Maintenance** | Frequent | Low | Very Low |
| **Resistance** | 100 milli ohms | 10 Ohms | 10 Ohms |
| **Deterioration due to Operation** | Yes | No | No |
| **Relay Programming** | No | Programmable | Programmable |
| **SCADA Compatibility** | No | Possible | Yes |
| **Fault Recording** | **Not possible** | Possible | Possible |
| **Visual indication** | Flags, targets | LEDs, LCD | LEDs, LCD |
| **Self-monitoring** | No | Yes | Yes |