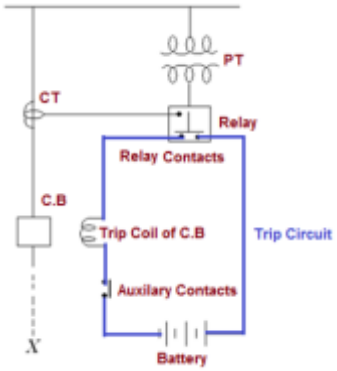
Types and Revolution of Electrical Relays

Introduction:

- Protective relays work in concert with sensing and control devices to accomplish their function. Under normal power system operation, a protective relay remains idle and serves no active function. But when fault or undesirable condition arrives Relay must be operated and function correctly.
- A Power System consists of various electrical components like Generator, transformers, transmission lines, isolators, circuit breakers, bus bars, cables, relays, instrument transformers, distribution feeders, and various types of loads. Faults may occur in any part of power system as a short circuit & earth fault. Fault may be Single Line to Ground, Double Line to Ground, Line to Line, three phase short circuit etc. This results in flow of heavy fault current through the system. Fault level also depends on the fault impedance which depends on the location of fault referred from the source side. To calculate fault level at various points in the power system, fault analysis is necessary.
- The protection system operates and isolates the faulty section. The operation of the protection system should be fast and selective i.e. it should isolate only the faulty section in the shortest possible time causing minimum disturbance to the system. Also, if main protection fails to operate, there should be a backup protection for which proper relay co-ordination is necessary. Failure of a protective relay can result in devastating equipment damage and prolonged downtime.

Working of Protective Scheme:

- Protective relaying senses the abnormal condition in a part of power system and gives an alarm or isolates that part from healthy system. Protective relaying is a team work of CT, PT, protective relays, time delay relays, trip circuits, circuit breakers etc.
- Protective relaying plays an important role in minimizing the faults and also in minimizing the damage in the event of faults.



- Figure shows basic connections of circuit breaker control for the opening operation. The protected circuit X is shown by dashed line. When a fault occurs in the protected circuit the relay connected to CT and PT actuates and closes its contacts.

- Current flows from battery in the trip circuit. As the trip coil of circuit breaker is energized, the circuit breaker operating mechanism is actuated and it operates for the opening operation. Thus the fault is sensed and the trip circuit is actuated by the relay and the faulty part is isolated.

What is Relay:

- A relay is automatic device which senses an abnormal condition of electrical circuit and closes its contacts. These contacts in turns close and complete the circuit breaker trip coil circuit hence make the circuit breaker tripped for disconnecting the faulty portion of the electrical circuit from rest of the healthy circuit.

Functions of protective Relay:

- To sound an alarm or to close the trip circuit of a circuit breaker so as to disconnect Faulty Section.
- To disconnect the abnormally operating part so as to prevent subsequent faults. For e.g. Overload protection of a machine not only protects the machine but also prevents Insulation failure.
- To isolate or disconnect faulted circuits or equipment quickly from the remainder of the system so the system can continue to function and to minimize the damage to the faulty part. For example – If machine is disconnected immediately after a winding fault, only a few coils may need replacement. But if the fault is sustained, the entire winding may get damaged and machine may be beyond repairs.
- To localize the effect of fault by disconnecting the faulty part from healthy part, causing least disturbance to the healthy system.
- To disconnect the faulty part quickly so as to improve system stability, service continuity and system performance. Transient stability can be improved by means of improved protective relaying.
- To minimize hazards to personnel

Desirable qualities of protective relaying:

1. Selectivity,
2. Discrimination
3. Stability
4. Sensitivity,
5. Power consumption
6. System Security
7. Reliability
8. Adequateness
9. Speed & Time

Terminology of protective relay:

- **Pickup level of actuating signal:** The value of actuating quantity (voltage or current) which is on threshold above which the relay initiates to be operated. If the value of actuating quantity is increased, the electromagnetic effect of the relay coil is increased and above a certain level of actuating quantity the moving mechanism of the relay just starts to move.
- **Reset level:** The value of current or voltage below which a relay opens its contacts and comes in original position.
- **Operating Time of Relay:** Just after exceeding pickup level of actuating quantity the moving mechanism (for example rotating disc) of relay starts moving and it ultimately close the relay contacts at the end of its journey. The time which elapses between the instant when actuating quantity exceeds the pickup value to the instant when the relay contacts close.
- **Reset time of Relay:** The time which elapses between the instant when the actuating quantity becomes less than the reset value to the instant when the relay contacts returns to its normal position.
- **Reach of Relay:** A distance relay operates whenever the distance seen by the relay is less than the pre-specified impedance. The actuating impedance in the relay is the function of distance in a distance protection relay. This impedance or corresponding distance is called reach of the relay.

