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A DESIGN OF PROTECTION SCHEMES FOR AC TRANSMISSION LINES CONSIDERING A CASE STUDY

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ABSTRACT

Transmission line protection is an important issue in power system engineering because 85-87% of power system faults are occurring in transmission lines. No power system can be designed in such a way that it would never fail, therefore, an automatic protective device is needed to isolate the faulty element as quickly as possible to keep the healthy section of the system in normal operation. The fault must be cleared within a fraction of a second because, if a short circuit persists on a system for a longer, it may cause damage to some important sections of the system. There is further possibility that protective relay itself may fail to operate correctly, and hence, provisions for back-up protections are made. Overcurrent, distance and pilot protections are used for the protection of transmission lines. Overcurrent relays offer the cheapest and simplest form of protection. They are mainly used on transmission lines which cannot justify more expensive protection such as distance or pilot relays. Whereas distance relays should be considered when overcurrent relays are too slow or are not selective. Distance relays are preferred to overcurrent relays because they are not nearly so much affected by changes in short-circuit-current magnitude as overcurrent relays are, and hence, are much less affected by changes in generating capacity and in system configuration. This is because, distance relays achieve selectivity on the basis of impedance rather than current. Pilot protection is the best type for line protection. It is used whenever high-speed protection is required for all types of short circuits and for any fault location. They fall into the category of unit protection. Pilot protection requires a sort of interconnecting channel over which information can be transmitted from one end to the other. The types of pilot protections in use are wire pilot, carrier current pilot and microwave pilot. A critical study of these three protection techniques has been made with a view to apply them judiciously in designing protection schemes for transmission lines of Nigeria.

Some typical cases of 330kV and 132kV Nigeria's transmission networks have been considered for designing the protection schemes using overcurrent, distance and pilot protections. Four cases of 330kV transmission lines have been considered, namely, Onitsha to New Haven, Kaduna to Jos, Jos to Gombe and Onitsha to Alaoji. Protection techniques used for the four cases mentioned earlier are two zone impedance protection, phase comparison carrier protection, three zone Mho, Mho and offset Mho protection, two zone Mho protection and three zone quadrilateral protection.In case of 132kV transmission lines, no specific cases are considered since there is quite large number of these lines. Two possible solutions are proposed to cover all the cases. The first solution is the protection of 132kV using all-distance protection for both phase and ground faults and the second solution is distance protection for phase faults and overcurrent protection for ground faults.

I. INTRODUCTION

An electrical power system consists of many components such as generators, transformers, transmission and distribution lines, e.t.c. However, the component with the highest fault incidence rate is transmission line due to their exposure to the environment i.e. it is the most susceptible element to experience faults. The main task of a transmission line is to maintain continuity of power supply from the generating station to the load centre, but this cannot be achieved because of line faults due lightning, storms, fog, vegetation fall e.t.c. which is beyond the control of man. So an automatic protective device is needed to isolate the faulty element as quickly as possible to keep the healthy section of the system in normal operation. Transmission line protection is an important issue to safe guard the electric power system. The balanced faults in a transmission line are three phase shunt and three phases to ground circuits. Single line-to-ground, line-to-line and double line-to-ground faults are unbalanced in nature. Transmission lines are protected by overcurrent, distance and pilot-relaying equipment, depending on the requirements. Overcurrent relayis the simplest and cheapest form of protection and they are normally used as back-up to distance protection on a transmission line. However, distance relay operates by using both voltage and current to determine if a fault is in its zone of protection. Distance relays provide high speed fault clearance and they are used where overcurrent relays become slow. They are the most widely used protective scheme for the protection of transmission line. While pilot protection scheme is the best type for line protection and it is used where high-speed protection is required for all types of short circuits and for any fault location. The combination of high-speed tripping and high-speed reclosing allows the transmission system to be loaded to nearly its stability limit, therefore providing maximum return on investment.

II. PROTECTIONS

Distance protection is a widely used protective scheme for the protection of high and extra high voltage (EHV) transmission and sub-transmission lines. This scheme employs a number of distance relays which measure the impedance or some components of the line impedance at the relay location. The measured quantity is proportional to the line-length between the location of the relay and the point where the fault has occurred. As the measured quantity is proportional to the distance along the line, the measuring relay is called a distance relay. Overcurrent relays have been found unsuitable for the protection of transmission lines because of their inherent drawbacks of variable reach and variable operating time due to changes in source impedance and fault type. Distance relays have been developed to overcome the problems associated with the use of overcurrent relays for the protection of transmission lines.

