

A Review on Protection of Transmission Lines

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Abstract: The growth of a country is scaled by the amount of energy it consumes. In the developing India, with the rise of population, increasing number of cities and demanding villages, caused to set up transmission lines with higher capacity. Inter-ties were connected through the transmission lines to lighten every city and village, thus making the whole system complex. This complex system required a robust protection, so that a fault in one place does not cause the unfaulted region to trip or series of trip undesirably, which may otherwise cause a situation of blackout. To protect the power system, we use protective relays-electromechanical, solid state or microprocessor relays. In this paper, different types of protections are discussed. The traditional protection schemes requiring a communication between two ends are discussed which include directional comparison blocking (DCB), permissive overreaching transfer trip (POTT), International Electrotechnical Commission (IEC) – 61850 to protect a transmission line using Generic Object Oriented Substation Events (GOOSE) messaging. At the process and station control levels, IEC 61850 define the rules for integration of protection, control, measurement and monitoring functions within a power system network. Successful tests were done by various manufacturers and utilities for substation automation using IEC 61850 proving enhanced interoperability between vendors and systems and elimination of substation wiring. Thus endeavors are now being directed to cover substation to control center and substation to substation automation using IEC-61850.

Keyword: International Electrotechnical Commission, permissive overreaching transfer trip, Generic Object Oriented Substation Events.

I. INTRODUCTION

The deregulation of electricity has brought new suppliers into the electricity market resulting the power system be operating close to its peak limits which requires good protection against any faults.

In section II, electromechanical relays and microprocessor based relays are discussed. In section III, different types of protection scheme are discussed. Section IV explains the communication schemes available for the protection of more critical transmission lines. In section V, International Electrotechnical Commission (IEC) 61850 and GOOSE messaging advantages are discussed.

II. ELECTROMECHANICAL RELAY

Relays are designed to make and break a connection, thus, we can construct Normally-open or Normally-closed connections to achieve desired results. In electromagnetic relays, electricity passes through a coil that induces magnetism which is the driving force to make or break a connection. Electromagnetic relays could work on two principles [1] – 1) electromagnetic attraction 2) electromagnetic induction. In electromagnetic attraction, the armature is wound with the actuating coil which magnetizes the movable armature and the polarity is developed in such a direction that it closes the contacts if current flows in one direction and stays open if the current flows in other direction [1]. In electromagnetic induction, the driving force is a movable rotor working on a.c. quantities.

Microprocessor relays receive the currents and voltage signals from the power system and acts according to the software and parameters fed to it. The current and voltage signals are periodically sampled, filtered and passed through an analog to digital converter [2].



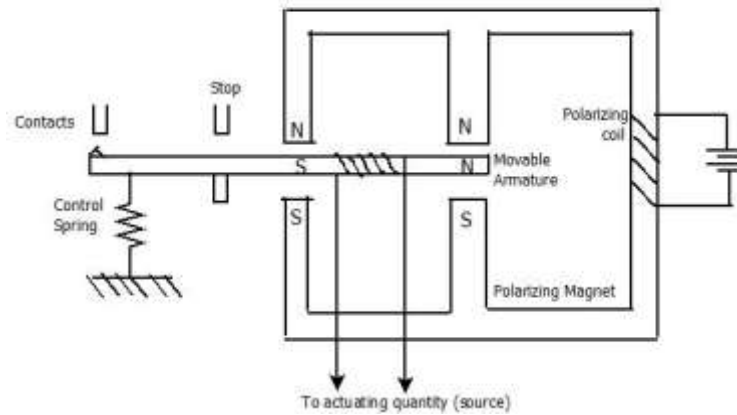


Figure1: Electromechanical attraction type relay [1]

III. PROTECTION SCHEMES

A. Distance Protection

Distance protection is very easy to implement, so, it is widely used in power systems to protect transmission lines. Distance protection operates if the calculated impedance by the microprocessor relay is less than the minimum fault impedance value fed to the relay. The relay calculates this value of impedance through measurements of voltage and current. In situation of fault in the power systems, the voltage drops down whereas amount of current flowing rises. Thus the impedance measured by the relay drops too, as $Z=V/I$, where Z =impedance, V =voltage and I =current. The distance protection has operating characteristics of circle on the R-X plane.

