A Globe Scan Of Urban Infrastructure In Third World Countries
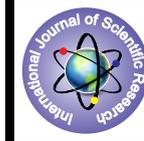
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ABSTRACT

The only way to ensure a protective relay will perform as expected is to test it under realistic power system conditions. This generally means that the relay should be subjected to testing with transient data that occurs during real network conditions at the time of an event or fault. Such transient data can be generated from commercially available network simulation programs or re-playing fault recorded files (Disturbance recorder files). Many such programs are available today such as the ATP, EMTP, PSCAD/EMTDC and others. In each of these tools, its power system program generates the transient data in IEEE COMTRADE FORMAT. The author proposes how new techniques allow these COMTRADE files to be modeled in detail and easily simulate various fault scenarios and system conditions such as power swing, SSRC. The paper will provide a concept for protection efficacy and evaluation through advanced relay testing with help of Transient data.

Introduction

Relay testing is a very important issue when applying the protective relays. The vendors need an evaluation tool to validate the design of the relay logic. The utilities need an assessment tool to compare the performance of different relays, calibrate relay settings and carry out post-event troubleshooting. The universities also need a simulation environment to investigate relay principles and develop new relay algorithms.

The methods using transient signals to implement relay testing are more accurate than the traditional phasor based methods because they use waveforms that are much closer to reality. Most of the transient testing solutions try to address the issue "How to implement transient based relay testing using available simulation tools?" That is actually the last step in implementing the methodology. For a much clearer view of the benefits of using transient based relay testing, we must extend the issue by asking the following question "What could be done with transient based relay testing?" For example, the final report of the July 15, 2009 Line Trip indicates that a number of protective relays have operated/miss-operated. A common belief is that the miss operation was caused by wrong selection of settings. This kind of issue can be studied only using transient based relay testing since the traditional methods may not provide adequate level of detail. When the scope of transient based relay testing is determined, a new methodology to match that scope should be discussed.

The implementation of relay testing is important, but the issues of selection of system model, generation of test scenarios, implementation of software simulation tool, etc., also need to be addressed. In the following sections, the new scope and methodology for testing distance relay using transients are discussed in detail.

Method to Test Protection relays

In general two methods to test protection relays can be identified:

• Steady State/Dynamic state Phasor Relay Testing
• Transient Relay Testing

Testing of relay has been done based on below power system model shown in figure the source impedance of Source "S2" is 5 Ohms @ 84 deg and Source "S1" is zero. Fault occurs at location F1. Fault current (IF1) fed by Source "S1" and (IF2) fed by Source "S2". Total amount of fault current at fault location is summation of fault current fed by "S1" and "S2". . Source to Line Impedance Ratio (SIR) for Relay "R1" is zero but for Relay "R2" is five, so the amount of fault fed by source "S2" is lesser than "S1". Now, the performance of relay is changing based on SIR value. We have conducted laboratory test on relay and found results which is described under point.
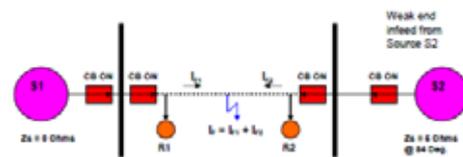

Fig. 1 Test circuit single line diagram
Steady State or Phasor Relay Testing
It is also called as conformance Test. The basic objective of conformance test is to verify

functionality and generic performance characteristics specified by vendors for different kinds of relays. It is described in two ways;

1) Steady State Phasor Testing
2) Dynamic state Phasor Testing
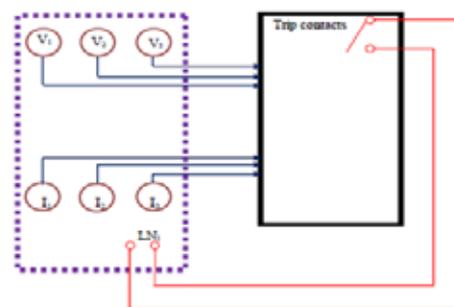Test Circuit for Steady state and Dynamic state testing by using F6150 Power system simulator

Fig. 2 Basic test circuit

Fig. 3 Real testing circuits & connections of SEL 421 relay with test simulator f6150 Doble test kit

Steady State Phasor Testing

Only one parameter (either amplitude of voltage or current or phase angle etc.) is changing at a time during testing following figure. Figure shows Impedance characteristic of Distance protection relay tested by using constant current method.
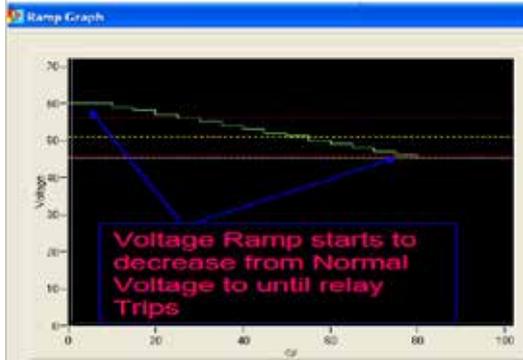