History of Protective Relay:

- The evolution of protective relays begins with the electromechanical relays. Over the past decade it upgraded from electromechanical to solid state technologies to predominate use of microprocessors and microcontrollers.
- The timeline of the development of protective relays is shown below

1900 to 1963	**1963 to 1972**	**1972 to 1980**	**1980 to 1990**
Electromechanical Relay.	**Static Relay**	**Digital Relay**	**Numerical Relay**
1925=Single Disc Type Relay (Single Input)	1963=Static Relay (All Purpose)	1980=Digital Type Relay (All Purpose)	1990=Numerical Type Relay (All Purpose)
1961=Single Cup Type Relay (Impedance Relay)	1972=Static Relay with self checking (All Purpose)		

Types of Relays:

- Types of protection relays are mainly

(A) Based on Characteristic:

1. Definite time Relays.
2. Inverse definite minimum time Relays (IDMT)
3. Instantaneous Relays
4. IDMT with Instantaneous.
5. Stepped Characteristic
6. Programmed Switches
7. Voltage restraint over current relay

(B) Based on logic:

1. Differential
2. Unbalance
3. Neutral Displacement
4. Directional
5. Restricted Earth Fault
6. Over Fluxing
7. Distance Schemes
8. Bus bar Protection
9. Reverse Power Relays
10. Loss of excitation
11. Negative Phase Sequence Relays etc.

(C) Based on Actuating parameter:

1. Current Relays
2. Voltage Relays
3. Frequency Relays
4. Power Relays etc.

(D) Based on Operation Mechanism:

- **(A) Electro Magnetic Relay**
- **(B) Static Relay**
- Analog Relay
- Digital Relay

- Numerical /Microprocessor Relay
- **(C) Mechanical relay.**
- **(1) Thermal**
  (a) OT Trip (Oil Temperature Trip)
  (b) WT Trip (Winding Temperature Trip)
  (C) Bearing Temp Trip etc.
- **(2) Float Type**
  (a) Buchholz
  (b) OSR
  (c) PRV
- (d) Water level Controls etc.
- **(3) Pressure Switches.**
- **(4) Mechanical Interlocks.**
- **(5) Pole discrepancy Relay.**

(E) Based on Applications:

1. Primary Relays.
2. Backup Relays

Type of Relay based on Relay Operation Mechanism:

(1) Electromagnetic Relay:

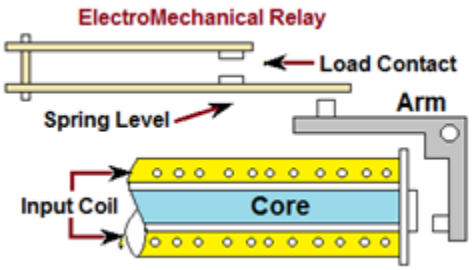
- Electromagnetic relays are further categorized under two following categories.
- **(A) Electromagnetic Attraction Relay:**
- This Relay works on Electromagnetic Attraction Principle
- **(B) Electromagnetic Induction Relay:**
- This Relay works on Electromagnetic Induction Principle

(2) Solid State (Static) Relay:

- Solid-state (and static) relays are further categorized under following designations.
- **(A) Analog Relay:**
- In Analog relays are measured quantities are converted into lower voltage but similar signals, which are then combined or compared directly to reference values in level detectors to produce the desired output.
- **(B)Digital Relay:**
- In Digital relays measured ac quantities are manipulated in analogue form and subsequently converted into square-wave (binary) voltages. Logic circuits or microprocessors compare the phase relationships of the square waves to make a trip decision.
- **(C)Numerical Relay:**
- In Numerical relays measured ac quantities are sequentially sampled and converted into numeric data form. A microprocessor performs mathematical and/or logical operations on the data to make trip decisions.

(1) Electromechanical Relay:

