Protective Relay Testing

Student ID: 250442424
Name: Dunisha Wijeratne
Degree: M.E.Sc.
Graduate Year: Year 1 Winter Term
Supervisor: Dr. G. Moschopoulos

Content

1. Introduction

Why do we use protective relays?
Relays are frequently found device in high voltage or medium voltage power system. Their main duty is to isolate a faulty section within few cycles but by ensuring minimum interruption to healthy sections. Therefore an ideal relay is a unit which would act by compromising costs of damage to imperfect section and cost interfere the perfect. With usage the connections of relay gets deteriorated or contaminated with carbon particles, etc. Therefore it's the interest of both the end user as well the manufacturer to check the behavior of relay after time intervals.

2. Types of Tests

2.1 Acceptance Testing
This is a bench test performed either by the manufacturer or end-user to check the acceptability of the unit for sale or purchase.

2.2 Commissioning
A field test to determine the relay functions accurately in the environment in which it's installed. Actually this starts at the point of procurement. The specs will be matched with the submitted drawings from the suppliers. Finally after installing it checks

- Accuracy of assembling the components in relay
- Ratings
- Calibration
- Conformity with entire system

2.3 Periodic Maintenance Testing
After a relay is commissioned it's important to carry out regular maintenance tests. Some of the advantages of such testing can be stated as, it will pin point a defective relay before it fails to act during a fault, relay coordination, its adaptability to latest power system as many feeders an loads might have got added over the years after the relay was installed.
Not every kind of relay requires the same frequency of maintenance testing however it's advised to have periodic maintenance tests once every 6-12 months. Rate will actually depend on the following factors,

- Experience with the relay type
- Service environment
- Importance placed on the protective unit
- Frequency of operation
- Availability of test equipment & personnel

The first generation relays have many mechanical parts, which have high chance of becoming tainted due to environment or contaminated with dirt due to less use. Also Static relays with transistors don't have an inbuilt system to detect internal circuit failures and give out an alarm. As an example if the power supply for the relay fails the system to be protected becomes unveil to over current hazards. On the other hand the Static relays with processors have many watchdogs to identify the absence of power supply etc.
The test results can then be audited and used for decision making with respect to system integration and to avoid relay problems in the future.

- Operational test/Trip test- Checks functionality of I/O logics with respect to design.
- Calibration Test-Verifies the relay operation is within its trip time and pick up current tolerances.
- Alarm test-checks the functioning of Alarm, which is to notify of the errors in the internal circuit.

2.4 Troubleshooting

This kind of test comes into effect after a power system disturbance had occurred and relay acted in an unanticipated way. Assuming the relay which is responsible is known further information is needed to be evaluated [1].

- Exact time at which relay created the disturbance & cleared it.
- Fundamental frequencies of currents and voltages during above times.
- Occurrences of relay trip signal, breaker opening, send/receive transfer signals etc.

Thereafter the data can be manipulated using an expert system to find the causes. For example relay operation was slower, such as pick up was more than 4 cycles (set value)

3. Methods of Testing

The method used by a tester will depend mainly on the equipment he has. Some of the frequently used can be stated as,

3.1 Steady State

Usually steady state testing is for checking the relay pick up. Injected current, voltage or frequency is held at predetermined value for duration longer than the planned time for relay. Then varied gradually at a rate much smaller than resolution of relay, either manually turning a knob or by an automated system. The fig. 3.1 indicates how relay picks when the current is raised and then fluctuated around pick up. Mostly found at the point of commissioning, due to lack of relation to actual power system faults this is of less use.

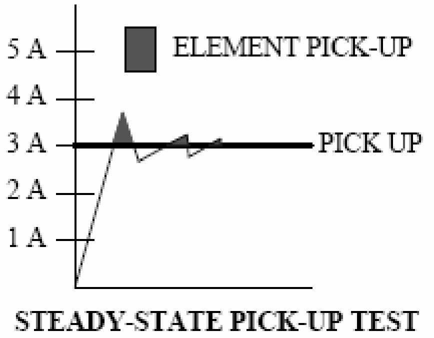

Fig. 3.1- Steady state test

3.2 Dynamic state

Dynamic-state test is defined as simultaneously applying fundamental frequency components of voltage & current which represents power system states of pre-fault, fault and post fault. Time for relay operation is measured. Used at commissioning and troubleshooting. The figure below depicts a simple dynamic state test waveforms used by a Manta test system.