Fig. 4 Ramping of voltage

Test case Example-1

We have conducted steady state testing of one of the distance protection relay type SEL421 which is having Mho characteristic options for five zones. We have set three zones and applied faults by using constant current methods as shown in below figure. Relay operation recorded on various fault angles as shown in below figure. Blue color is showing theoretical set circle characteristic of relay and while color is showing the actual operating points where relay operated. Actual operating characteristic is exactly superimposing on theoretical set characteristic.
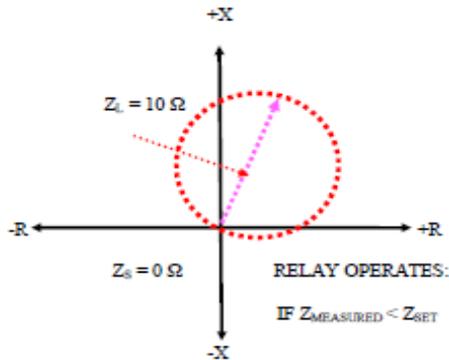

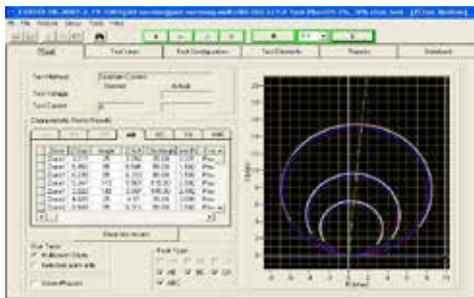**Fig. 5 Theoretical result of test case one**

Fig. 6 Results of test case-1, fault characteristics & result data

Such kind of the traditional phasor based test methods are used to verify calibrations, accuracy, operating time & Characteristic what is given in to relay manual. The input signals are ideal sinusoidal functions as shown in figure1. By adjusting the magnitude and angle of the signals, the operating characteristic of relay is obtained and compared to the theoretical one or the one given by the vendor. But, actual Power system phenomenon; Voltages & Currents are changing dynamically which is simulated by using Dynamic state phasor testing on relay.

Dynamic state Phasor Testing

Amplitude of Voltages/Currents & Phase angles are changing simultaneously by using different states. It is possible to simulate by using State simulation (SSIMUL) Program. It can generate various dynamic conditions on fundamental frequency.
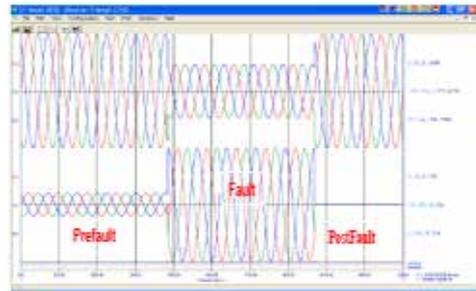

Fig. 7 State simulation models (Pre-fault, Fault & Post-fault)
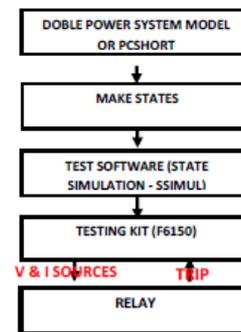Testing Procedure is;

Fig. 8 Test methodology

The methodology of the conformance tests is as follows:
- Select a "standard" state sequence model suitable for creating different test scenarios.
- Generate a reasonable set of test scenarios and form a scenario library for easy reuse.
- Automate the test procedure to minimize the test time.
- Implement comparative tests for a set of different relays with similar functions.

Test case Example-2

We have conducted dynamic state testing on distance protection relays R2 by using constant source impedance methods based on power system model as shown figure. We have used Constant source impedance module in Doble F6TEST software & injected faults on various angles.
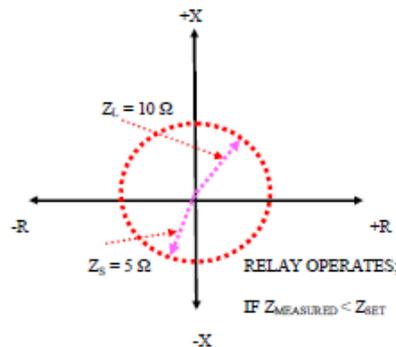