- **History of Relay:** This is the first generation oldest relaying system and they have been in use for many years. They have earned a well-deserved reputation for accuracy, dependability, and reliability. There are two basic types of operating mechanisms: the electromagnetic-attraction relay and electromagnetic-induction relay.
- **Measuring Principles:** The electromechanical protective relay converts the voltages and currents to magnetic and electric forces and torques that press against spring tensions in the relay. The tension of the spring and taps on the electromagnetic coils in the relay are the main processes by which a user sets in a relay.
- **Function of Relay:** These relays are usually instantaneous in action, with no intentional time delay, closing as soon after pickup as the mechanical motion permits. We can add time delay by means of a bellows, dashpot, or a clockwork escapement mechanism. However, the timing accuracy is considerably less precise than that of induction type relays. As such, users seldom choose these relays with time delay in switchgear applications.
- Electromechanical Relays can operate with either AC or DC on the coils. Therefore, the DC component of an asymmetrical fault definitely affects these relays using this principle.
- Most relays come enclosed in a semi flush-mounting draw out case. Installers typically install relays usually on the door of the switchgear cubicle. They bring sensor and control wiring to connections on the case. The relay inserts into the case and connects by means of small switches or a bridging plug, depending on the manufacturer.
- As such, we can disconnect and withdraw it from the case without disturbing the wiring. When the relay is disconnected, the current transformer (CT) connections in the case are automatically shorted to short circuit the CT secondary winding and protect the CT from over voltage and damage.
- **Operation of Electromagnetic-attraction Relay:** Figure shows a typical electro-mechanical relay. An input voltage is applied to the coil mechanism. The input voltage magnetizes the core which pulls the arm towards it. This action causes the output contacts to touch, closing the load circuit. When the input voltage is removed, the spring lever will push the contacts away from each other, breaking the load circuit connection.



- **Operation of Electromagnetic-Induction Relay:** Induction relays are available in many variations to provide accurate pickup and time-current responses for a wide range of simple or complex system.
- They are actually like induction motors. On the relay, the moving element (rotor) is usually a metal disk, although sometimes it's a metal cylinder or cup. The stationary part (stator) is one or more integral electromagnets, with current or potential coils inducing currents in the disk, causing it to rotate. Until the rotational forces are great enough to turn the disk and bring its moving contact against the stationary contact, a spring restrains the diskmotion

- This closes the circuit the relay is controlling. The greater the sensed fault, the greater the current in the coils, and the faster the disk rotates.
- A calibrated adjustment called the time dial sets the spacing between the moving and stationary contacts; this varies the operating time of the relay from fast (contacts only slightly open) to slow (contacts nearly a full disk revolution apart). Reset action begins upon removing the rotational force, either by closing the relay contact that trips a breaker or by otherwise removing the malfunction the relay is sensing. The restraining spring resets the disk to its original position. The time required to reset depends on the type of relay and the time-dial setting (contact spacing).
- Most electromechanical Relays are typically rated for minimum input to output isolation voltages of 1500 to 2000 VAC.

Limitations of Electromagnetic relays:

- Low speed of operation.
- Change in characteristics over a period due to ageing effect.
- Component failure leading to relay failure.
- Relay is Bulky: Because there are internal mechanical components with physical dimension restraints, the package size of an electromechanical Relay can limit the size of a PCB design Excessive power consumption.
- Imposes high burden on CT
- No fault data available except phase indication.
- Inherent in its design, the Electromechanical Relay must make mechanical contacts in order to switch a load. At the point of these contacts, oxidation breakdown occurs over extended life cycling (typically 106 operations), and the relay will need to be replaced.
- When an electromechanical Relay is activated, bounce occurs at the contact site. Bounce creates a window of time where the load circuit is flickering between open and closed, a condition which may need to be considered in load design.
- Isolation voltage is another area where Electromechanical Relays are limited.

(2) The Solid State Relay (Static Relay):

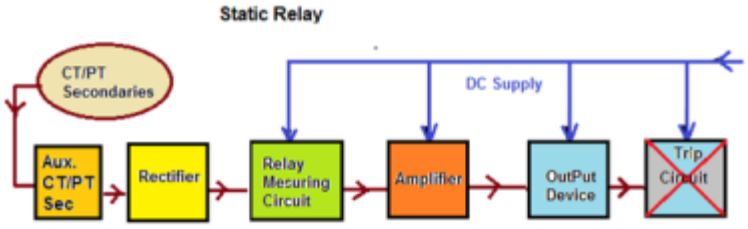
- **History of Relay:** The static relay are next generation relays .The Solid Static relays was first introduced in 1960's. The term 'static' implies that the relay has no moving mechanical parts in it. Compared to the Electromechanical Relay, the Solid Static relay has longer life-span, decreased noise when operates and faster respond speed. However, it is not as robust as the Electromechanical Relay.

