Challenges Facing Protective Relay Engineers in Modern Times

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Abstract: Specifically the testing of old electro-mechanical relays requires test devices that are capable of delivering sufficient power to drive the required high test current through the burden of a relay under test. For modern Intelligent Electronic Devices (IED), which in effect are numerical relays with additional functions, the state of the art communications standards IEC61850 is often deployed, which needs to be configured and tested adequately. This paper describes a number of case studies from the various generations of protective relays, describing the challenges in understanding, setting, commissioning and maintaining such relays.

Introduction

Power system equipment in our substations have a long life cycle. Specifically protective relays can be up to fifty years old. On the other hand with the constant expansion and growth within our networks, such old substations often need to be extended and hence it is not uncommon to find the latest technology being introduced in these same substations. Hence one of the biggest challenges facing a protective relay engineer is being able to understand, set, commission and maintain the protective relays from all such generations.

Electromechanical Relays

Electro-mechanical relays are often quite simple in operation, easy to set as often only a handful of settings need to be determined.

Normally the injection testing of such relays during commissioning and/or routine maintenance testing also is quite straight forward, as often only a single source of voltage and current, with no dynamic and/or transient capabilities, is required. However, the test equipment used, needs to have sufficient power available not to overload the voltage sources when injecting the test voltage into the VT circuit and sufficient compliance voltage to drive the test current through the burden of the CT circuit. To test a 1A rated CDG16 earth fault relay set at a pickup of 0.2A with a test current of 2A (i.e. ten times pick-up), a compliance voltage of 140Vpk is required from the current sources.

Often the older relays are also rated at 5A for the CT circuits. To test especially the High Set overcurrent function of such overcurrent relays, the test current needs to exceed the theoretical pickup current by at least 20%. Hence, if a high set function is set at 20 times nominal current, a test current in excess of 100A is required.

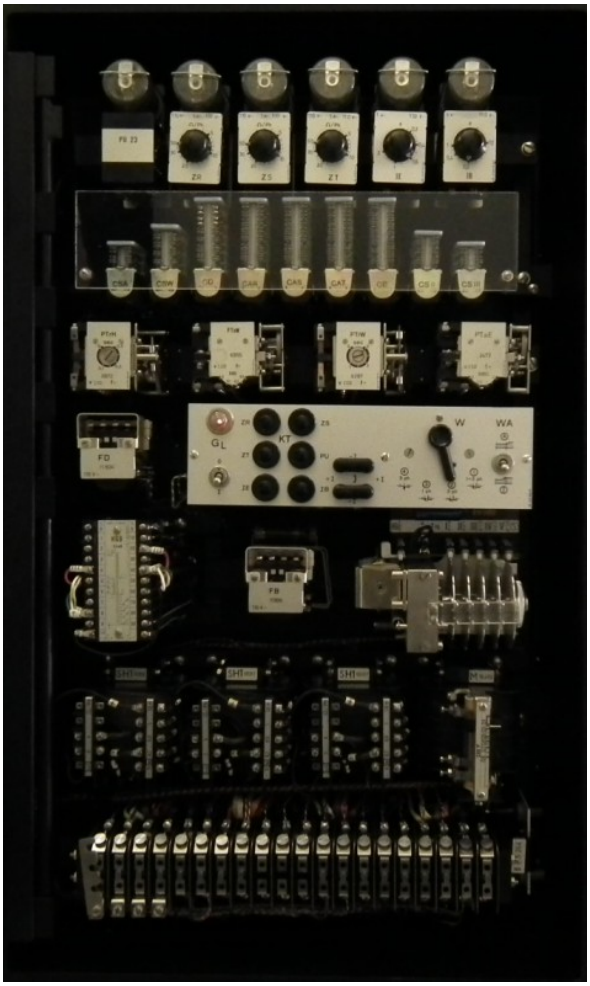

Figure 1: Electro-mechanical distance relay

Integration

Since the advent of numerical protective relays, such relays fulfil many more functions than just protection functions: Such Intelligent Electronic Devices (IED) include functions such as substation local control mimic diagrams, local substation automation and interlocking functions, as well as measurement functions to feed the Scada systems with data.