2.1Three Zones of Distance Protection

In this scheme of protection, three distance elements are used at each terminal. The zone 1 element covers first 80% to 90% of the line and is arranged to trip instantaneously for faults in this portion. The zone 2 element trips for faults in the remaining 20% to 10% of the line and for faults in the next line section, but a time delay is introduced to prevent the line from being tripped if the fault is in the next section. The zone 3 element provides back-up protection in the event a fault in the next section is not cleared by its circuit breaker.

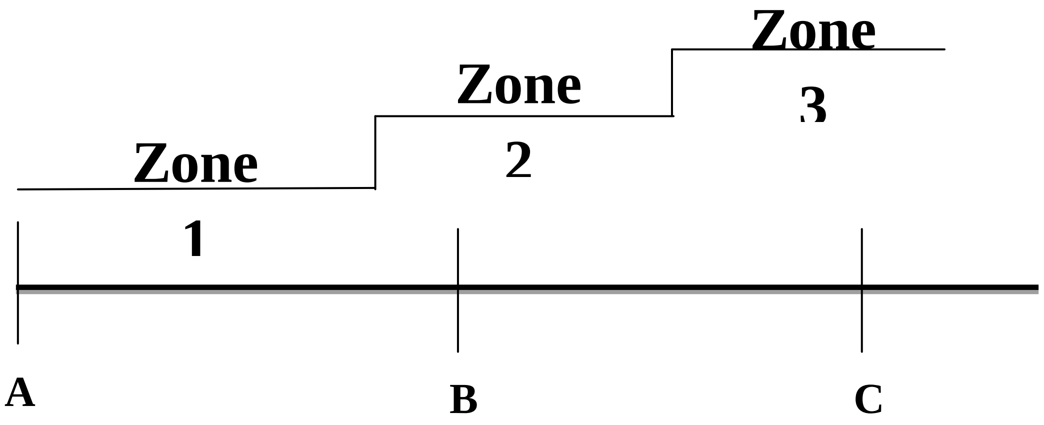

Fig.2.1 Three Zones of Distance Protection

2.2 Pilot Protection

Pilot relaying schemes are used for the protection of transmission line sections. They fall into the category of unit protection. In these schemes, some electrical quantities at the two ends of the transmission line are compared and hence they require some sort of interconnecting channel over which information can be transmitted from one end to the other. Such an interconnecting channel is called a pilot. Three different types of such channels are presently in use, namely wire pilot, carrier-current pilot and microwave pilot. A wire pilot may be buried private cables or alternatively, rented Post Office or private telephone lines. A carrier-current pilot is one in which a low voltage, high frequency signal (50kHz-700kHz) is used to transmit information from one end of the line to the other. In this scheme, the pilot signal is coupled directly to the same high voltage line which is to be protected. This type of pilot is also called a power line carrier. A microwave pilot is a radio channel of very high frequency, 450 to 10,000MHz. Wire pilot schemes are usually economical for distances up to 30km. Carrier-current schemes are more economical for longer distances. When the number of services requiring pilot channels exceeds the technical or economical capabilities of carrier-current pilot, the microwave pilot is employed. A distance range up to 150km is possible in a flat country, otherwise it is limited by hills and building. The link may operate up to 40-60km without repeater station. The system is applicable only where there is a clear line of sight between stations. The power requirement for signal transmission is less than a watt because highly directive antennas are employed.

2.2.1 Wire Pilot Protection

In a wire pilot relaying scheme, two wires are used to carry information signals from one end of the protected line to the other. A wire pilot may be buried cable or a pair of overhead auxiliary wires other than the power line conductors. The scheme is a unit protection and operates on the principle of differential protection. The comparison is made between the CT secondary currents at the two ends of the line. As the pilot channels are very expensive, a single phase current is derived from three-phase currents at each of the line, thereby using only a pair of pilot wires to carry information signal. For short lines, wire pilot schemes are less expensive than carrier-current schemes because terminal equipment is simpler and cheaper. It is more reliable because of its simplicity. From cost considerations, the break-even point is about 15-30 km, but the distance is usually limited due to attenuation of the signal caused by distributed capacitance and series resistance, rather than the cost. For short important lines, wire pilot relaying is recommended. For unimportant lines, slow-speed over-current relays are employed. For long lines, carrier-current schemes are cheaper and more reliable than wire-pilot schemes. The two alternative operating principles which are used for most of the practical schemes are circulating principles and balanced voltage principles. Most wire pilot schemes use amplitude comparison in circulating current scheme since they are easier to apply to multi-ended lines and are less affected by pilot capacitance.