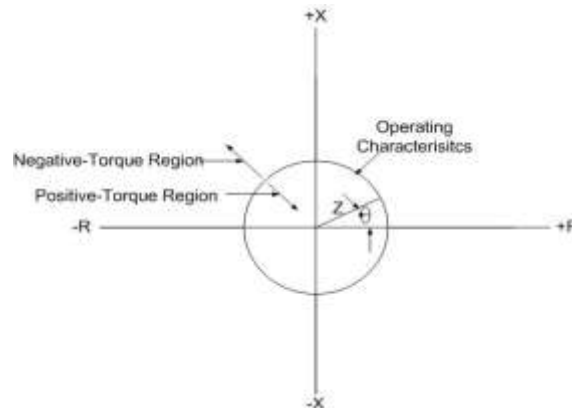


Figure 2: Impedance Relay operating characteristics [1].

B. Differential Protection

Kirchoff's current law forms the basis for the differential protection. It says that current entering a point should be equal to current leaving that point. If they are unequal, there must be some kind of fault at that point. Thus differential protection looks for the amount of current entering the protected object (could be a transmission line, transformer, etc) and leaving it. Since, differential relays require both values of current entering and leaving to make a correct decision about the state of the power system, so we cannot implement differential protection beyond the switchyard. But, this problem is overcome by the use of pilot wires in case of transmission lines. Now along with the pilot wires, fiber optics is also used to send the signal from remote end to the relay to make correct decision.



C. Overcurrent Protection

Whenever there is current in excess to the preset value fed to the relay (called pick-up value of current), it operates. This kind of relay is called overcurrent relay [3]. Overcurrent relays can be easily applied to motors, transmission lines, generators and transformers. Depending upon the time-current characteristics, overcurrent relay are classified into definite-time overcurrent relay, instantaneous overcurrent relay, inverse-time overcurrent relay, inverse definite minimum time overcurrent relay, very inverse-time overcurrent relay, extremely inverse-time overcurrent relay [3].

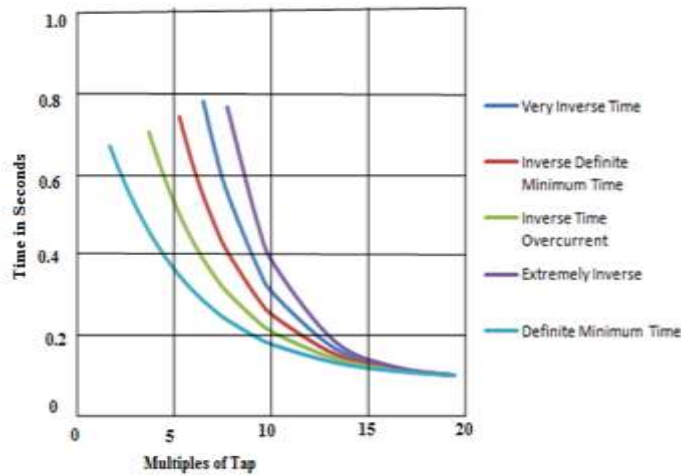


Figure 3: Inverse time overcurrent characteristics [2].

IV. COMMUNICATION SCHEMES

Distance protection protects the transmission line in zones. So, the remote end of the line is protected time delayed. Differential protection cannot be implemented over wide distances. So, communication schemes are used to get the information from the remote end and such schemes are called pilot protection schemes or communication assisted schemes. Examples of pilot protection schemes are Directional Comparison Blocking, Permissive Overreaching Transfer Trip, Permissive underreaching transfer trip.

A. Directional Comparison Blocking (DCB)

In DCB scheme, power flow direction is compared at the terminals. If the power flow is observed to be flowing into the line i.e. internal faults, the high speed tripping is permitted. If the power flow is observed to be flowing in and going out at other terminal i.e. for external faults, the tripping is blocked. DCB is explained in the figure4 given below:

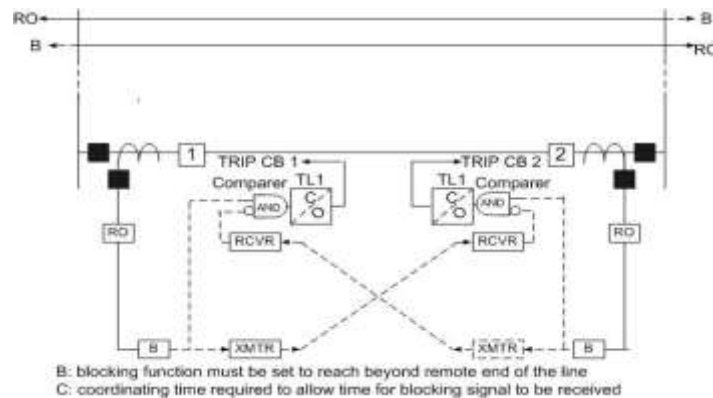
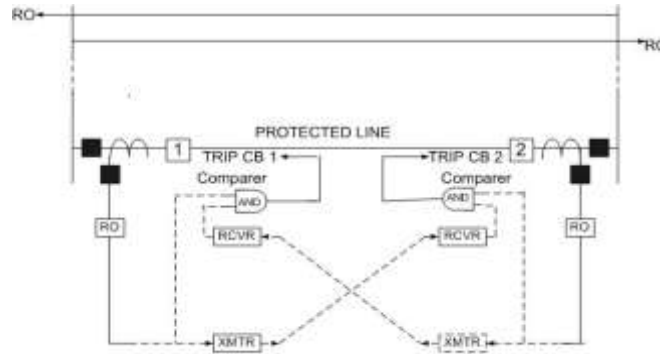