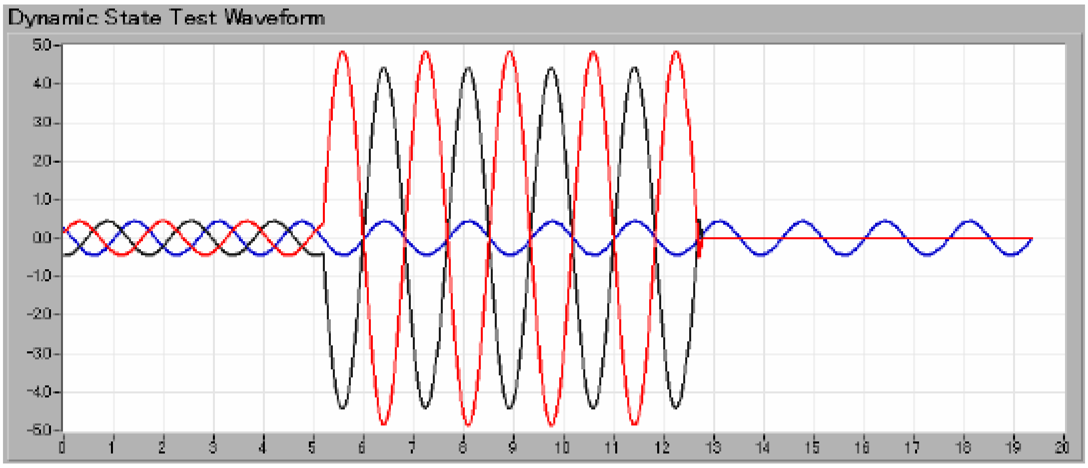

Fig. 3.2-Dynamic state test-without DC offset

This can be made complicated by using a DC offset which is dependent on the impedance of the system and the point at which fault occurs. Found rarely in the state-of-art relays. See the fig. 3.3.

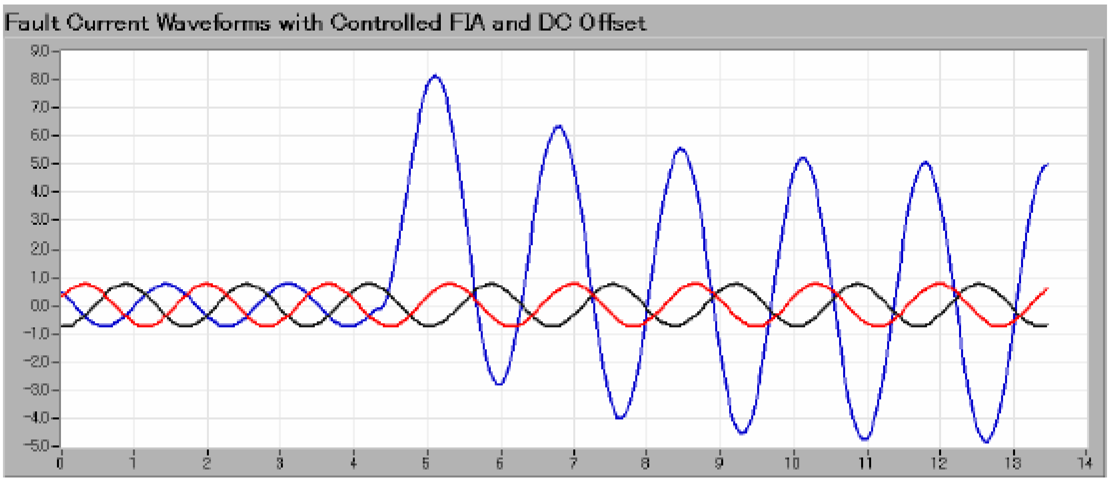

Fig. 3.3-Dynamic state with DC offset

3.3 Transient Test

By definition transient testing is, simultaneously applying fundamental and non-fundamental frequency components of voltage & current that represent power system conditions obtained from digital fault recorders (DFR) or electromagnetic transient programs (EMTP) to a relay.
Both Dynamic state and transient test can be stated as far better than steady state test.

4. Testing Principles

There are two main principles as primary injection and secondary injection.

- Primary injection- High current is injected to primary side of the CT. Test carried out covers CT, conductors, relay and sometimes circuit breaker as well. The relay unit has to be isolated from the power system. Usually this principle is used at commissioning and also if the secondary of the CT is not accessible.
- Secondary injection- Relay is disconnected from the CT and the stepped down current is directly injected to relay. Therefore no need the primary side of the CT to be disconnected from the rest of the system.

5. Computer Aided Relay Testing

Instead of testing a relay function manually a computer program is used to test the same. There are many reasons why the testers have drifted from manual testing to automated, such as

- Many modern microprocessor relays can't be tested with slow speed of amplifier injection.
- Due to lack of speed, the relay will have to be in heat for a longer duration, results more stresses.
- Since the type of tests, test procedure, frequency etc. are decided by the computer, tester need not be an expert.
- Maintenance of uniformity.
- Test report format is available

Fig. 5.1 shows how automated testing is done. We need amplifier to apply 3 phase currents and voltages to the relay. Communication between the amplifiers and the pc is governed by IEEE 488 interface bus [2].