2.3 Carrier Current Protection

This is the most widely used scheme for the protection of EHV and UHV power lines. In this scheme a carrier channel at high frequency is employed. The carrier signal is directly coupled to the same high voltage line that is to be protected. The frequency range of the carrier signal is 50 kHz to 700 kHz. Below this range, the size and the cost of coupling equipment becomes high whereas above this range, signal attenuation and transmission loss is considerable. The power level is about 10-20W. In this scheme, the conductor of the power line to be protected is used for the transmission of the carrier signals. So the pilot is termed as a power line carrier. In a carrier current scheme, the carrier signal can be used either to prevent or initiate the tripping of a protective relay. When the carrier signal is used to prevent the operation of the relay, the scheme is known as carrier-blocking scheme. When the carrier signal is employed to initiate tripping, the scheme is called a carrier intertripping or transfer tripping or permissive tripping. Carrier current schemes are cheaper and more reliable for long lines compared to wire pilot schemes, even though the terminal equipment is more expensive and more complicated. In some cases, the carrier signal may be jointly utilized for telephone communication, supervisory control, telemetering as well as relaying. Thus, the cost of carrier equipment chargeable to relaying work can be reduced. The coupling capacitors required for carrier signal can be used also as potential dividers to supply reduced voltage to instruments, relays, etc. This eliminates the use of separate potential transformers.

2.4 Microwave Protection

Microwave communication is used in the protection of long transmission lines where power line carrier does not offer enough channel capacity, or as a second communications path in addition to power line carrier. This is a radio channel employing very short wavelength or high frequency for point-to-point communication. Unlike power line carrier, the microwave signal is propagated through the atmosphere between line-of-sight antenna locations. The basic microwave channel is subdivided or multiplexed so that it can be used for a large number of different functions at a same time. When one of the sub-carrier channels of a microwave scheme is used for protective relaying, it is usually modulated by frequency shift audio tone equipment. The term "audio tone" as used here which is not restricted to a frequency audible to the human ear, but any frequency within the modulation capability of the microwave equipment. Audio tones in a nominal voice channel of 250 to 3,150 cycles per second can modulate the microwave frequency directly, or may be impressed on one of the multiplexed channels.

III ANALYSIS AND CASE STUDY

3.1 Case Studies of Protection of Nigerian 330kv Transmission Network

The transmission system in Nigeria comprises 330 kV and 132 kV circuits and substations.

Currently, the transmission capacity of the Nigerian Electricity Transmission system is made up of about 5,523.8 km of 330 kV lines and 6,801.49 km of 132 kV lines, 32no 330/132kV Substations with total installed

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transformation capacity of 7,688 MVA (equivalent to 6,534.8 MW) and 105no 132/33/11kV Substations with total installed transformation capacity of 9,130MVA (equivalent to 7,760.5MW). In its continued effort to increase transmission capacity in order to accommodate the planned increase in generation capacity, TCN is constructing 986.5KM of 330kV Lines and 705.3kM of 132kV Lines. Also 1,350MVA Capacity of 330/132kV transformers and 3,000MVA Capacity of 132/33kV transformers are presently being installed in new substations, overloaded Transmission stations are constantly being reinforced with additional capacity and overloaded transmission lines are being reconductored with higher capacity conductors. The single line diagram of the Nigerian 330kV transmission network is shown in fig.3.0 below.