To commission such relays, the test system must be able to simulate the many binary status signals, such as breaker and isolator position status, to and from the primary plant. To test and certify the calibration of the measurement functions, the voltage and current outputs of the test system need to be of sufficient accuracy as well as the feedback of the IED in the form of a DC analogue control signal needs to be connected to the test system for closed loop testing.

Figure 2: Modern integrated IED

Complexity of Relays

Electromechanical relays utilize simple characteristics, which are controlled by one or two settings. An example would be a distance relay with a Mho characteristic, which has a characteristic angle as well as a reach setting. The characteristic angle is fixed for both earth and phase faults as well as for all zones.

Numeric relays do not utilize Mho characteristics to a large extend any longer, but rather quadrilateral characteristics. The characteristic, consisting of various blinders, can be set in software with many degrees of freedom. For a common numerical impedance relay ten settings need to be entered, where previously four settings were sufficient. All the settings also need to be understood. On some relays, for instance, the impedance reach is entered as impedance to the fault, whereas in some relays it is the total loop impedance.

In addition specific elements have specialized measurement algorithms. An example would be the treatment of the arc resistance coverage. In some relays the arc resistance portion of the fault impedance is compensated for by the earth fault compensation factor, i.e. it is treated as part of the line impedance, in other cases the arc resistance is not compensated, while the line impedance portion is compensated.

The challenge is to firstly verify that each and every setting has been entered correctly in the settings software of the relay, and secondly to test each function controlled by such a setting.

As the relay expects to be supplied with realistic voltages and currents, testing such modern relays with simplified models, such as with just one voltage and one current source, or by not simulating any pre-fault condition and then switching instantaneously to the fault condition, might result in the relay algorithm not performing optimally and hence to operate incorrectly.

A further example is the testing of transformer differential relays, which nowadays require the injection of six independent currents to simulate each of the phase currents on the high and low voltage side of a transformer, as the relay internally compensates for the vector group and CT mismatch correction of the transformer scheme.

Complex Networks

The increasingly interconnected networks utilized, even in distribution networks, call for protection relays which need to be smarter to fulfil the basic protection function. Examples are tele-protection schemes, Direct transfer tripping etc.

To be able to test such real-time communication schemes, test systems need to be synchronised together by a common timing signal, such as the GPS timing signal, to allow the synchronous injection of fault quantities at different substations.

Managerial Environment

The local electrical engineering fraternity is faced with a constant loss of skills and loss of experience mainly due to an increased staff turnover, as a career in other disciplines or in other countries appear to be more attractive. This means less experienced staff need to understand the increasingly complex relays in even less amount of time.

Every effort is necessary to assist such staff to understand the relays, but also to assist them to still be able to fulfil the job function of setting and testing the relay properly.

After the actual tests, great time savings are possible by automatic report generation tools. This also allows the reports to be emailed to colleagues, uploaded into databases for safekeeping and loading them into third party software tools for post data processing. A mere static report in for instance a PDF file does not fulfil this requirement, as the actual data in the report is not accessible any longer.

Regulatory Environment

Regulatory rules also will increasingly hold engineers accountable for their actions, i.e. to prove that they have performed their duty to the best of their abilities. For this accurate test reports, which are clearly time stamped and cannot be tampered with, are required. The results of a report also need to be accurate and repeatable, which calls for standard test procedures. Should a relay then trip and electricity consumers be disconnected, the test technician can easily prove that the commissioning and/or routine maintenance was performed correctly by means of such test reports. Results can easily be repeated, by re-testing such relays using the standard test templates.

IEC 61850

The IEC 61850 standard defines the communication between IEDs and devices within a substation. Three basic forms of information exchange exist:

1. IEC61850-7-2 - Client / Server communication between IEDs and to the Scada system.
2. IEC61850-8-1 – GOOSE (Generic Object Oriented State Event) messages transmit any binary pick-up signal via LAN, replacing copper based wires transmitting such signal.
3. IEC61850-9-2 – Sampled values. All voltages and currents are transmitted in sampled values via the process bus, i.e. replacing the copper based wires transmitting analogue voltages and currents.

