by Volker Leitloff, France

RTE - Transmission Line Protection (Issues and Solutions)

Highly meshed networks lead to constraints in protection coordination

RTE IS THE FRENCH TRANSMISSION System Operator. It operates a network comprising approximately 100 000 km of lines and 2450 substations. Almost half of the lines correspond to the transmission level (400 kV and 225 kV) including the interconnections to the neighbor countries, the other half belong to the regional sub-transmission level (90 kV and 63 kV). Today, RTE operates approximately 16,000 line protection relays, 15% of which are digital.

RTE has elaborated a set of documents used as reference for the protection of all network components. The protections to be used are defined depending on the voltage level, the component to be protected and its characteristics (underground or overhead lines, busbar, transformers, etc.) and the importance of this component in the network. One of the main principles applied to the protections by RTE is that a protection should only clear faults related to short circuits or other equipment failures. That means that protections must neither trip under overload conditions nor due to power swing. There are specific automatons dedicated to detect these conditions and to trip, if required, in a controlled and preset way that limits the consequences to the network

In this context, a "short line" is defined as a line for which the zone 1 of distance protections cannot be set to 80% of the line length, requiring thus a blocking scheme with the associated telecommunication equipment.

The main problems RTE is confronted with at the moment as far as line protection is concerned arise from the fact that several regions have a highly meshed network, leading to particular constraints in the coordination of the protections of several substations. The installation of capacitor banks, transmission lines with high load capability, phase shifting transformers, SVC's and multi-terminal lines have been adding constraints over the past decade.

RTE

For transmission lines (400 kV and 225 kV) RTE uses 2 main protections (Distance and / or Line differential), each from a different vendor. The power supply of these protections relies on the same battery and charger. The circuit breakers have in some particular cases a redundant trip coil and single pole tripping. RTE also uses an elaborated reclose scheme. For this voltage level, RTE uses a permissive tripping scheme of the distance protections. For the HV voltage level, only three-phase tripping and reclosing is normally used.

On the sub-transmission level, line bays are equipped with one main and one backup protection. Except the lines where blocking schemes have to be applied (short lines) or for cables (current differential, sometimes transfer trips), there is usually no communication between the relays at the ends of the line.

The new equipments appearing in the network (those mentioned above and probably others to come) increase both the need for selective tripping and the difficulties to obtain it.The growing complexity of setting parameters, the proper administration of hard- and software versions of protections and of the associated setting parameters are included in the challenges the protection engineers will have to face in the coming decade. ■

RTE uses on transmission lines 2 main protections from different manufacturers.

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by Graeme Topham , S. Africa

ESKOM - Transmission Line Protection Issues and Their Solutions

One of the main challenges currently being faced is an increase in the number of high resistance faults which fall outside the capability of the impedance protection. The current solution being considered is to apply direction earth-fault comparison protection as an additional protection function.

Eskom is the South African electricity utility, generating 95% of the electricity used in South Africa. Eskom's total net generation capacity is 40 GW.

Rapid growth in the country in recent years has seen the load increase so that the current spinning reserve is less than 8 %. This has put immense pressure on the transmission system in terms of transferring the required power from the generation to load centres.

The 28 000 km transmission system includes lines above 132 kV at voltage levels of 220 kV, 275 kV, 400 kV and 765 kV. Also included is 1 000 km of 533 kV d.c. used for importing power from the neighboring Cahorra Bassa scheme. In the mid-1980s, Eskom commissioned the first 765 kV transmission line and currently has 1 153 km of 765 kV lines in operation. As part of the current 42 billion USD expansion programme over the next 5 years, Eskom is building an additional 1 500 km of 765 kV lines to strengthen the transmission capacity between the generation pool in the North East to the Cape (one of the main load centres in the South West of the country).