- Static relays were manufactured as semi conductor devices which incorporate transistors, ICs, capacitors, small micro processors etc.
- The static relays have been designed to replace almost all the functions which were being achieved earlier by electromechanical relays.
- **Measuring principles:** The working principle of the Solid Static relays is similar to that of the Electromechanical Relay which means the Solid Static relays can perform tasks that the Electromechanical Relay can perform.
- The Solid Static relays use analogue electronic devices instead of magnetic coils and mechanical components to create the relay characteristics. the measurement is carried out by static circuits consisting of comparators, level detectors, filter etc while in a conventional electro-magnetic relay it is done by comparing operating torque (or force) with restraining torque (or force). The relaying quantity such as voltage/current is rectified and measured. When the quantity under measurement attains certain well-defined value, the output device is triggered and thereby the circuit breaker trip circuit is energized.
- In a solid state relay, the incoming voltage and current waveforms are monitored by analog circuits, not recorded or digitized. The analog values are compared to settings made by the user via potentiometers in the relay, and in some case, taps on transformers.
- In some solid state relays, a simple microprocessor does some of the relay logic, but the logic is fixed and simple. For instance, in some time over current solid state relays, the incoming AC current is first converted into a small signal AC value, and then the AC is fed into a rectifier and filter that converts the AC to a DC value proportionate to the AC waveform. An op-amp and comparator is used to create a DC that rises when a trip point is reached. Then a relatively simple microprocessor does a slow speed A/D conversion of the DC signal, integrates the results to create the time-over current curve response, and trips when the integration rises above a set point. Though this relay has a microprocessor, it lacks the attributes of a digital/numeric relay, and hence the term “microprocessor relay” is not a clear term.
- **Function of Relay:** Early versions used discrete devices such as transistors and diodes in conjunction with resistors, capacitors, inductors, etc., but advances in electronics enabled the use of linear and digital integrated circuits in later versions for signal processing and implementation of logic functions. While basic circuits may be common to a number of relays, the packaging was still essentially restricted to a single protection function percase, while complex functions required several cases of hardware suitably interconnected.

Static Relay

- User programming was restricted to the basic functions of adjustment of relay characteristic curves. Therefore it can be viewed in simple terms as an analogue electronic replacement for electromechanical relays, with some additional flexibility in settings and some saving in space requirements.
- In some cases, relay burden is reduced, making for reduced CT/VT output requirements. in a static relay there is no armature or other moving element and response is developed by electronic, magnetic or other components without mechanical motion.
- A relay using combination of both static and electro-magnetic units is also called a static relay provided that static units accomplish the response.

- Additional electro-mechanical relay units may be employed in output stage as auxiliary relays. A protective system is formed by static relays and electro-mechanical auxiliary relays.
- The performance of static relay is better than electromagnetic relays as they are fast acting and accuracy of measurement is better than electromagnetic relay.
- The constraint in static relay is limited function/features. In the last decade, some micro processors were introduced in this relay to achieve the functions like (i) Fuse failure features (ii) Self check feature (iii) Dead Pole detection and iv) Carrier aided protection features.
- **Operation of Relay:** The essential components of static relays are shown in fig. The output of CT and PT are not suitable for static components so they are brought down to suitable level by auxiliary CT and PT. Then auxiliary CT output is given to rectifier. Rectifier rectifies the relaying quantity i.e., the output from a CT or PT or a Transducer



- The rectified output is supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits. The output is actuated when the dynamic input (i.e., the relaying quantity) attains the threshold value. This output of the measuring unit is amplified by amplifier and fed to the output unit device, which is usually an electro-magnetic one. The output unit energizes the trip coil only when relay operates.

Advantages of Solid State Relay:

- Static Relay burden is less than Electromagnetic type of relays. Hence error is less.
- Low Weight
- Required Less Space which results in panel space saving.
- Arc less switching
- No acoustical noise.
- Multi-function integration.
- Fast response.
- Long life (High Reliability): more than 109 operations
- High Range of Setting compared to electromechanical Relay
- More Accurate compared to electromechanical Relay
- Low Electromagnetic Interference.
- Less power consumption.
- Shock and vibration resistant
- No contact bounce
- Microprocessor compatible.
- Isolation of Voltage
- No moving parts: There are no moving parts to wear out or arcing contacts to deteriorate that are often the primary cause of failure with an Electro Mechanical Relay.

- No mechanical contact bounce or arcing: A solid-state relay doesn't depend on mechanical forces or moving contacts for its operation but performs electronically. Thus, timing is very accurate even for currents as low as the pickup value. There is no mechanical contact bounce or arcing, and reset times are extremely short.
- Low input signal levels: Ideal for Telecommunication or microprocessor control industries. Solid state relays are fast becoming the better choice in many applications, especially throughout the telecommunication and microprocessor control industries.
- Cost Issues: In the past, there has been a rather large gap between the price of an electromechanical relay and the price of a solid state relay. With continual advancement in manufacturing technology, this gap has been reduced dramatically making the advantages of solid state technology accessible to a growing number of design engineers.

