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Overcurrent Protection of Feeder Using Numerical Relay

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Abstract— Short circuits occur in power systems when equipment insulation fails, due to system overvoltages caused by lightning or switching surges, to insulation contamination, or to other mechanical and natural causes. Careful design, operation, and maintenance can minimize the occurrence of short circuits but cannot eliminate them. Such short-circuit currents (for balanced and unbalanced faults) can be several orders of magnitude larger than normal operating currents and, if allowed to persist, may cause insulation damage, conductor melting, fire, and explosion. Windings and busbars may also suffer mechanical damage due to high magnetic forces during faults. Clearly, faults must be quickly removed from a power system. Hence, proposed journal deals with removal of fault by sensing overcurrent element using Numerical Relay REF615, meant for Feeder Protection. Along with Overcurrent Protection few more protection schemes such as CB Failure Protection and Trip Circuit Supervision (TCS) are also described here. Moreover, Relay Status can also be detected i.e., whether healthy or unhealthy. When we say that system has to be protected against fault, then it means to disconnect faulty part from healthy one by opening CB of corresponding feeder section. In case of CB failure i.e., when Main CB (downstream CB) fails to operate, Backup CB (upstream CB) must be operated after predefined time interval.

Keywords— Circuit Breaker, Fault, Feeder, IEC 61850, Network, Overcurrent, Protection, REF615, Relay, Substation.

I. INTRODUCTION

Protection systems have three basic components:
1. Instrument transformers
2. Relays
3. Circuit breakers

Below figure shows a simple overcurrent protection schematic with:

(1) One type of instrument transformer- the current transformer (CT),
(2) An overcurrent relay (OC), and
(3) A circuit breaker (CB) for a single-phase line.

The function of the CT is to reproduce in its secondary winding a current I' that is proportional to the primary current I. The CT converts primary currents in the kiloamp range to secondary currents in the 0–5 ampere range for convenience of measurement, with the following advantages.

- Safety: Instrument transformers provide electrical isolation from the power system so that personnel working with relays will work in a safer environment.
- Economy: Lower-level relay inputs enable relays to be smaller, simpler, and less expensive.
- Accuracy: Instrument transformers accurately reproduce power system currents and voltages over wide operating ranges.

The function of the relay is to discriminate between normal operation and fault conditions. The OC relay in Figure has an operating coil, which is connected to the CT secondary winding, and a set of contacts. When | I'| exceeds a specified ''pickup'' value, the operating coil causes the normally open contacts to close. When the relay contacts close, the trip coil of the circuit breaker is energized, which then causes the circuit breaker to open.

Note that the circuit breaker does not open until its operating coil is energized, either manually or by relay operation. Based on information from instrument transformers, a decision is made and ''relayed'' to the trip coil of the breaker, which actually opens the power circuit - hence the name relay.

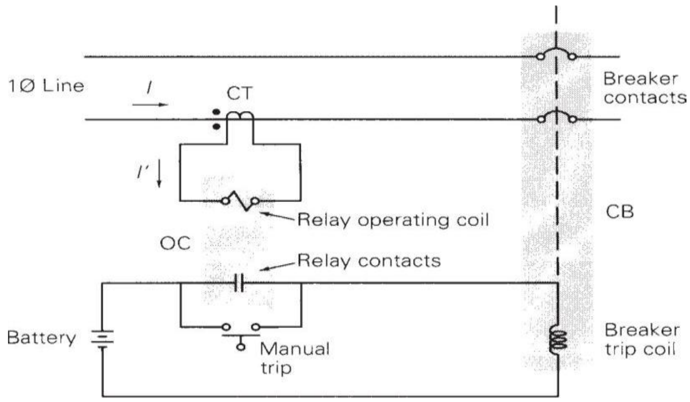

Figure 1. Overcurrent Protection Schematics

In order to fulfil the requirement of protection with the requirement of profitable operation, any protection system is required to satisfy the 5-S principles listed below:

- Security
- Sensitivity
- Speed
- Selectivity
- Stability

II. Relay Technology

In this section, the author describes the previous research works in the form of title, problem statement, objectives, not repeat the information discussed in Introduction. The electromechanical relay in all of its different forms has been replaced successively by static, digital and numerical relays, each change bringing with it reductions in size and improvements in functionality. Reliability levels have also been maintained or even improved and availability significantly increased due to techniques not available with older relay types.

