CONCEPT “ONE FEEDER-ONE RELAY” FOR THE CONTROL AND PROTECTION OF SUBSTATIONS - OPERATION EXPERIENCE AND NEW DEVELOPMENTS

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INTRODUCTION

In the past, each function of a distribution switchgear was separately performed by function-dedicated equipment. The installation, testing and operation of each kind of equipment has sometimes even been the responsibility of separate departments.
Comprehensive relay and control schemes were engineered and assembled from individual relays and associated equipment. Interwiring between individual components and scheme testing were carried out manually in the manufacturer's or user's workshops.
The migration of local control and metering functions into protection relays is an attractive option for efficient and economic distribution system management. Sharing of data by all involved functions, and data communication from the feeder level up to system level, fully utilises all viable synergies.
The combined Relay & Control Unit provides most standard functions for system protection, control and metering. It replaces three, separate, function-dedicated equipment components, and requires only one set of instrument transformers, control cabling, and supervisory circuits.
One unit can protect, meter, and control a feeder or motor. The unit is suitable for metal-clad switchgear, where the unit is located in the low voltage compartment, as well as for relay and control panels in a separate location from the switchgear. In the latter case especially, the cost of engineering, assembly, panel wiring, testing, commissioning and maintenance is drastically reduced.

SCOPE OF FUNCTIONS IN ONE UNIT

Which technical functions are selected out of the total scope depends on the requirements for a particular feeder, as well as on the service policies of the power distributor. For example, in applications with separate control facilities, an advanced protection relay which displays meter readings will suffice. For a totally integrated approach (Fig. 1), a configurable graphical display shows the feeder mimic diagram, meter readings (current, voltage, and power), and diagnostic data.
A keypad enables local access to data, manual control, and alteration of relay set points. The unit features on-screen menus and password-security.
As an alternative to using the front-panel display and keypad, the man-relay dialogue is possible remotely via the utility’s communications network, or off-line by a temporarily connected laptop computer via a data port on the front panel.

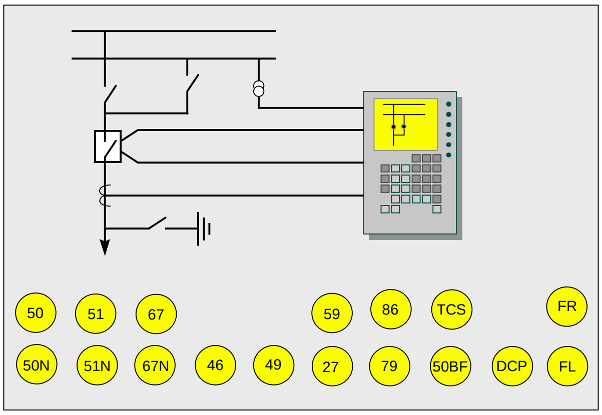

Figure 1 : Relay for metering, protection and control

All settings and parameters may be selected in an engineer’s office, then downloaded at site to the relay via serial data links. For repetitive use, the engineer can create a set of “master settings,” so that in future applications only a few settings need be altered.
Since all the data is stored on modern media, it can be made available to anyone that needs it for configuration, operation, analysis or diagnostic. Paper-based filing becomes obsolete.

RELIABILITY AND SECURITY CONSIDERATIONS

A multifunction unit has to satisfy the minimum requirements of each of the embedded functions. In particular, the unit may not compromise on vital issues affecting system security. While a loss of control and

metering does not instantly endanger the power supply, a loss of protection would immediately threaten the distribution system. Therefore, a lowering of the existing high performance standards for protection is not tolerable. The complete hardware system must meet the stringent relay standards concerning redundancy, working environment, and maintenance.
A loss of metering or supervisory control leaves the remote operator "blind" and allows only slow actions, but it has no immediate impact on the distribution system. Sufficient time remains for troubleshooting and, if necessary, for local control using back-up facilities.
Relays and meters have contradictory current-transformer and voltage-transformer requirements. Whereas relays operate at a multiple of the nominal current and a fraction of the nominal voltage, meters operate exclusively under normal service conditions. Relays require accurate measurement quantities during system faults, while meters only do so during service conditions.
There are two broad classes of metering applied in distribution systems. One for system and equipment monitoring, and one for revenue purposes. For accurate revenue metering, dedicated metering current-transformers are mandatory. For monitoring purposes, however, where less stringent accuracy is acceptable, the protection current-transformers may be shared for both applications.