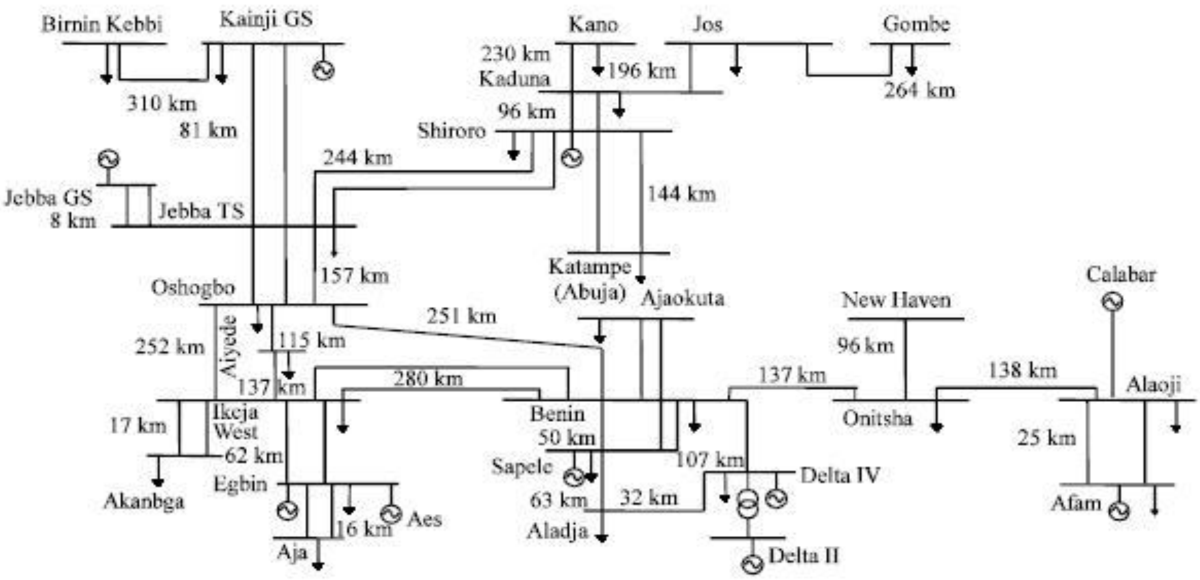

Fig.3.0 Single line diagram of Nigerian 330kV transmission network

The on-going national integrated power project (NIPP) which is aimed at increasing generation capacity includes increase in 330kV transmission capacity by 5,590 MVA (2,194 km), increase in 132kV transmission capacity by 3,313 MVA (809 km), construction of 10 new 330kV substations, 7 new 132kV substations and expansion/reinforcement of 32 existing 330kV and 132kV substations so as to have a transmission Grid that can efficiently evacuate all generated power.Plans are also in place to see that all power stations to have alternative evacuation routes, all State capitals to have 330/132kV transmission stations, all local govt. headquartersto have 132/33kV transmission substations all major towns, local govt. headquarters and state capitals to be on dual source of supply, all Transmission Stations to have at least 2 transformers that are less than 75% loaded at any time and all Transmission Stations to be rehabilitated for automation operation.Future expansion plan of the transmission company of Nigeria includes introduction of 760kV lines by constructing 2,460km of 760kV line, additional 2,349km of 330kV line and 2,353km of 132kV line which will translate into 3,000MVA capacity at 760/330kV, 3,900MVA capacity at 330/132kV and 3,680MVA capacity at 132/33kV respectively.

IV. CONCLUSION

Over current protection scheme is essentially a simple protection scheme. Consequently, its accuracy is not very high. It is comparatively cheap as non-directional protection does not require VT. However, it is not suitable for protection of meshed transmission systems where selectivity and sensitivity requirements are more stringent. Overcurrent protection is also not a feasible option, if fault current and load currents are comparable. Distance protection scheme provides both higher sensitivity and selectivity. It has been found to be more feasible and effective as compared to overcurrent relay. They are used where overcurrent relays become slow, and there is difficulty in grading time-overcurrent relays for complicated networks. Pilot protection is the best type for line protection. It is used whenever high-speed protection is required for all types of short circuits and for any fault location. They fall into the category of unit protection. Pilot protection requires a sort of interconnecting channel over which information can be transmitted from one end to the other. The types of pilot protections in use are wire pilot, carrier current pilot and microwave pilot. Some of the cases of Nigeria's 330kV and 132kV transmission networks are studied and a number ofschemes for protection of the transmission lines are proposed using conventional protection types.Four cases of 330kV transmission lines were considered, namely, Onitsha to New Haven, Kaduna to Jos, Jos to Gombe and Onitsha to Alaoji. In case of 132kV transmission lines, no specific cases are taken as there are very large numbers of 132kV lines, therefore, two possible solutions are provided.

V. FUTURE SCOPE

Design of protection schemes for ac transmission linesare very challenging and complex task, therefore, this dissertation will be found useful not only by the students but also the power system engineers. Conventional protection relays such as overcurrent relays, distance relays as well as carrier-current relays are used for the protection of Nigeria's 330kV and 132kV transmission lines. The increased growth of power system both in size and complexity has brought about the need for fast and reliable relays to protect major equipment and to maintain system stability. The concept of digital protection employing computers which shows much promise in providing improved performance has evolved during the past two decades. Digital relays based on unconventional principles, like traveling wave, artificial intelligence and adaptive features, have turned out to be very fast and /or highly selective. The present work can be extended to design protection schemes for higher-voltage transmission networks such as 400kV and 750kV lines using these new generation relays.

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