Limitations of static relays:

- Auxiliary voltage requirement for Relay Operation.
- Static relays are sensitive to voltage transients which are caused by operation of breaker and isolator in the primary circuit of CTs and PTs.
- Serious over voltage is also caused by breaking of control circuit, relay contacts etc. Such voltage spikes of small duration can damage the semiconductor components and also cause mal operation of relays.
- Temperature dependence of static relays: The characteristics of semiconductor devices are affected by ambient temperature.
- Highly sophisticated isolation and filter circuits are required to be built into the relay design to take care of electromagnetic interference and transient switching disturbances in the power system.
- Highly reliable power supply circuits are required.
- Effect of environmental conditions like humidity, high ambient temperature, dust accumulation on PCB leading to tracking.
- The component failure.
- Non availability of fault data.
- Characteristic variations with passage of time.

(A) Digital Relay:

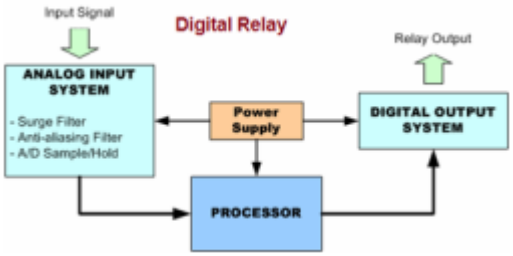
- **History of Relay:** Around 1980s the digital relay entered the market. Compared to the Solid State Relay, the digital relay takes the advantages of the development of microprocessors and microcontrollers. Instead of using analog signals, the digital relay converts all measured analog quantities into digital signals.
- Digital protection relays is a revolution step in changing Relay technology. In Digital Relay Microprocessors and micro controllers are used in replacement of analogue circuits used in static relays to implement relay functions. Digital protection relays introduced in 1980. However, such technology will be completely superseded within the next five years by numerical relays.
- By the mid-1990s the solid state and electromechanical relay had been mostly replaced by digital relay in new construction. In distribution applications, the replacement by the digital relay proceeded a bit more slowly. While the great majority of feeder relays in new applications today are digital, the solid state relay still sees some use where simplicity of the application allows for simpler relays, and which allows one to avoid the complexity of digital relays

- **Measuring principles:** Compared to static relays, digital relays introduce Analogue to Digital Convertor (A/D conversion) of all measured analogue quantities and use a microprocessor to implement the protection algorithm. The microprocessor may use some kind of counting technique, or use the Discrete Fourier Transform (DFT) to implement the algorithm.
- The Microprocessors used in Digital Relay have limited processing capacity and memory compared to that provided in numerical relays.
- **Function of Relay:** The functionality tends therefore to be limited and restricted largely to the protection function itself. Additional functionality compared to that provided by an electromechanical or static relay is usually available, typically taking the form of a wider range of settings, and greater accuracy. A communications link to a

Digital Relay

remote computer may also be provided.

- The limited power of the microprocessors used in digital relays restricts the number of samples of the waveform that can be measured per cycle. This, in turn, limits the speed of operation of the relay in certain applications. Therefore, a digital relay for a particular protection function may have a longer operation time than the static relay equivalent. However, the extra time is not significant in terms of overall tripping time and possible effects of power system stability.
- **Operation of Relay:** Digital relay consists of: (1) Analogue input subsystem, (2) Digital input subsystem, (3) Digital output subsystem, (4) A processor along with RAM (data scratch pad), main memory (historical data file) and Power supply



- Digital relaying involves digital processing of one or more analog signals in three steps: Conversion of analogue signal to digital form Processing of digital form Boolean decision to trip or not to trip

Advantages of Digital Relay:

- High level of functionality integration.
- Additional monitoring functions.
- Functional flexibility.
- Capable of working under a wide range of temperatures.
- They can implement more complex function and are generally more accurate
- Self-checking and self-adaptability.
- Able to communicate with other digital equipment (pear to pear).
- Less sensitive to temperature, aging
- Economical because can be produced in volumes

- More Accurate.
- plane for distance relaying is possible
- Signal storage is possible

Limitations of Digital Relay:

- Short lifetime due to the continuous development of new technologies.
- The devices become obsolete rapidly.
- Susceptibility to power system transients.
- As digital systems become increasingly more complex they require specially trained staff for Operation.
- Proper maintenance of the settings and monitoring data.

