Recent Trend in Pilot Based Power Transmission and Distribution Protection

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Abstract -- The development of protection schemes for transmission and distribution lines began more than a hundred years ago, with voltage restrained time over current relay being one of the more prominent attempts in history. However, phase and neutral overcurrent protection, in its simplest forms, offered a significant disadvantage for line protection because its fault coverage of the protected circuit is dependent on source impedance variations. Since then, the line protection schemes have faced undeterred evolution, which essentially provides a rather simplistic and more efficient protection schemes available today.

Indexed Terms: pilot, protection, transmission, distribution

I. INTRODUCTION

Transmission and distribution systems are considered to be two essential subsystems of an electrical power system. Transmission grids supply the electric energy generated by the generation unit to the sub-transmission and distribution grids connected to the respective consumers. Since the core responsibility of the entire electrical power system is to ensure reliable supply of electricity to the consumers, the role of transmission and distribution grids is invaluable. [1,2] Transmission and distribution lines serve as the primary mode of fulfilling the operative demands of their respective grids. These lines are most commonly found in the form of over-head lines. However, the promotion of idea to preserve the aesthetic nature of the environment in recent times and long-distance offshore energy transfer due to development of large offshore wind farms has increased the employment of underground and undersea cables. The more common method of electricity transfer includes a combination of both Over- head lines and cables. [3,4].

The exposure of transmission and distribution lines to the environment makes them susceptible to highest fault incidence fault rates in the electrical network. These faults do not originate only due to the natural phenomena like lightning strikes, storms, breakage of overhead lines conductors due to icing and intrusion of vegetation, but can also arrive as a result of human negligence [5].

In order to ensure reliable operation of the entire power system and minimal equipment damage, these faults must be accurately detected, isolated and cleared within a short period.
Failure to which can result in stability issues, especially in transmission grids, which can even lead to total system blackout in the worst case [6]

II. PERFORMANCE OF MODERN PILOT PROTECTION SCHEMES

Communication-based protection schemes provide high-speed, reliable and simultaneous clearing of faults along the entire line [7]. According to an IEEE survey [3], directional comparison distance protection schemes, which utilized both current and voltage information, were considered to be the most widely employed communication-based transmission line protection scheme in North America until the late 1980's. This trend slowly shifted towards other methodologies including phase-comparison and conventional current-Differential schemes with the developments in the field of communication systems and hardware processing speeds [6]. Over the last two decades, the protection of high-voltage transmission lines has been performed by simultaneously using multiple relaying principles to ensure secure and reliable operation of power systems[5].

The performance of piloted protection schemes severely depends upon the execution of the communication system and the employed methodology. Current-based line differential protection or phase comparison methods, although more accurate than the distance protection, are greatly influenced by the performance of communication system such as channel asymmetry, data insecurity and latency, since these schemes require transfer of actual pharos quantities. [8]

The directional comparison scheme, which is apparently less-dependent on communication system performance, has evolved significantly since the 1980's due to development of ultra-high speed protection [5]. The protection of transmission and distribution lines require quick fault detection, while accurate and fast distance and direction estimation are also essential in modern relays. The principle of operation of modern directional digital relays can usually be classified into two categories, these include:

- Power frequency components based methods; this method has been widely used in traditional protection practices including voltage-based, sequence current components-based, distance approximation based principles, etc.

- Transient signals-based methods; this method is utilized by ultra-high speed protection, either based on travelling waves or superimposed components-based methods.

III. METHODOLOGY OF PILOTED SCHEMES

These schemes are widely employed in protection of long lines because the complexity of non-piloted protection schemes, which is required to offer reliable operation for long lines, restricted their application. Whereas, availability of information from all line terminals allow spilot protection scheme to perform high-speed simultaneous fault clearing. Fig. 1 presents the scheme's methodology in its simplest form.

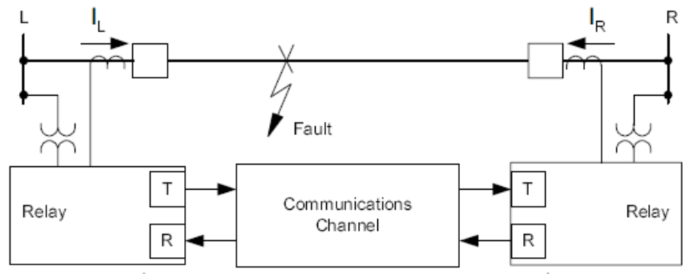

Figure 1 Methodology of Piloted Protection Scheme

Traditionally, pilot wires, power line conductors and microwave radio channels have served as the communication channels for piloted schemes [2]. The Emergence of fiber-optics in late1980's revolutionized the market for this scheme because of its inherent broad bandwidth, high signal to noise ratio (SNR), minimal electrical induction and no electrical insulation problems[7]. The recent researches are evaluating the feasibility of using long-distance wireless communication channels. The data that is transferred over the communication path might bereal-time sampled values, phasors or logical decisions [1].