ESKOM

Lines having a length of more than about 200 km are considered to be long whereas short lines are generally those less than 10 km. However, from a protection perspective, the Source to line Impedance Ratio provides a better assessment in terms of the protection needs. Duplicated protection is used for all transmission lines, with duplicated impedance being applied in the majority of cases. For short lines, duplicated current differential protection is used. In most instances, identical relays are used for Main 1 and Main 2. The decision to apply identical protection systems is based on a number of considered issues (e.g. training, spares holding etc.) and also on doing rigoros type and model power system simulator testing on all relays before applying them to the network. To date, this philosophy has proved successful. All transmission stations are equipped with dual battery systems feeding each Main protection system. Trip coils are also duplicated in all instances. Approximately 30 % of transmission line protection relays applied are of numerical technology.

A number of the 400 kV lines are series compensated, with plans to add additional series capacitors to both the 400 kV and 765 kV networks. Single-pole tripping and reclosing is applied on the majority of the transmission lines. There are some exceptions where operational requirements or limitations of equipment preclude the use of single-pole tripping and reclosing. On the impedance-based protection schemes, Permissive Overreaching is applied. In addition, a separate channel for direct transfer tripping is employed to facilitate the transfer tripping of the remote line end when required.

All impedance relays are selected to block for power swing conditions. Separate power swing tripping relays are applied at strategic locations to measure out-of-step conditions and to effect system separation at pre-determined locations so that the resultant sub-systems are viable and stable with the minimum of load shedding needing to be applied.

One of the most important issues related to transmission line protection is ensuring that the engineered protection schemes meet the increasingly demanding needs of the Eskom power system. ■

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by Dean Sharafi, Western Power, Australia

Western Power Transmission Line Protection Design & Philosophy

Western Power is the state-owned utility of Western Australia and operates varios voltage levels in Transmission and Distribution network. Transmission voltages include 66KV to 330KV covering a large area connected through the network (South West Interconnected System-SWIS). It contains around 88000 km of power lines with load around 3600MW.

The complete scheme for 220KV and 330KV lines consists of duplicated, fully independent and discriminative protections capable of providing high-speed fault clearance over the entire line length. These protections may be either unit types, such as differential, phase comparison, or distance with tele-protection signalling (using direct or permissive transfer tripping).

These protections use separate tele-protection signalling equipment. A single communication bearer to accommodate all the signalling channels is considered acceptable except where both protections require information from the remote end for its basic operating characteristics. In this case, each protection has independent bearer.

The complete scheme for major transmission inter-connectors (132kV and below) consists of duplicated, fully independent and discriminating protections capable of providing high speed local fault clearance and high speed remote fault clearance on one protection, and medium speed remote fault clearance on the second protection. These protections may be unit, interlocked distance or plain distance types. Regional inter-connecting lines at 132kV and 66kV have the same philosophy for protection.

Regional transmission feeders from major transmission substations enjoy the same standard of protection with addition of a remote backup protection (of the form of an IDMT overcurrent function) to cover conditions on the regional transmission network outside the scope of normal design. Designing the protection for each line category depends on the length of the line. Short lines are less than 10 km, intermediate lines - up to 25 km and long lines - more than 25 km.

Fault levels in the major transmission network are high, for example, 20 GVA at 330kV. One of the main limitations in our system design is the speed at which high power faults can be cleared from the system, particularly three phase faults.

The types of protection schemes adopted for transmission lines are:

- Current differential (*comparison over microwave radio/optical fibre*)
- Circulating current/opposed voltage (*pilot*)
- Interlocked distance
- Distance
- Over-current and earth fault

Unit protection schemes (eg. pilot protection) and non-unit protection schemes (eg. distance protection) are often used on the same line to take advantage of their complementary performance. Protection No.1 has arbitrarily been chosen for the unit protection, or the protection with the highest speed.

Where both protection schemes on a line are of the same type (eg. double distance protection) they are based on different operating principles or are sourced from different manufacturers. This is to reduce the risk of common mode protection failure.

Where duplicate unit schemes (eg current differential) are used they use separate communications bearers over different routes. Voltage transformer supervision is used in conjunction with all distance relays.

Earth fault relays are used on all lines (as part of Protection No 2) to help detect high resistance earth faults outside the sensitivity of the main protections, and to provide general system back up protection.

