TRANSMISSION AND DISTRIBUTION

Goose messages for automated testing: 765 kV transmission network

by Alexander Dierks, Alectrix

Associated with the 765 kV system upgrade in Eskom, the implementation of a breaker-and-a-half substation layout and the introduction of IEC61850 based communication in Eskom Transmission substations, a new generation protective relay schemes for transmission feeders (both line impedance and line differential), transformers, reactors and busbars have been developed.

One objective of this development is to improve the efficiency of commissioning and routine maintenance testing in terms of speed and quality of testing and generation of results. Utilising a specifically designed “test Goose” message, the need to interfere with the test object, the test equipment and/or test procedure during the execution of a test procedure is reduced to a minimum. With the test procedure subscribing to function specific pick-up signals, which are part of the “test Goose” message, the need to switch off overlapping functions on the relay is eliminated. Also as the function specific pick-up signals respond instantaneously, much faster tests are possible compared to triggering to a time delayed trip signal. Lastly all the pick-up signals are available on-line, eliminating the need to re-wire hardwired trigger signals during the test procedure. The result is a fully automatic test procedure which improves the quality of testing and reduces the overall test time.

Transmission strengthening project

Eskom Transmission has embarked on a project to strengthen the power transfer capability between the main generation pool in Mpumalanga to the large load centres in the Western and Eastern Cape. The project is realised with a 765 kV transmission backbone between the substations Zeus (in Mpumalanga), Omega (in the Western Cape) and Grassridge (in the Eastern Cape). All substations will be based on a breaker-and-a-half layout to make the grid more robust and reliable as well as to utilise the limited land being available for air insulated substations.

All present protection scheme applications on Eskom national contract for use on transmission applications are designed for a double bus substation arrangement. To cater for the new breaker-and-a-half arrangement, new protection schemes, which will be applied to feeders, transformers, bus reactors and auxiliary transformers are being developed. All schemes utilise the IEC61850 standard for substation communication. The protocol is used to communicate between the IEDs (horizontal communication), and between the IEDs and the central substation computer (vertical communication). Goose messages will be utilised for horizontal and vertical communication of substation automation data as well as inter-relay data transmission. GOOSE messages will also be used to simplify the testing and commissioning of the various schemes [1].

Protection scheme arrangement

As part of this project, standard protection and control schemes have been developed for the various diameter combinations which can be configured within the substation arrangement. Fig. 1 shows the schematic layout of a typical feeder – transformer diameter.

Each diameter consists of the following IEDs:

- Duplicated main protection devices (main 1 & main 2) for each of the two protected objects (typically feeder – transformer or feeder – feeder).
- Diameter control device (DCD) which includes local / remote control functions, measurements, auto-reclose as well as synch check functions for the diameter.
- Diameter marshalling kiosk (DMK) which can be viewed as an intelligent junction box situated in the HV yard.
- Ethernet switch.

All the IEDs are interconnected via fibre optic network. The protection IEDs connected to the diameters will be based on a single manufacturer’s IEDs. These relays are suited...
TRANSMISSION AND DISTRIBUTION

to breaker-and-a-half applications due to the capability of accepting individual CT connection inputs. The advantage of this is that the circuit-breaker failure function can be performed internally in the relay since the relay has access to the individual currents in each circuit-breaker.

All protection functionality is included within one hardware device. Tripping is performed by issuing a trip signal to both busbar and tie circuit-breakers. Initially IEC 61850 Goose messages will primarily be utilised for communication at bay level. For example, the line protection relays sends an auto-reclose initiate Goose message to the diameter control device IED (which incorporates the reclose functionality). The main advantage of this approach is a reduction and simplification of the hard-wiring between the devices within a bay. In addition Goose messages will extensively be used to facilitate the objectives of efficient testing of such schemes.

Objectives of the test routine

With increasing complexity of the protective relay IEDs and the associated communications scheme, the test routine has to fulfil the following objectives:

- The test routine should completely test all the functions within a single IED.
- Individual tests should be engineered in order to confirm the settings on the IED. The algorithm of the relaying function (e.g. the impedance characteristic) or the output logic of the relaying function need not be tested, as this has been scrutinised during the factory acceptance testing of the scheme.
- Each function should be tested on its own to prevent overlapping results, i.e. one function picking up for another similar fault event. This is best achieved by triggering the test on the function specific pick-up signal directly from the function (logical node). One further advantage is that such signals normally are instantaneous, i.e. not time-delayed, resulting in faster testing.
- The test should be completely non-intrusive, i.e. setting or hardware changes on the IED are to be avoided during the execution of the test routine. This will reduce the risk of after-test maloperations to a minimum, as the test is non-intrusive with regards to the disabling/enabling of certain functions on the relay as well as connecting to the output of such functions.
- The test routine should be automated as far as possible to minimise human intervention as well as to reduce the overall test time. The main benefit of automated and standardised test routines is the repeatability and increased reliability of the test results.

Specification of the test system

The test system is to be suitable to test the IEDs and all protective relaying functions. The test system hardware is to provide three-phase voltages and two groups of three-phase currents – all independently adjustable in amplitude, phase angle and frequency. Two groups of currents are required, not only to test the transformer differential functions adequately, but also to be able to inject currents independently into the two current transformer (CT) current inputs of the breaker-and-a-half scheme without the need to rewire. The three voltage signals as well as six current signals are injected to the IED via special test blocks on the panel, which also isolate the primary plant at the same time. A sequence of voltage and current conditions simulating all specific fault conditions to the IED is to be injected automatically.