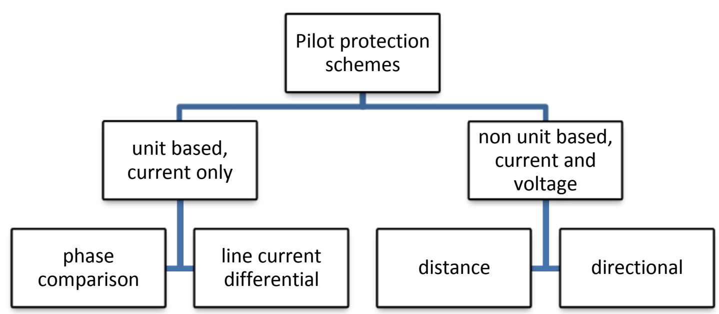

Fig 2: Components of modern pilot Protection schemes

Components of modern pilot protection schemes are presented in fig 2, Piloted Schemes were divided in to two categories:

1) Non-Unit Based, Current and Voltage protection schemes: As the term non-unit suggests, these schemes do not require comparison of the locally and remotely measured quantities before reaching a decision. The only data that is transferred over the channel is discrete and logical, usually trip and block commands or fault direction. Reference [2] uses the

terms 'state-comparison protection scheme' and 'open system 'for this scheme. It must be noted that the relays based on this scheme always require the complete terminal information (i.e. current and voltage) before reaching the relevant decision.

a) Distance Protection Schemes: These schemes improve the non-piloted distance protection and eliminates the inherent time delays associated with it by allowing permissive tripping or blocking signals to the subsequent relays. The concept is called permissive transfer tripping (under and over reach) and blocking. This allows instantaneous detection and communication of faults in Zone 2 and 3 of Fig 3.However, the application is limited to fault detection only because the actual clearance of zone 2 and 3 is performed unless the fault time equals the zone time settings, in order to ensure system selectivity [9,2].

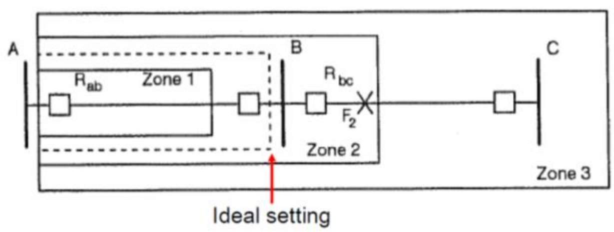

Figure 3 Zones for Distance Protection Schemes [1]

b) Directional Protection Schemes: These schemes utilize both the current and voltage information of the local terminal to detect the fault and determine its direction. The direction is then transmitted to the remote terminal which then compares it with the direction of fault determined by its own relay and takes necessary measures. These schemes have been the most widely used pilot protection scheme [3], particularly because of following reasons:

- Limited channel requirement: The transferred data is usually discrete and logical which limits the required channel bandwidth.
- Inherent redundancy of directional and distance protections.
- Fault resistance coverage is better [7]
- Channel delay/asymmetry etc. are not as critical (as compared to unit based schemes)
- Offers better tolerance against CT Saturation

However, the following critical restrictions must be acknowledged:

- This scheme requires voltage information of each terminal, which restricts its application in distribution and even some sub-transmission networks.
- Problems associated with voltage transformers (VTs): loss of potential foreclose-in faults and other problems such as blown potential fuses, Ferro resonance in VTs and transients in CVTs)
- Sensitivity may be limited because of system unbalance and CT/VT errors.

2) Unit Based, Current only protection schemes: These schemes perform actual

Comparison of the measured quantities (usually amplitude, phase of current or complete current phasors) of the local and remote ends before a relevant decision has been reached. The logical decision achieved by each local relay may or may not be transferred to the respective remote relay. These schemes often require only the current information to reach the correct decision and they are essentially based on differential protection principle. The tripping action is performed if the differential value of the compared quantity (current magnitude or phasors) crosses the set threshold. In order to perform this comparison the real time sampled values of the respective quantities are transferred over the channel; which signifies the importance of sizable communication channels [7,9].

a) Line Current Differential Protection: This scheme follows the conventional differential protection principle which is based on Kirchhoff's current law and compares the amplitude of the terminal currents.
b) Phase Comparison Schemes: The current phases of the remote and local

Terminals are compared in these schemes.

This scheme has the following advantages:

- Better performance for complex faults (evolving, cross-country and inter circuit faults)
- Less affected by variation in line loading [2]
- Better performance than non-unit based protection for series-compensated lines,

power swings, current reversals, zero sequence mutual induction effects, multi terminal operation, short transmission lines etc.

- Doesn't require voltage (therefore all VT related problems resolved)
- Extremely sensitive in detecting earth faults, advantage over distance protection, especially for short lines [7]
- Immune to series compensation related applications.

However the scheme is associated with the following prominent drawbacks:

- Exchanges digital info (phasor, Fourier coefficients etc.) which increases the BW requirement of the communication path [7].
- Data alignment/synchronization of measured signals is required.
- False differential current in line differential application [10,1] caused by:

i. Line Charging current (cables and long overhead lines) and Tapped load
ii. Channel time-delay
iii. CT saturation

It must be noted that a reliable communication path is extremely critical for proper operation of current based differential protection schemes, [11] and redundant solutions must always be present (E.g. Distance Relays, which would require Potential Transformer)

IV. 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.

Piloted protection schemes offer significant improvement in performance in terms of speed, security, and selectivity, which advocates the employment of these schemes for critical HV and EHV long transmission lines. The only restrictions are limited to communication issues including channel asymmetry, communication latency and data insecurity

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