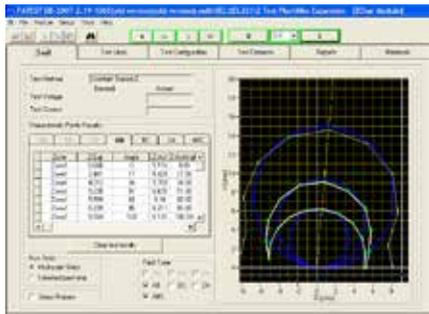**Fig. 9 Theoretically accepted result of test case – 2**

Fig. 10 Results of test case-2, fault characteristics & result data

Conclusion of our tests
In the test case 1, the source impedance is considered as a zero; and in test case 2, the source impedance is considered 5 ohms. So by focusing the characteristics of both the results, its comes to knew that the operating area of relay in case 2 is increased dynamically based on source impedance values which shows that the relay is covering in faults during week end in-feed conditions

Advantages:-
• Generate several cases with Pre-fault, Fault & Post fault condition to test some of the applications

Disadvantages:-
• Voltages and currents are calculated as sine variables only without transient signal components, but this method is not represent an actual situation during fault and is not enough to verify the security & dependability of relay because relay performance can be quite different during transient.
• A sudden change of amplitudes will be realized using an absolute amplitude shift.
• The DC-component is calculated based on a mathematical equation, but not as the result of a network simulation.

No transient signal components can be used e.g. for ground faults in insulated or Peterson coil grounded networks.

Dynamic Transient Relay Testing
A transient type test consists of voltages and currents using components of the power frequency and from DC to high order frequencies experienced during system operating conditions.
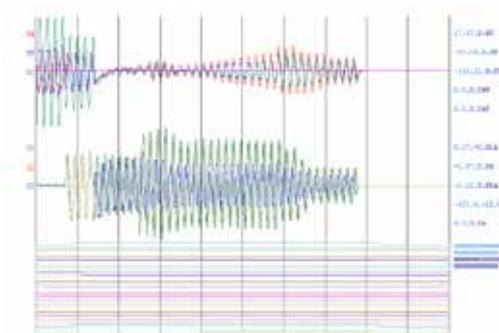

Fig. 11 Presence of DC & higher order frequencies in system frequency in fault duration
The objective of Transient test is to verify whether a relay can operate correctly under certain circumstances in a particular system. After the basic relay characteristics evaluation is performed by the conformance test, the Transient test can be used for analyzing the very specific performance issues. It can also be used for trouble-shooting of a specific relay operation/mal operation. A simple example is diagnosis of the reason of the distance relay failing to trip a faulted transmission line or falsely tripping a healthy transmission line. This kind of problem can be analyzed with the help of transient based relay testing. The approach can be divided into a preventive study and a post-event analysis. For the preventive study, the problem should be analyzed using Network Simulation Programs which can able to

simulate & generate transient data files. Through a series of contingency analysis, one can find out several worst cases, and use transient testing to make sure the relay settings are appropriate for those scenarios or applications. For the post-event analysis, the relay miss-operation cases will be collected through DFRs. By replaying the recorded fault waveforms to the relay, one can find out the problem and correct it to avoid similar events in the future. Transient testing is very helpful in determining basic relay performance characteristics.

Preventive Study:-
Using Transient Data created by Network Simulation Programs (i.e. EMTP /ATP /PSCAD-EMTDC etc.). A network simulation system calculates voltages and currents by solving the differential equations of the electrical network. This method takes into account the dynamic characteristic of the electrical network. Transient phenomena are taken into account, too.

• Voltages and currents contain transient signal (Fundamental + Harmonics + DC offset) components.
• Amplitudes and phases will be changed continuously.
• Voltages and currents depend on the characteristic of the electrical power network.

Protection engineer has to design a suitable model of electrical network. The network simulation software calculates voltages and currents for each network node. Voltages and currents have to be used to stimulate the protection devices. Transient phenomena are taken into account depending on the chosen network model.
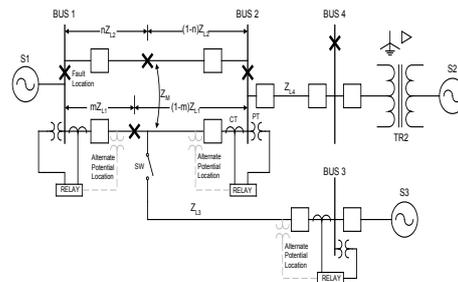
IEEE Basic System Model for distance Protection
The basic model is suitable for testing most transmission line protection applications. The model is made up of various components lines, transformers, sources, etc. There are three sources in the network – S1, S2 and S3. The source angle can be varied to simulate power flows. The transmission lines consist of one pair of mutually coupled lines (betweenFigure.2 buses 1 and 2), out of which one is a three terminal line. Intermediate nodes are provided in the line models to enable application of faults at various locations. Breakers are also included to simulate different configurations.