Breaker failure protection is installed with the fastest and most comprehensive protection.

Single shot reclose is used for feeders at metropolitan substations and two shot reclose for feeders at rural substations. On newly designed EHV lines high-speed single phase auto-reclosing scheme is used to improve reliability of the system.

In our transmission network 90% of relays are micro-processor based. Older relays are constantly replaced with new micro-processor ones. ■

When both protections are of the same type, they are from different manufacturers or principles.

Western Power

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by Iony Patriota de Siqueira

Brazilian Transmission Line Protection

Issues & their Solutions

The main issue related to transmission line protection seems to be the large number of specific cases.

The Brazilian electric system is singular due to its large geographical area, supplied mainly by hydro power plants located on rivers far from the load centers. The main generation source is Itaipu, a bi-national (Brazil & Paraguay) power plant with an installed capacity of 12,600 MW. Large portions of the Brazilian territory, mainly on the Amazon region, remain attended by isolated thermal systems, with scarce transmission resources. At the other extreme, highly dense load centers are located on main industrial and metropolitan areas on the Atlantic coast. The main transmission corridors and international connections of this system cover an area superior to that of the whole Western Europe

To cover such a large area, Brazilian electric system has more than 1150 transmission lines (greater than 69kV) at 138, 230, 345, 440, 500 and 750kV, linking over 600 substations, most considered long transmission lines (> 30km). The highest voltage in use links Itaipu power plant to the Sao Paulo area by two 565 mile (910 km), 750-kV AC lines and two 600 mile (980 km), 600-kV DC lines. The 500-kV technology is mostly based on compact transmission lines with self-supporting steel towers that have been successfully used on the Brazilian system for more than 10 years. Load concentration has also determined the need for short transmission lines (< 30km) connecting mainly urban stations.

Many special issues need to be dealt in the protection of a system this large, from zone reach settings and selectivity of short lines to high line charging with low short circuit current in 500kV long lines. On series compensated lines, several special measures are taken: zone 1 setting is disabled when capacitor is located at the remote end and the line is 70% compensated (overreaching of 2nd/3rd zones may occur, especially when there are capacitors at the remote end or at the beginning of the next line).

Voltage inversion is dealt using positive sequence voltage memory polarized relays, while overreaching due to sub-synchronos resonance between line and capacitor is compensated for Zone 1 (when enabled) by means of a security factor. Fault location errors occur for specific cases. Current inversions are not common, but have been recently detected during a protection type test using RTDS for some lines in the Southwest 230 kV system.

In mutually coupled lines, overreaching of ground Zone1 due to zero sequence current reversals dictates the use of mutual compensation. In lines with tapped loads, Zone1 settings are compensated for under-reaching due to in-feed effects.

The following protection philosophies are used: two identical distance or differential plus distance protection (Main 1 and Main 2) for all 500kV and new 230kV lines (after Grid procedures took place), with redundant batteries and trip coils. Primary and backup distance plus ground overcurrent protection continues to be used in old 230kV lines, with single battery and trip coil. Single pole trip and reclosing is used on selected 500kV lines for SLG faults. Communications are used for some line differential protection and teleprotection (all 230kV and above) in several schemes: Permissive Overreaching Transfer Trip (POTT), Permissive Under-reaching Transfer Trip (DUTT), and Direct Transfer Trip (DTT). Blocking is used for power swings, with tripping when separation of interconnected systems is required. Load encroachment has not been necessary but is available on the relays.

Adaptable multifunctional digital relays, supporting interoperability with other schemes look like the right direction to their solution. ■

Iony Patriota de Siqueira, was born in 1951 in São José do Egito, Brazil. He graduated in Electrical Engineering, with an M.Sc. degree in operations research from Federal University of Pernambuco and an MBA on Information Systems from Catholic University of Pernambuco. He is a member of Cigré and IEEE, Manager of Protection and Automation at Chesf Hydro Electric Company of San Francisco River) and Regional Vice-Director of Abraman, the Brazilian Maintenance Association.