This makes obsolete having separate metering current-transformers and interposing saturation current-transformers for thermal protection of meters. The relay is designed to relay standards with a thermal-withstand capability of 100 times full load current.
With unconventional instrument transducers these considerations do not apply. The small output signals do not overload the connected devices and the huge linear range is sufficient for both, relaying and metering.

APPLICATION AND OPERATION EXPERIENCE IN SUBSTATION 11 kV BOVENBERG

The relay 7SJ531 of Siemens is used as a protection, control and supervision device in each panel of a double bus-bar metal clad switchgear.

An illustration of the growing optimisation of protection and control techniques is given by the substation of Bovenberg 11 kV. This substation located in the city of Brussels is supplied by three transformers 36/11 kV (2 x 25 MVA + 1 x 12 MVA).
The double busbar switchgear is composed of 17 bays (3 incomings, 5 radial feeder circuits, 6 ring main feeder circuits, 1 coupling, 3 reserves).
A modern numerical protection relay with control functions type 7SJ531 is installed in each low voltage compartment of the metal clad switchgear (Fig. 2).

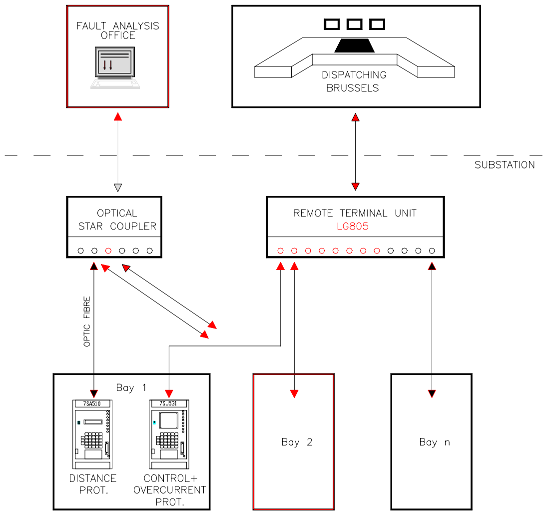

Fig. 2 : Bovenberg 11 kV – Protection and Control System – Architecture of the communications

The user Electrabel has parametrised the intelligent electronic device :

- to trip, on base of user specified inverse time phase and earth overcurrent protection functions. Furthermore, the "reverse interlock" principle is used to realise a fast busbar protection. "Reverse interlocking" means that the overcurrent time protection is independent of the grading time, it is not blocked by pick-up of one of the next downstream overcurrent time relays.
- to give alarm on base of unbalanced load.
- to control the circuit breaker.
- to store fault data (like distance-to-fault location) and instantaneous values during a fault for fault recording. Throughout a fault in the network, the instantaneous values of the last three faults are stored for a period of maximum 5 seconds and are available for subsequent fault analysis. Fault inception is tagged with the real time.
- to monitor continuously the measured values and permits annunciation of faults in the current transformer circuits which lead to asymmetry of the currents.
- to indicate the operational values on the front display : load currents, operating voltages, power, frequency, power factor, metering of active and reactive energy, thermal overload, phase sequence checks, …
- to link the serial interface with the RTU (type TG805 of Telegyr) en so to ensure the remote control of the circuit breaker and the harmony of annunciations (circuit breaker position : open, circuit breaker position : closed, drawer position, fault detection, failure 110 V dc, failure I or U, watchdog of the relay) and measured values (feeder current and bus voltage) to the dispatching. The quantity

of transmitted data to the dispatching (CCD Ixelles) is reduced to avoid drowning the operator in case of fault
The use of fibre optic cables reduce significantly the total noise generated into the station low voltage circuits.

For the ring main feeders, an overcurrent protection can not optimise simultaneous the selectivity and the tripping time and that’s why the power distribution uses a distance protection. The first zone (setting of 90 %) of the distance relays operates undelayed.

These numerical relays can be operated from a remotely located PC via modem connection. A star coupler is used as a communication mode for all the relays of the substation. The relays are connected to the star coupler via optical fibre links.
“DIGSI” offers the possibility of accessing bay protection and :

- to read out from the office desk the operational and fault events as well the fault recording data, which are stored with a millisecond realtime resolution. This enable effective and rapid fault analysis, which contributes to optimisation of protection in network operation (Fig. 3).

