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Pilot Communication Channels in Power System Protection

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***Abstract-* This Paper explores Pilot protection System by providing background details on Communication channel in pilot protection, Justification of Pilot Protection on Transmission Lines, Protection schemes, settings and parameters, thereby given reason for chosen pilot protection technique and different zones of operation. The paper could serve as a tool for protection engineers to assist in determining when pilot protection should be installed for transmission line protection, in addition to a communications independent system.**

I. INTRODUCTION

Pilot protection schemes use communication channels to send information from the local relay terminal to the remote relay terminal, thereby allowing high-speed tripping for faults occurring within the protected line. The term 'pilot' refers to a communication channel between two or more ends of a transmission line to provide instantaneous clearing over the whole length of the line. Communication channels typically used include power line carrier, microwave, fibre optic, and communication cable.

Pilot protection for lines provides possibilities for high speed simultaneous detection of phase and ground faults protection for the whole line segment being protected from all terminals. It is a type of protection for which quantities at the terminals are compared by a communication channel rather than by a direct wire interconnection of the relay input devices [1]. The increment in time delays when using distance relays becomes impractical, because of the distance between several terminals. Pilot protection offers increased certainty when a fault is present in a system. Implementation of pilot protection in transmission systems is widely used because of its adaptability. Thus, pilot protection does not require any coordination with protection in the adjacent system unless additional backup is included.

This is especially important in extra high voltage (EHV) circuits because of a considerable system disturbance that occurs when a heavy load line is opened. For the protection system, the relaying system must be selective and precautions are taken to ensure no operations are initiated by the relay logic or other means that would cause tripping of important lines or other facilities when not absolutely necessary. Thus, pilot protection is an adaptation of differential relay principles that avoid the use of control cables between terminals.

II. COMMUNICATION CHANNEL IN PILOT PROTECTION

The development of modern optical fiber communication technology has become increasingly popularized due to its long-distance, large-capacity, high-speed, and real-time synchronous data transmission. Fiber optic communication is applied in power protection because the appearance of digital communication technology makes information exchange reliable and fast. Hence, proposes the construction of an intercommunicated protection system. Pilot protection can improve relay reliability with communications between protections schemes. Fiber optic-based communications in pilot protection systems can detect faults more rapidly with a low time delay. With the implementation of fiber optics, information exchange is not limited to the digital state value. A variety of information exchange by the same communication channel provides sufficient information. Pilot protection can be implemented with distance relays, which distinguish internal and external fault by comparing fault direction of fault distance on both sides. The information exchange is logical instead of analog quantities [2]. Therefore, in a pilot protection system, protection Intelligent Electronic Device (IED) on each side of a transmission line collects information and calculates fault direction, fault distance, and other parameters based on local information and then send the results to the IED on the opposite side.

The information exchange is voltage and currents values, protection start-up signal, fault direction, and distance information, fault phase selection information, and breaker status. Reference concludes that, besides providing better reliability and rapid communication, the digital communication channel also provides the possibility for various and large amounts of synchronous electrical information exchange. With the aid of an optical digital channel, multiple protection criteria can be executed to improve the operation performance of traditional pilot protection system which can complete various functions such as relaying protection, auto reclosing, measurement of transmission line parameters, and more functions within the unified pilot protection.

Pilot protections based on fiber communication technology have become one of the primary forms of transmission line. Consequently, many of these configurations rely on differential protection, but problems such as low sensitivity or poor reliability because of CT saturation and influence of large charging current because of line distributed capacitance for long transmission lines arise when implementing differential protection. These complications are seriously impairing and threatening to the speed and sensitivity of conventional current differential protection. To reduce CT saturation and line distributed capacitance, an Enhanced Transmission Line Pilot Impedance (ETLPI) scheme is adopted [3]. ETLPI is defined as the ratio of voltage difference of fault-superimposed components at both terminals of the protected line, which can be calculated from real-time voltages and currents measurements synchronously transmitted from local terminal to remote terminal. When this model is implemented, the amplitude of ETLPI is greater than the amplitude of the positive sequence impedance of the protected segment of the line. ETLPI also effectively avoids distributed capacitances and CT saturation. Therefore, this scheme may suit larger transmission lines.

III. JUSTIFICATION OF PILOT PROTECTION ON TRANSMISSION LINES

The protection zone for a transmission line is unique because the zone limits generally extend to geographically separate locations. In addition to their relay sources, elements entirely at one location can have instantaneous tripping configured. In order to affect high speed tripping for 100% of a transmission line, each terminal of the protected line must communicate with the other terminal(s) in some way.

When pilot protection is evaluated for implementation, its goal is to improve system stability by fault clearing in the shortest amount of time. From the perspective of electric utilities, clearing time reduction improves stability, reduces equipment damage, and improves power quality in addition to providing quality service.

IV. PROTECTION SCHEME

a) Permissive Overreaching Transfer Tripping Scheme

In the Permissive Overreaching Transfer Tripping (POTT) scheme, a distance element is set to reach beyond the remote end of the protected line to send a signal to a remote end. However, the received relay contact must be monitored by a directional relay contact to ensure that tripping does not occur unless the fault is within the protected section.

In Fig 2, the contacts of Zone 2 are arranged to the signal, and the received signal, supervised by Zone 2 operation, is used to energize the trip circuit. The scheme is known as a POTT. Since the signalling channel is keyed by overreaching Zone 2 elements, the scheme requires duplex communication channels [4].

To prevent the relay from operating under current reversal conditions in parallel feeder circuit, a current reversal guard timer must be used to restrain tripping of the forward Zone 2 elements. Otherwise, malfunction of the scheme may occur under current reversal conditions. It is necessary only when the Zone 2 reach is set greater than 150% of the protected line impedance [2].