(B) Numerical Relay:

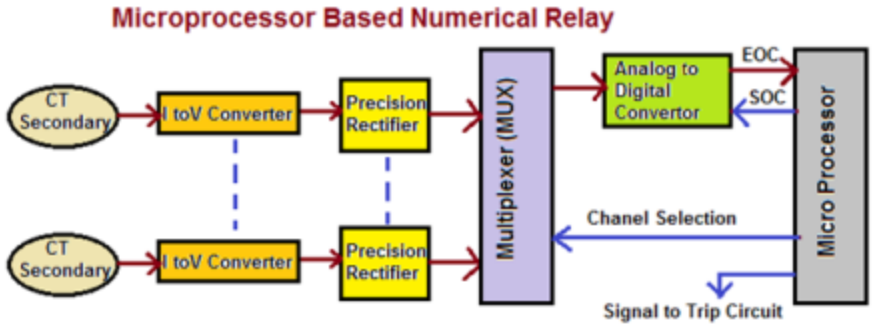
- **History of Relay:** The first protection devices based on microprocessors were employed in 1985. The widespread acceptance of numerical technology by the customer and the experiences of the user helped in developing the second generation numerical relays in 1990.
- Conventional electromechanical and static relays are hard wired relays. Their wiring is fixed, only their setting can be manually changed. Numeric relays are programmable relays. The characteristics and behaviour of the relay are can be programmed.
- First generation numerical relays were mainly designed to meet the static relay protection characteristic, whereas modern numeric protection devices are capable of providing complete protection with added functions like control and monitoring. Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information.
- **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.
- **Measuring principles:** The input analogue signals are converted into a digital representation and processed according to the appropriate mathematical algorithm. Processing is carried out using a specialized microprocessor that is optimized for signal processing applications, known as a digital signal processor or DSP for short. Digital processing of signals in real time requires a very high power microprocessor.
- The measuring principles and techniques of conventional relays (electromechanical and static) are fewer than those of the numerical technique, which can differ in many aspects like the type of protection algorithm used, sampling, signal processing, hardware selection, software discipline, etc. These are microprocessor-based relays in contrast to other relays that are electromechanically controlled.
- **Function of Relay:**Modern power system protection devices are built with integrated functions. Multifunction like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer.
- Traditionally, electromechanical and static protection relays offered single-function, single characteristics, whereas modern numeric protection offers multi-function and multiple characteristics.
- The measuring principles and techniques of conventional relays (electromechanical and static) are fewer than those of the numerical technique, which can differ in many aspects like the type of protection algorithm used, sampling, signal processing, hardware selection, software discipline, etc.

- First generation numerical relays were mainly designed to meet the static relay protection characteristic, whereas modern numeric protection devices are capable of providing complete protection with added functions like control and monitoring. Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information. Numerical protection devices are available for generation,transmission and distribution systems

Numerical Relay

- Numerical relays are micro processor based relays and having the features of recording of parameter used as disturbance recorder flexibility of setting & alarms & can be used one relay for all type of protections of one equipment hence less area is required. Wide Range of setting, more accurate, Low burden hence low VA of CT is required which minimize the cost. Numeric relays take the input analog quantities and convert them to numeric values. All of the relaying functions are performed on these numeric values.
- The following sections cover relay hardware, relay software, multiple protection characteristics, adaptive protection characteristics, data storage, instrumentation feature, self-check feature, communication capability, additional functions, size and cost-effectiveness.
- Numerical protection devices are available for generation, transmission and distribution systems. Modern power system protection devices are built with integrated functions. Multi-functions like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer.
- These relays provide great precision and convenience in application in the sophisticated electronic products. By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays. The disadvantages of a conventional electromechanical relay are overcome by using micro controller for realizing the operation of the relays. Micro controller based relays perform very well and their cost is relatively low
- Also, the communication capability of these devices facilitates remote control, monitoring and data transfer. Traditionally, electromechanical and static protection relays offered single-function, single characteristics, whereas modern numeric protection offers multifunction and multiple characteristics. Some protections also offer adaptable characteristics, which dynamically change the protection characteristic under different system conditions by monitoring the input parameters.
- Operation of Relay: A current signal from CT is converted into proportional voltage signal using I to V converter.
- The ac voltage proportional to load current is converted into dc using precision rectifier and is given to multiplexer (MUX) which accepts more than one input and gives one output.

- Microprocessor sends command signal to the multiplexer to switch on desired channel to accept rectified voltage proportional to current in a desired circuit.



- Output of Multiplexer is fed to analog to digital converter (ADC) to obtain signal in digital form. Microprocessor then sends a signal ADC for start of conversion (SOC), examines whether the conversion is completed and on receipt of end of conversion (EOC) from ADC, receives the data in digital form. The microprocessor then compares the data with pick-up value. If the input is greater than pick-up value the microprocessor send a trip signal to circuit breaker of the desired circuit.
- Incase of instantaneous over current relay there is no intentional time delay and circuit breaker trips instantly. In case of normal inverse, very inverse, extremely inverse and long inverse over current relay the inverse current-time characteristics are stored in the memory of microprocessor in tabular form called as look-up table.