From a testing and commissioning point of view, the test equipment needs to be able to communicate with the LAN system to read IEDs (i.e. read reports), subscribe to GOOSE messages to be able to trigger and time specific pick-up and timing tests. To ensure the correct operation from a relay, the test system also needs to be able to simulate GOOSE message to a LAN. Looking into the future, the test system needs to be able to simulate the sampled values produced by a merging unit to be able to test the IED which normally utilizes the data from a specific merging unit.

Conclusions

Test technicians and engineers, having to fulfil the commissioning and maintenance of protective relays in substations are faced with a number of challenges. The tools to perform such tasks adequately need to be powerful and strong enough to be able to inject sufficient current into protective relays from the older electro-mechanical generation and need to be flexible and sophisticated enough to test modern numeric relays, which support much more flexible and complex characteristics as well as integrate control, substation automation and measurement functions into one device. The test device also needs to be able to support testing in an IEC 61850 environment, i.e. subscribe and simulate GOOSE messages as well as simulate Sampled Values streams. Automatic test templates and electronic intelligent reporting will assist the test technician to master the present managerial challenges, such as post-processing data, repeating test results and being able to produce a professional test report.

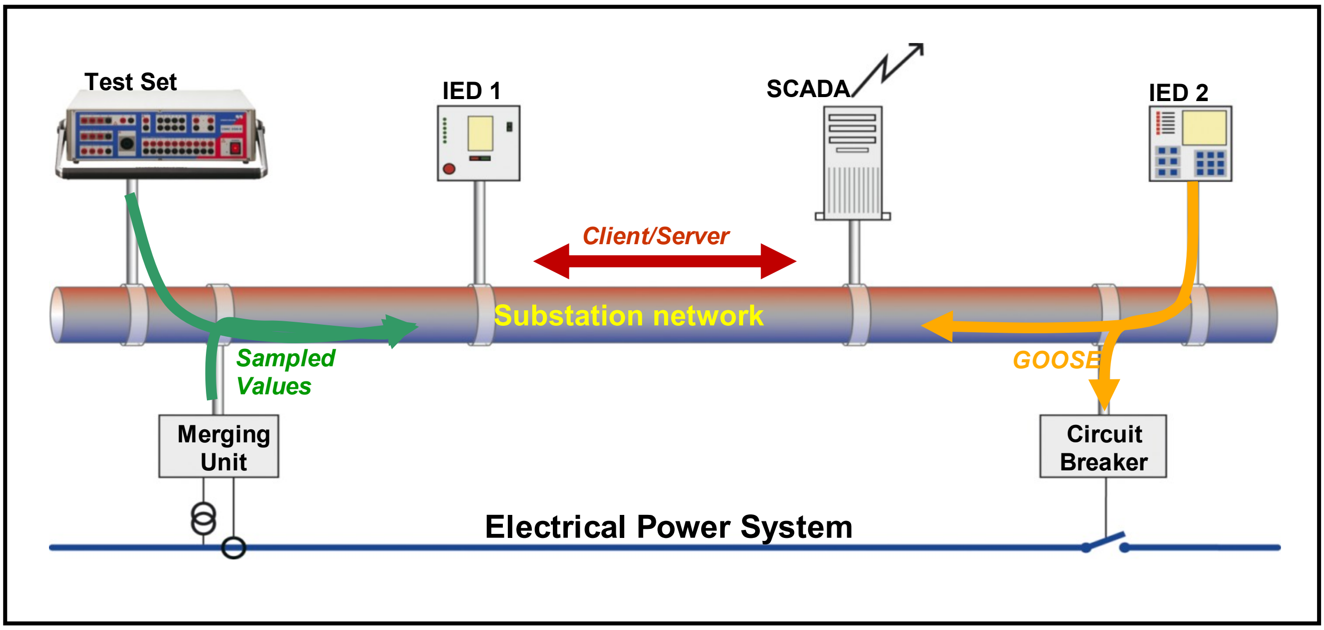

Figure 3: An IEC61850 substation