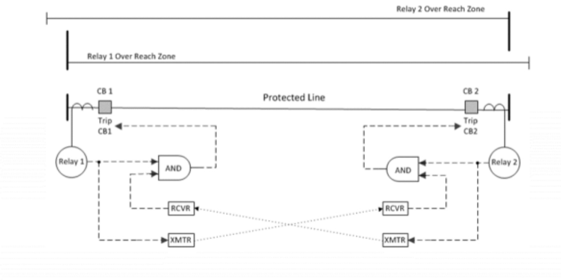

Fig 1: Permissive Overreaching Transfer Tripping (POTT) Scheme

b) Pilot schemes

The non-pilot protection schemes have usually an acceptable performance on short or medium lines. However, for long lines which are mostly operating in EHV or UHV levels and transmitting large electric power, the tripping time delays would cause severe network stability problems due to the system acceleration. Also the huge fault currents could cause dramatic damages for equipment. In such cases, more complex transmission line protection schemes are required in order to perform a high speed tripping in both ends of the line.

An alternative protective scheme which has been in use for protection of EHV/UHV transmission lines, utilizes local information, as well as remote information for a relaying decision. In this category known as "pilot protection schemes "the relays installed at terminals, as shown in Figure 2, are able to make a common decision about tripping the line in case of fault inceptions inside the protection zone [5].

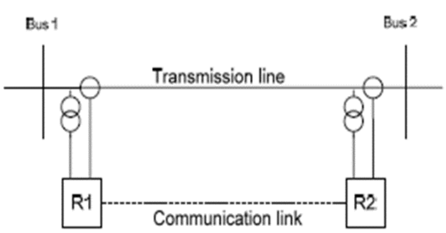

Fig 2: single line diagram of pilot protection scheme for transmission line

The integrated communication system in pilot protection schemes usually uses analog or digital signals transmitting in DC or AC power frequencies or in higher frequency bands such as:

- Audio frequencies of approximately from 20 to 20000 Hz,
- Power line carrier frequency in the range from 30 to 600 kHz,
- Radio frequencies with practical limits of roughly 10kHz to 100,000MHz,
- Microwave frequency bands loosely applied to radio waves from 1000 MHz,
- Visible light frequencies with nominal wavelength range of about 0.3μm - 30μm.

In pilot protection schemes depending on quantities which are communicated and used in relay decision making, as illustrated in Figure 2, the schemes belonging to this group can be classified in two following major subgroups:

Unit pilot protection schemes are sometimes also referred to as "analog comparison protection" or "closed" schemes. In these schemes analog quantities such as amplitude and/or phase information of power system in one end is compared with the other end.

Two important unit pilot protection schemes are identified as longitudinal differential and phase comparison schemes. In such schemes the main communicated information between the ends of the protected line are either amplitude and/or phase data of the transmission line components.

In case of an internal fault the result of the compared data will be a differential value and for specific threshold values the relays in both terminals perform a relaying operation. Since there is an instantaneous comparison between the analog values, the information acquired from both relays needs to be time synchronized to guarantee the comparison of measured data at same time instants from both ends.

i) Longitudinal Differential Scheme

The operation principle of the relay is expressed by Kirchhoff's first law that says: "the sum of the currents flowing to a node must be equal with the sum of the currents leaving the same node".

In external faults the same current is entering to protected zone and leaving it from the second end. But in case of internal fault the current entering the protected zone is not equal to the current which is leaving the same zone. Therefore, this principal could be utilized in directional protection schemes for protection of transmission lines.

ii) Phase Comparison Scheme

In a phase comparison scheme the relay is able to distinguish an internal inception of the fault on protected transmission line by comparing the current phase angle at one end with current phase angle at the second end. Where in case of the internal faults there will be a notable phase difference. However, incorrect operation of the relay can happen by changing the system configuration which may affect the polarity of the quantities used for directional comparison.

Non-unit pilot protection schemes are sometimes also referred to as "state comparison protection schemes" or "open system" schemes [5] [6]. In these schemes direct comparison of measurements is not performed between two ends and only logical status related to fault information is exchanged between protective relays located at each end of transmission line.

V. POTT SCHEME SETTINGS AND PARAMETERS

This section presents the parameters, settings, and zones of the POTT scheme of various protection zones. Figure 3 shows one line diagram simplified and its different zones of protection. In this case, three zones of protection are evident, two of which are forward looking and the remaining one is backward looking.

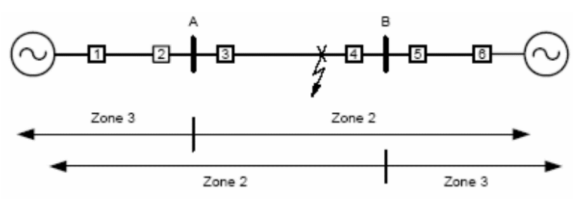

Fig 3: three distance zones and their directions POTT scheme

In the three protection zones, the first zone is instantaneous protection and is set at 90% percent of the total length of the transmission line. The second zone is set at 120% percent of the total length of the transmission line, overreaching the bus, and the third zone is set to protect 20% of the transmission line backward looking. Table 1 outlines protection zones for the POTT scheme [5].

Table 1: protection zone

Zone 1	Forward Looking	90% of the Line Instantaneous Protection
Zone 2	Forward Looking	120% of the Line comm. assisted with Time Delay
Zone 3	Backward Looking	20% of the Line With Time Delay

CONCLUSION

Piloted Schemes which are based on communication between two or more relays, and the relaying decision is based on the mutual decision of these relays. In the most simplistic case, each end of the transmission/distribution line is equipped with a relay. Therefore, each end has one local relay that communicates with at least one remote relay

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