Using traditional test techniques each of these voltage and current injections would have been stopped, or triggered, by a hardwired binary signal issued by a physical output relay of the IED under test. In this application, however, a specific “test Goose” message has been set up. Each of the relevant logical nodes in the protection IEDs have been assigned to send dedicated Goose messages for the pick-up of all relevant functions to the test system as well as from the test system to the relevant IEDs for fault playback evaluations. Instead of triggering to a physical binary signal, the test system hence triggers to a digital Goose message, which is multicasted on the substation network. This approach allows the testing of all relevant functions without the need to disable any functions on the relay that could cause irrelevant results by only processing the trip data from the relay under test. The test system hence is to be compatible with IEC61850 in terms of being able to subscribe to Goose messages which are published on the substation network, as well as to simulate specific Goose messages, which specific IEDs can then subscribe to.
All Goose messages available in a substation are described in the substation configuration description file (SCD file), and the Goose messages available from and to a specific IED are described in the configured IED description (ICD file). A typical test setup configuration is shown in Fig. 2.

**Structure of the test template**

The structure of a typical test routine is shown in Fig. 3. The test sequence follows a top-down approach. Starting the test document the tester is firstly presented with important safety and warning instructions. The IED settings have been pre-prepared by a settings engineer utilizing a custom settings spreadsheet developed for this specific type of IED. The second step of the test routine would be to import the IED settings from this setting spreadsheet via an XML interface into the test object parameters of the test document. Manual checking as well as editing of settings is possible inside the test document – as shown in Fig. 4.

The third step would be to import the substation configuration description (SCD file) from the system configuration tool into the so-called Goose test module. This file contains all details about the Goose messages available within the substation, including the “test Goose” for the IED under test. In the Goose module any “test Goose” message can be mapped to any of the normally hard-wired binary inputs of the test system. Fig. 5 shows the user interface of the Goose module with the available binary inputs shown in the upper window and the available Goose messages to map to such binary inputs are shown in the lower window. A summary of the mapped signals is shown in the report view on the right.

The actual test module is set up in the normal fashion by injecting a specific test condition in terms of voltages and currents into the IED. The Link2XRIO [6] automation feature allows the automatic adaptation of a test routine to the settings of the IED. Hence each parameter can be verified by ramping the relevant voltage and/or current from, for instance, 90 to 110% of the set pick-up parameter. The IED, upon picking up, would then issue the relevant “test Goose” message, which in turn is interpreted by the Goose module of the test system as a trigger to the test module. In this way pick-up and timing tests can be performed on each specific function of the IED. Lastly the test module would compare the actual pick-up/timing against the assumed setting parameter and issue a “pass” assessment if the deviation is within a specified range.

For testing the multiple functions of an IED, multiple tests are necessary. As the test Goose contains all the pick-up messages for each function already, only a re-mapping of the relevant Goose message is required before such a test module, eliminating the need to pause the execution of a test to connect to the relevant hardware pick-up signal on the IED. This greatly supports the objectives of the test routine to ensure a non-intrusive test without the need to rewire any signals. The structure of the test routine to test all feeder impedance functions of an IED is shown in Fig. 6.

**Specific test templates**

For this specific project test templates for the following IEDs are being developed:

- REL670: Line impedance protection IED
- RED670: Line differential protection IED
- REC670: Diameter control device (incl. auto-reclose and synch check function)
- RET670: Transformer differential IED
- RET670: Auxiliary transformer differential IED
- RET670: Reactor differential IED
- REB500: Buszone protection IED

For each specific diameter, the relevant test templates from the above library will need to be selected. For a typical line – transformer diameter, for example, the following test templates will need to be selected:

- 2x REL670 (for Main 1 and 2) (or alternatively 1x REL670 and 1x RED670 if a line differential relay is used as Main 2).
- 2x RET670 for Transformers (for Main 1 and 2)
- 1x REC670

Each of the test templates will need to be executed step by step as instructed in the test document.

**Playback of transient signals**

For the playback of transient recordings it will be necessary to also simulate binary signals to the IED, such as a permissive receive signal, to test the accelerated tripping of a permissive scheme. Although the actual signal is hard-wired from the tele-protection equipment to the IED, the IED also subscribes to a permissive receive Goose message which could be published by the test system. The IED hence uses...
either the hard-wired signal or the Goose message to accelerate the tripping of a permissive scheme.

Hence during transient playback tests, again, only the analogue voltage and current signals from the test system to the IEDs will need to be connected. All binary inputs and outputs will be subscribed and simulated via the “test Goose” message.

Training

One of the big advantages of automated testing is the reduced need for the test technician to understand and know the full details of the complex protective relay scheme. This supports the challenge of constant loss of experience within the secondary grids of Eskom Transmission.

To run the test template a fundamental knowledge of the test system as well as the protective relay scheme is required. As part of the introduction of the schemes to the various grids, the test template will be presented and the execution of the test template explained. Particular attention will be given to explain the structure of the Goose messages and how to map such Goose messages for the purpose of testing.

Conclusions

The automated test approach described provides a sound basis for commissioning and maintenance of the protection equipment. Benefits are standardised test routines, repeatable and reliable test results as well as a considerable time saving over manual testing. The test routine is completely non-intrusive to avoid unnecessary delays during the execution of a test as well as reduced risk of “after test” maloperations due to an intrusion having not been reset. Utilising instantaneous Goose messages to test each individual protection function has the benefit of being able to test and verify the relay settings for each such function without neighbouring functions interfering. This will enable Eskom Transmission to achieve the goal of faster and more efficient commissioning and routine maintenance testing of the new protection schemes associated with the 765 kV Cape strengthening project.

Acknowledgement

This article was presented at the Cigré 2009 6th Southern Africa Regional Conference: Cape Town and is reprinted with permission.

References


Contact Alexander Dierks, Alectrix, Tel 021 790-1665, alex@alectrix.co.za