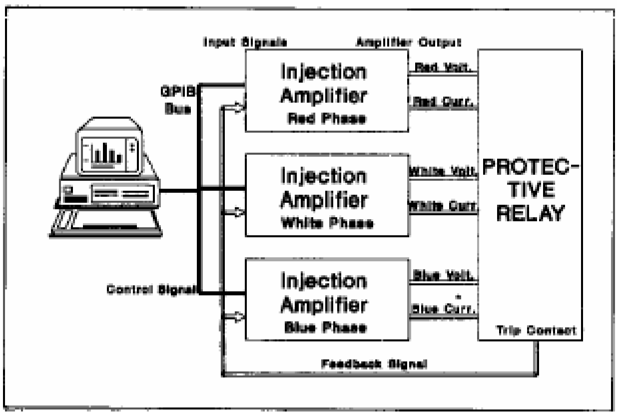

Fig. 5.1- Hardware configuration for computer aided testing

Computer aided test can be two of kinds.

- Model specific- This kind of program is to check a particular type of relay. It actually checks all the functions of the particular relay produced by a certain manufacturer. This governs the uniformity, and test results can be stored to find the trends.
- Application specific-This is a kind of program used to check the primary side of CT, i.e. the actual circuit relay is protecting and the system around it. No focus is given to relay and its functions.

The main drawbacks of automation of testing are lack of flexibility and high cost.

6. Testing Process

Fig. 6.1 shows a flow chart of the test procedure.

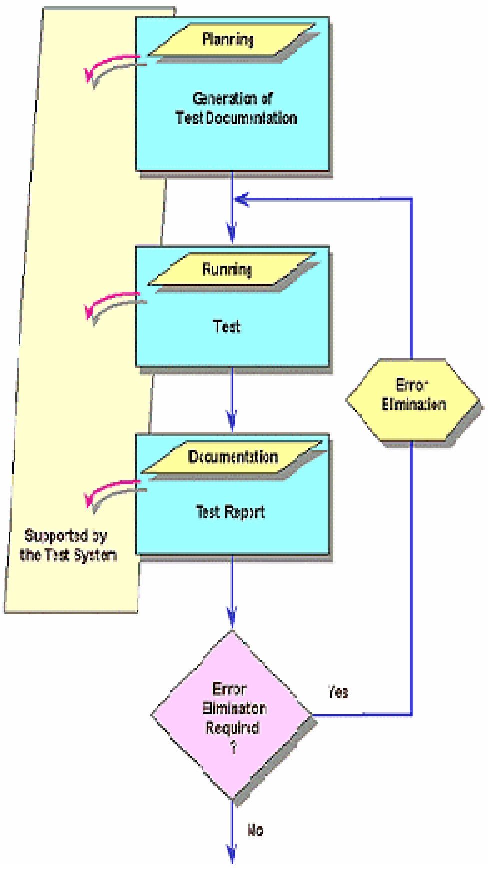

Fig.6.1-Test Process flow chart

Planning phase: At this stage the tester will decide which tests to be carried out and what kind of test data to be recorded for decision making as well as for future auditing. The necessary test sheets will be prepared, annex1.

Running phase: This is the actual point of implementing the test. It should be noted never to open circuit an energized CT, so that no over voltages will be built and damage personnel and property [4]. by running preliminary tests like CT test, polarity test, ratio test etc. Then the real test should be carried out as per the manufacturers guide lines.
Documentation phase: This is also very important as it tells and stores date for decision making. Most test systems used nowadays provides Taylor made report.

7. Modern Relay Test Systems

7.1 Freja 300
Over the time relay technology has evolved so has the testing. Many manufacturers have developed a variety of computer aided testing systems for latest microprocessor relays. Freja 300 is one of the most famous, made by General Electricals (GE) see fig 7.1.

Fig. 7.1 Freja 300

It can operate even without a pc. Principle behind it is secondary inject. It has the capability of generating voltages & currents inputs, 4x150 V (82 VA) and 3x15 A (87 VA). Each input to the relay can be modified independently of the other.
It can either create the simulated disturbances or call store actual disturbance data stored in EMTP files. Another advantage is test system can be applied to almost all the kinds of relays as, IEEE 21, IEEE50, IEEE51, IEEE 87 etc.