Test Procedure
The thorough evaluation of a relay by a manufacturer could result in the application of thousands of cases given the practically infinite numbers of varying conditions that its various customers could meet in real life applications. A user perspective could be different in the sense that he should normally concentrate on the conditions that he is most likely to meet on his network.
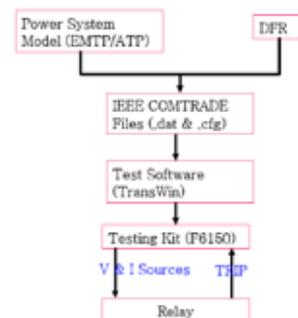

Fig. 12 Relay testing procedure

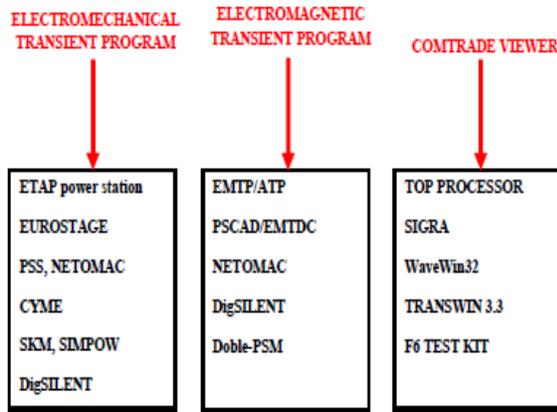**Available power system simulation tools for transient relay Testing**

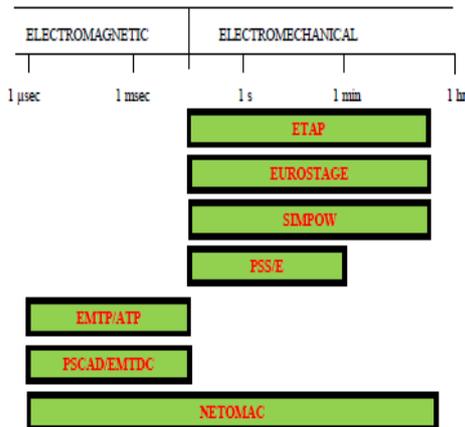**Fig. 13 Electrical network simulation software**

Fig. 14 Fault detection time requirements for different simulation programs

Electro-mechanical transient program
The Electro-Mechanical Transient Program is very good graphical user interface which is use to simulate electro-mechanical phenomena like behavior of steam turbine generator, transient stability, steady state stability, steady state fault condition with DC offset. It requires less input parameter for modeling. This modeling is good for visualize load flow study of large system such kind of effect or phenomena can be simulate & replay on the relay based on application.

But, CT saturation, Transient CT saturation, ferro-resonance, sub-synchronous resonance, high frequency transient ground fault, heavy capacitor inrush current phenomena during line charging are difficult to simulate with using this program due to low sampling rates (1-2 kHz). So power transmission & distribution utilizes are normally using such kind of simulation prog9ram for their entire system steady for their electrical network.

Electro-magnetic transient program
Electro-magnetic transient program having good graphical interface which is more precise for real time simulation practice of symmetrical, asymmetrical, evolving faults & fast transient phenomena. Such kind of real time simulation & replay on relay precisely & see the dynamic performance of relay based on application. But, here simulation can be done for maximum 1-2 seconds time. So system behavior of large electrical network cannot be simulating by EMTP. The sampling rate of this kind of software is about 10-20 kHz.

COMTRADE viewer
Application of COMTRADE (Common Format For Transient Data Exchange) viewer is to import IEEE COMTRADE files for analysis of transient data of electrical transient condition. We can analyze the harmonic data, symmetrical, asymmetrical components including phasor in COMTRADE viewer program

CONCLUSION
COMTRADE Data creation from network simulation model and collection from recorded waveforms are essential for expediting the troubleshooting of protective relay operations. The analysis is important for quick identification and classification of the recorded waveforms.

Fault playback is important for repeating the problem in the field as well as lab conditions. The playback methodology was presented through three cases experienced in a real power system where the fault playback helped solving the problems. Field recorded data and analysis results may be essential for calibrating and tuning the system model used in simulation.

The typical relay engineer performs only pre-fault analysis: performing fault studies, checking system impedances, & specifying relay settings which is only half of the complete job. Post-fault analysis completes the loop, providing feedback on how the protective system operated, if the intended elements operated. This allows the engineer to make any necessary adjustments in relay settings or in overall scheme philosophy.

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