Electromechanical Relays: - These relays were the earliest forms of relay used for protection of Power System. They work on principle of mechanical force causing an operation of relay.

Static Relays: - These relays don't have moving parts. The design of static relays is based on the use of Analog Electronics instead of coils and magnets to create relay characteristics.

Digital Relays: - To implement the relay functions, Analog Circuits used in static relays are replaced with Microprocessors and Microcontrollers in digital relays.

Numerical Relays: - These relays can be viewed as natural developments of digital relays as a result of advances in technology. These relays use DSP processor as a computational hardware, together with the associated software tools.

Here ABB's Numerical Relay REF615 is used. REF615 is a dedicated feeder protection and control Relay designed for the protection, control, measurement and supervision of utility substations and industrial power systems including radial, looped and meshed distribution networks with or without distributed power generation. REF615 is a member of ABB's Relion product family and part of its 615 protection and control product series. The 615 series relays are characterized by their compactness and withdrawable unit design.

Re-engineered from the ground up, the 615 series has been designed to unleash the full potential of the IEC 61850 Standard for communication and interoperability between substation automation devices.

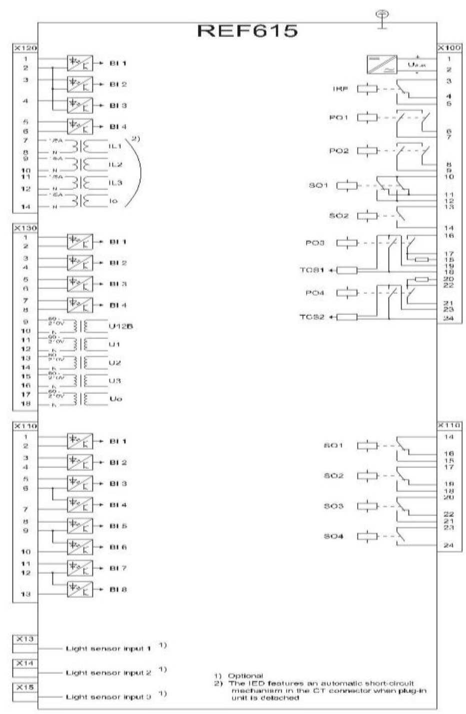

Figure 2. Terminal Diagram

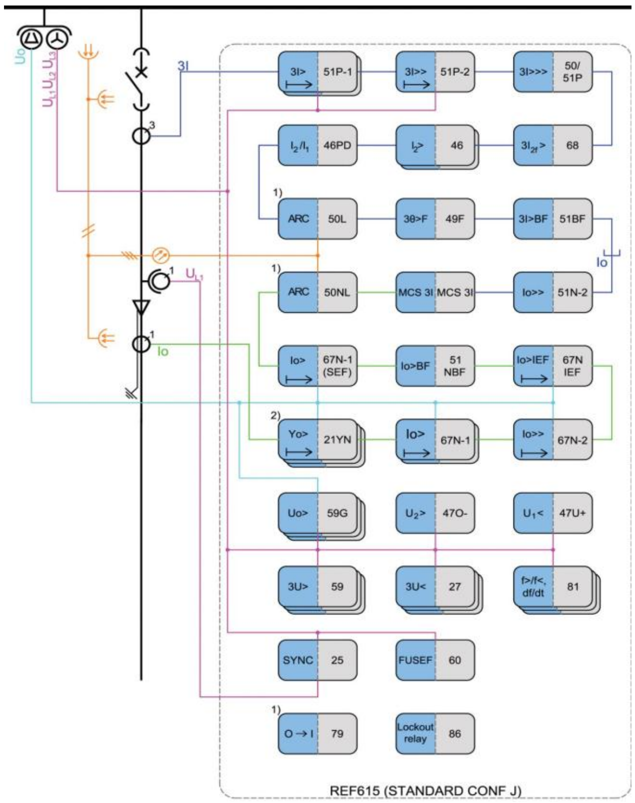

Figure 3. REF615 (Standard Conf. J)