Advantages of Numerical relays:

- **Compact Size:** Electromechanical Relay makes use of mechanical comparison devices, which cause the main reason for the bulky size of relays. It uses a flag system for the indication purpose whether the relay has been activated or not. While Numerical Relay is in Compact Size and use Indication on LCD for Relay activation.
- Digital protection can be physically smaller, and almost always requires less panel wiring than equivalent functions implemented using analog technology.
- **Flexibility:** A variety of protection functions can be accomplished with suitable modifications in the software only either with the same hardware or with slight modifications in the hardware.
- **Reliability:** A significant improvement in the relay reliability is obtained because the use of fewer components results in less interconnections and reduced component failures.
- **Multi Function Capability:** Traditional electromechanical and static protection relays offers single-function and single characteristics. Range of operation of electromechanical relays is narrow as compared to numerical relay.
- **Different types of relay characteristics:** It is possible to provide better matching of protection characteristics since these characteristics are stored in the memory of the microprocessor.
- **Digital communication capabilities:** The microprocessor based relay furnishes easy interface with digital communication equipments. Fibre optical communication with substation LAN
- **Modular frame:** The relay hardware consists of standard modules resulting in ease of service.
- **Low burden:** The microprocessor based relays have minimum burden on the instrument transformers.
- **Sensitivity:** Greater sensitivity and high pickup ratio.
- **Speed:** With static relays, tripping time of ½ cycle or even less can be obtained.
- **Fast Resetting:** Resetting is less.
- **Data History:** Availability of fault data and disturbance record. Helps analysis of faults by recording details of (1) Nature of fault, (2) Magnitude of fault level, (3) Breaker problem, (4) C.T. saturation , (5) Duration of fault.

- **Auto Resetting & Self Diagnosis:** Electromechanical relay do not have the ability to detect whether the normal condition has been attained once it is activated thus auto resetting is not possible and it has to be done by the operating personnel. while in Numerical Relay auto Resetting is Possible
- By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays
- Separate connection is not required, zero sequence voltages and currents can be derived inside the processor
- Basic hardware is shared between multiple functions, the cost of individual protection functions can be reduced significantly.
- Loss of voltage feature helps block the relay in case of momentary/permanent loss of voltage.

Limitations of Numerical Relay:

- Numerical Relay offers more functionality, and greater precision. Unfortunately, that does not necessarily translate into better protection.
- Numerical Relay can make faster decisions. However, in the real world, faster protection itself is of no value because circuit breakers are still required to interrupt at the direction of the protective equipment, and the ability to make circuit breakers interrupt faster is very limited.
- Numerical Relay protection often relies on non-proprietary software, exposing the system to potential risk of hacking.
- Numerical Relay protection sometimes has exposure to externally-sourced transient interference that would not affect conventional technology.
- Numerical Relay protection shares common functions. This means that there are common failure modes that can affect multiple elements of protection. For example, failure of a power supply or an input signal processor may disable an entire protective device that provides many different protection functions. This problem has receive a lot of design attention, and experience generally has supported the notion that the equipment has a very high reliability once it is past the infant mortality stage. But it remains something to be aware of.
- A multifunction numeric relay can provide three phase, ground, and negative sequence directional or non-directional over current protection with four shot recloser, forward or reverse power protection, breaker failure, over/under frequency, and over/under voltage protection, sync check, breaker monitoring and control, It would take 10 – 11 single function Solid State or Electromechanical relays at least 5 to 6 times the cost. Additionally Numeric relays have Communications capabilities, sequence-of-events recording, fault reporting, rate-of-change frequency, and metering functions, all in an integrated system.

Comparison of Different Type Relay:

Characteristic	**Electro Mechanical Relay**	**Static Relay**	**Digital Relay**	**Numerical Relay**
Technology Standard	1st generation Relays.	2nd generation Relays.	Present generation Relays.	Present generation Relays.