7.2 Pulsar

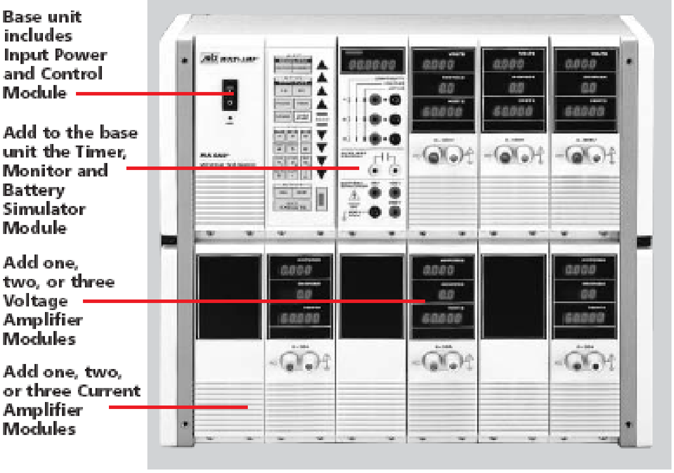

Fig. 7.2 Pulsar

This is another example of a highly intelligent test system, which is a product of Megger.

Reference:

[1] "Troubleshooting Protective Relay Operations Using Field Recorded Waveforms" by M. Kezunovic, *Fellow, IEEE*, H. DoCarmo, *Member, IEEE*, T. Roseburg, *Member, IEEE*, M. Hofmann, *Member, IEEE*, T. Popovic, *Member, IEEE*
[2] "Relay Specific Computer Aided Testing for Protective Relays" by K.C.A. Dierks, Eskom, Republic of South Africa.
[3] Freja 300 Relay test system manual.
[4] IEEE Std. C37.103-2004, IEEE guide for Differential and Polarizing Relay circuit Testing

Annex 1-A Test Sheet for Differential Relay Test

PO&M-101 (5/56)
Bureau of Reclamation

DIFFERENTIAL RELAY TEST REPORT

LOCATION.......... CIRCUIT.......... DATE OF TEST..........
RELAY MFR.......... TYPE.......... STYLE OR MODEL No..........
RELAY RATING:
TAPS.......... AMPERES. % SLOPE..........

C.T. MARKED RATIOS.......... ACTUAL RATIOS..........

	PHASE A	PHASE B	PHASE C
RELAY SERIAL No.			
RELAY SETTING:			
TAP - AMPERES			
SLOPE - %			
MINIMUM PICK-UP CURRENT TESTS:			
RESTRAINING COIL No.1 AMPS.			
RESTRAINING COIL No.2 AMPS.			
RESTRAINING COIL No.3 AMPS.			
OPERATING COIL AMPS.			
MEDIUM PICK-UP CURRENT TESTS:			
RESTRAINING COIL No.1 AMPS.			
RESTRAINING COIL No.2 AMPS.			
RESTRAINING COIL No.3 AMPS.			
OPERATING COIL AMPS.			
HIGH PICK-UP CURRENT TESTS:			
RESTRAINING COIL No.1 AMPS.			
RESTRAINING COIL No.2 AMPS.			
RESTRAINING COIL No.3 AMPS.			
OPERATING COIL AMPS.			
OVERCURRENT OPERATING TESTS:			
A. RESTRAINING COIL No.......AMPS.			
OPERATING COIL AMPS.			
OPERATING TIME - CYCLES			
B. RESTRAINING COIL No.......AMPS.			
OPERATING COIL AMPS.			
OPERATING TIME - CYCLES			
CURRENT BALANCE FOR THRU PRIMARY CURRENT:			
CIRCUIT No.1 AMPS.			
CIRCUIT No.2 AMPS.			
CIRCUIT No.3 AMPS.			
DO RELAYS TRIP ALL CONNECTED DEVICES?			
DO OPERATION INDICATORS OPERATE?*			
DO AUXILIARY CONTACTS OPERATE?*			

*RECORD MINIMUM PICK-UP AMPS

NOTE: ALL DATA ARE FOR CONDITION AS LEFT UNLESS OTHERWISE NOTED.

PO&M-101 - Differential relay test report

TRIP CIRCUIT MEASUREMENTS:

MINIMUM AMPS. TO TRIP________________ TOTAL RESISTANCE__________ OHMS AT________°C

RESISTANCE OF TRIP COIL ONLY________________________________ OHMS AT________°C

MAIN CONTACT GAP CLEARANCE____________________ INCHES

GENERAL CONDITION OF RELAYS AS FOUND:

DUST OR DIRT INSIDE OF RELAYS?____

CONDITION OF CONTACTS?____

CONDITION OF PIVOTS?____

STICKING OR BINDING OF MOVING PARTS?____

MAGNETIC PARTICLES IN AIR GAP?____

CONDITION OF COILS?____

WHAT MAINTENANCE OR REPAIRS WAS FOUND NECESSARY?____

WHAT CHANGES WERE MADE IN SETTINGS AND C.T. RATIOS?____

REMARKS:____

TESTED BY:________________________________ ASSISTED BY:________________________________