Figure 4. Directional Comparison Blocking scheme [4]



B. Permissive Overreach Transfer Trip (POTT)

POTT scheme operates for internal faults and blocks for any external fault. For POTT scheme to operate overreaching element of the relay must see the fault and should receive a trip signal from the remote end.



RO: overreaching trip function, must be set to reach beyond end terminal
 Figure 5. Permissive Overreach Transfer Trip scheme [4]

V. INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) 61850

Different manufacturers of relays use their proprietary protocols which creates problem for protection engineer, since, a protection engineer has to use a third party software to make two different brand relays to talk to each other, which is a difficult task and an added cost. IEC 61850 standardizes the organization of data by set of standard model structures for data and rules defining how to exchange the data [5, 6]. IEC61850 ‘abstracts’ the data model i.e. it keeps the data model independent of the communication systems which assists to achieve interoperability and makes the standard more flexible to future advancements.

A. Generic Object Oriented Substation Event (GOOSE) Messaging

IEC 61850 uses two types of multicast messaging techniques GOOSE and GSSE. GSSE is binary only whereas GOOSE can support both binary and analog values. In order to multicast the GOOSE messages, the addressing layer is removed. This reasons why GOOSE messages are not routable and cannot be send through a Wide Area Network (WAN). It can be routed inside a Local Area Network (LAN) because the network address is a group address and not a specific device address [5].

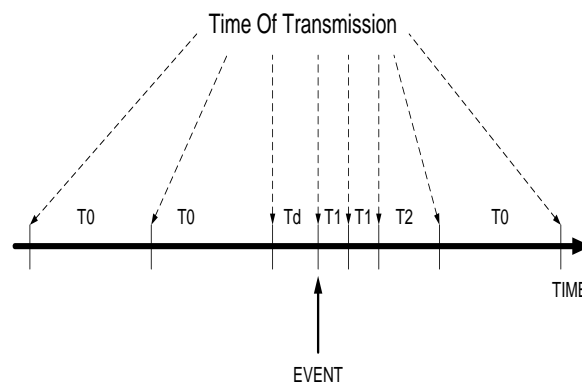


Figure 6. Example for time change between GOOSE message publications.

The Figure 6 shows GOOSE message is given a parameter max time (mt) to wait between message publications. In present case $mt = T_0$. As soon as there is a change in data set, the messages are published very frequently and the time of transmission (tot) is 4 milliseconds [5]. The messages are sent very frequently to increase the probability that all subscribers receive them. After the initial rapid publications, the tot increases till it reaches the normal publication time of mt.

Publisher calculates time to live (ttl) for every message, based on the next tot. ttl is 2(tot) when tot is equal to T0 and ttl is 3(tot) when tot is other than T0. Subscribers constantly calculate time to wait (ttw) based on ttl. Subscribers declare the data “stale” if the ttw expires and they did not receive new message from the publisher. It then assumes that communication is lost and modifies its relay logic accordingly [5].

To reduce the burden on the LAN because of the constantly multicast of GOOSE messages two techniques are used. First is the Virtual LAN (VLAN) and the other is Priority Tagging. VLAN isolates network traffic from different departments inside one enterprise whereas GOOSE messages can be tagged from 0 to 7 according to the priority requirement. The default GOOSE message is given a priority level of 4. Trip messages are set at high priority.

CONCLUSION

In this paper, electromechanical and microprocessor based relays were discussed. Now microprocessor based relays are replacing the electromechanical relays, but, it is advantageous for protection engineer to know the working of electromechanical relays. Distance protection, differential protection and over current protection forms the basic protections that are used in any substation or generating plant. Communication schemes are necessary to have 100% of the transmission line protected. Various other factors like security and dependability needs to be considered before implementing any pilot protection.

IEC-61850 is now being implemented in most substations because of its flexibility to implement interoperability of different vendor relays. GOOSE messaging can provide instantaneous information of the power system for control, metering and protection purposes.

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