Operating Principle	They use principle of electromagnetic principle.	In this relays transistors and IC's r been used	They use Microprocessor. Within built software with predefined values	They use Microprocessor. Within built software with predefined values
Measuring elements/ Hardware	Induction disc,Electromagnets, Induction cup, Balance Beam	R, L, C, Transistors, Analogue ICs comparators	Microprocessors, Digital ICs, Digital Signal Processors	Microprocessor s,Digital ICs, DigitalSignal processors
Measuring method	Electrical Qtysconverted intomechanical force, torque	Level detects,comparison withreference value in analogue Comparator	A/D conversion,Numericalalgorithm techniques	A/D conversion,Numericalalgorithm techniques
Surrounding Environment	Depend upon gravitation and the value changes to the surrounding magnetic fields also.	There value may vary with respect to temperature also.		
Relay Size	Bulky	Small	Small	Compact
Speed of Response	Slow	Fast	Fast	Very Fast
Timing function	Mechanical clock works, dashpot	Static timers	Counter	Counter
Time of Accuracy	Temp .Dependant	Temp. Dependant	Stable	Stable

Reliability	High	Low	High	High
Vibration Proof	No	Yes	Yes	Yes
Characteristics	Limited	Wide	Wide	Wide
Requirement of Draw Out	Required	Required	Not Required	Not Required
CT Burden	High	Low	Low	Low
CT Burden	8 to 10 VA	1 VA	<0.5 VA	<0.5 VA
Reset Time	Very High	Less	Less	Less
Auxiliary supply	Required	Required	Required	Required
Range of settings	Limited	Wide	Wide	Wide
Isolation Voltage	Low	High	High	High
Function	Single Function	Single Function	Multi Function	Single Function
Maintenance	Frequent	Frequent	Low	Very Low
Resistance	100 mille ohms	10 Ohms	10 Ohms	10 Ohms

Output Capacitance	< 1 Pico Farad	> 20 Pico Farads	> 20 Pico Farads	> 20 Pico Farads
Deterioration due to Operation	Yes	No	No	No
Relay Programming	No	Partially	Programmable	Programmable
SCADA Compatibility	No	No	Possible	Yes
Operational value indication	Not Possible	Possible	Possible	Possible
Visual indication	Flags, targets	LEDs	LEDs, LCD	LEDs, LCD
Self monitoring	No	Yes	Yes	Yes

Parameter setting	Plug setting, dial setting	Thumb wheel,dual in line switches	Keypad for numeric values,through computer	Keypad for numeric values,through computer
Fault Disturbance Recording	Not possible	Not possible	possible	possible

Relay’s Nomenclature as per ANSI:

No	**Type of Relay**
2	Time delay relay
3	3 Checking or Interlocking relay
21	21 Distance relay
25	Check synchronizing relay
27	Under voltage relay
30	Annunciation relay
32	Directional power (Reverse power) relay
37	Low forward power relay
40	Field failure (loss of excitation)

46	Negative phase sequence relay
49	Machine or Transformer Thermal relay
50	Instantaneous Over current relay
51	A.C. IDMT Over current relay
52	Circuit breaker
52a	Circuit breaker Auxiliary switch “Normally open” (‘a ‘contact)
52b	Circuit breaker Auxiliary switch “Normally closed” (‘b’contact)
55	Power Factor relay
56	Field Application relay
59	Overvoltage relay
64	Earth fault relay
67	Directional relay
68	Locking relay
74	Alarm relay
76	D.C Over current relay
78	Phase angle measuring or out of step relay
79	AC Auto reclose relay
80	Monitoring loss of DC supply
81	Frequency relay

81 U	Under frequency relay
81 O	Over frequency relay
83	Automatic selective control or transfer relay
85	Carrier or pilot wire receive relay
86	Tripping Relay
87	Differential relay
87G	Generator differential relay
87G	T Overall differential relay
87U	UAT differential relay
87NT	Restricted earth fault relay
95	Trip circuit supervision relay
99	Over flux relay
186A	Auto reclose lockout relay
186B	Auto reclose lockout relay

Relays for Transmission & Distribution Lines protection:

No	Line	Protection
1	400 KV Transmission Line	Main-I: Non switched or Numerical Distance Scheme
		Main-II: Non switched or Numerical Distance Scheme

2	220 KV Transmission Line	Main-I : Non switched distance scheme (Fed from Bus PTs)
		Main-II: Switched distance scheme (Fed from line CVTs) With a changeover facility from bus PT to line CVT and vice-versa
3	132 KV Transmission Line	Main Protection: Switched distance scheme (fed from bus PT).
		Backup Protection: 3 Nos. directional IDMT O/L Relays and 1 No. Directional IDMT E/L relay.
4	33 KV Lines	Non-directional IDMT 3 Over Current and 1 Earth Fault relays
5	11KV Line	Non-directional IDMT 2 Over Current and 1 Earth Fault relays

Reference:

- Handbook of Switchgear –Bhel
- Digital/Numerical Relays -T.S.M. Rao

Source: http://electricalnotes.wordpress.com/2012/12/01/types-and-revolution-of-electrical-relays/