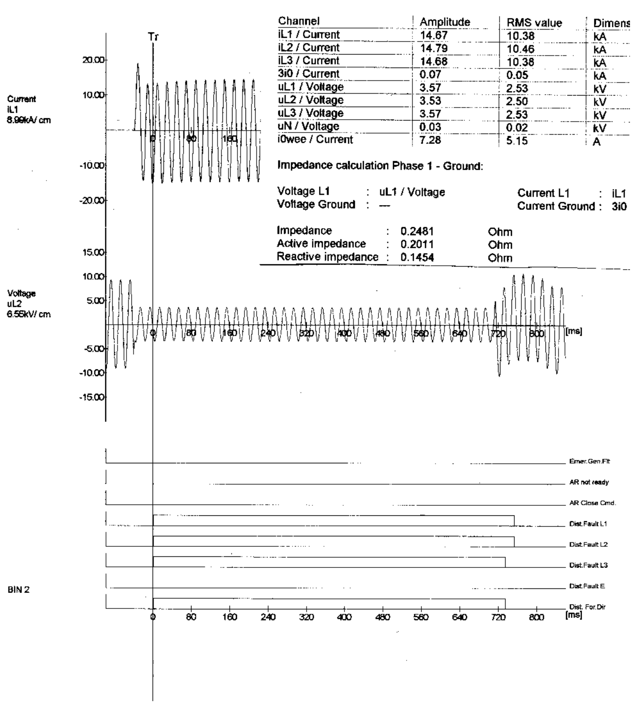

Fig. 3 : Evaluation of a fault record

- to send secure the parametrisation and the settings to the relay. Diagnostics and control of test routines are also possible without the need for visiting the substation.

NEW DEVELOPMENTS

The new unit “multifunction protection relay and bay controller” SIPROTEC 4 (Fig. 4) offers to the user new possibilities to optimise his process.

Fig. 4 : New Protection Metering and Control Device

The integrated logic functionality (CFC according to IEC 1131) allows the user to implement his own functions for automation of a switching bay (interlocking) or substation via a graphic user interface. No special knowledge of software is required. Logical elements, such as AND, OR and time elements are available (Fig. 5).

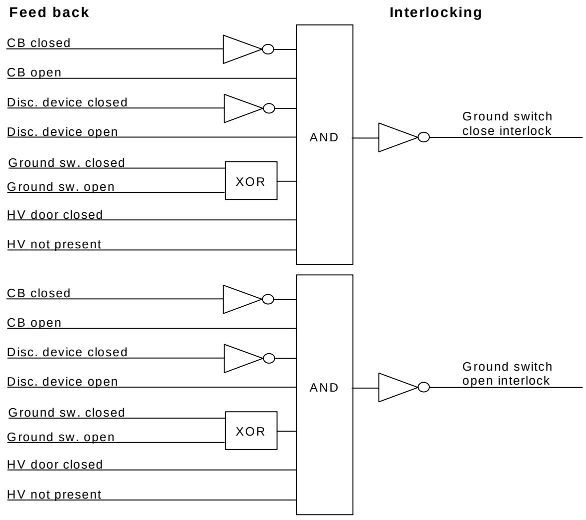

Fig. 5 : Grounding switch interlocking

The local operation has been extended with assignable function keys and designed according to ergonomic criteria. Large, easy-to-read displays were a major design aim. The configurable function keys permit the user to initiate frequently used actions fast and simply. Typical applications include jumps to certain points in the menu tree to display the list of operational measured values, or execution of automatic functions such as applying safety grounds. Key switches ensure fast and reliable access to "switch between local and remote control" and "switch between interlocked and non interlocked operation".

The SIPROTEC 4 is tailor for use in all energy automation system. It has a system interface for connecting to a control system via IEC 60870-5-103 (star connection) as well as via PROFIBUS (bus connection). This one is an internationally standardised communication system (EN 50170) and supported internationally by several hundred manufacturers.

In the future, the "feeder unit" will be available with a larger variety of protective functions. Particularly, the integration of the distance algorithm will support the user in cost effective power management.
Other communication protocols (Modbus RTU, DNP3.0, …) will also follow soon to comply with the requirements of different communication networks.

CONCLUSIONS

More efficiency and cost reduction occur if all control, supervision and protection functions are performed by one common intelligent hardware unit. Furthermore, maintenance is less intrusive and takes only place upon failures alarmed by a monitor. This type of event-oriented rather than preventive maintenance saves costs and reduces human mistakes to a minimum.
The combination of protection and control functions into a single unit capable of data communication greatly simplifies the implementation of data communication across an existent network.
The data of a comprehensive fault report can be accessed easily, retrieved and analysed, converted into information for the engineer. The engineer is able to take action upon all feeders of the power system as quickly as possible.

Two trends have emerged in the sphere of substation secondary equipment : protection and control in one IED (intelligent electronic device) and effective use of data communication across an existent network.

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