III. Power Circuit

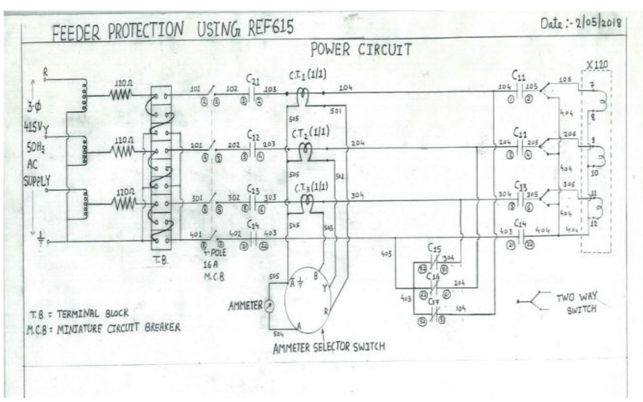

Figure 4. Power Circuit

As shown in above figure prototype of Real time Protection scheme for 3 phase feeder is developed by using 3 phase autotransformer as incomer 3 phase supply source. Here circuit for secondary injection is made (i.e., relay is connected directly to source and not from CT secondary) also called "Relay Testing Circuit".

Now 3 phase 4 wire from autotransformer is connected to the terminal block from where all control panel connections are taken/started. Contactors are used in place of circuit breaker that disconnects the feeder from load during fault conditions. Upstream breaker C2 is connected to the source side as a backup of downstream breaker C1 which is connected to the load side. (Here as secondary injection is made relay is present instead of load.)

Before C1 connections, 3 phase short circuiting facility (thus making relay bypassed) is provided so as to measure feasible current from ammeter before injecting current directly to relay. Current for all 3 phases are measured using CT connections along with Ammeter Selector Switch (ASS). Thus at first C2 is made close and measurement of current is done by ammeter by keeping relay bypassed. Now when suitable current is recorded, injection is made ON to relay by closing C1 contacts at same time opening short circuiting NC contacts.

IV. Control Circuit

Now as we have seen Power Wiring, now let us move on to it's controlling i.e., making CB open or close as and when required.

The following sequence of operations must be followed so as to have reliable and actual operation of Feeder Protection.

- C2 is made close and value of current is to be measured.
- Then C1 is made close so as to make Injection ON.
- Now, in case of undesired situation C1 has to open making relay Bypassed.
- In case C1 (downstream breaker) fails to operate, C2 (upstream breaker) has to be open as that happens in actual System Protection.

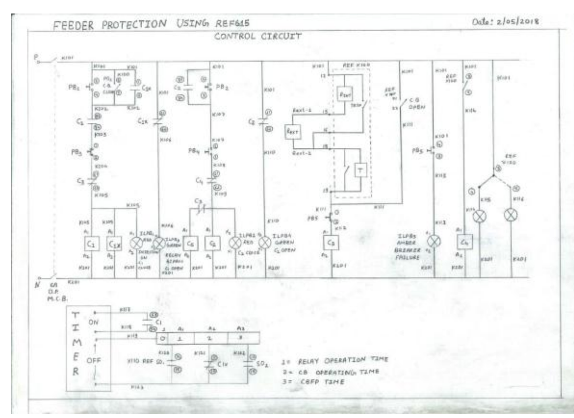

Figure 5. Control Circuit

As shown in above figure, PB1 and PB2 is used to energise coils of C1 and C2 respectively. Latching is provided by keeping respective NO contacts in parallel with PB. NO contact of C2 is kept in series with PB1 so that C1 closes only when C2 is closed. C1 can also be closed by relay command “CB Close”.

Red LEDs are connected across coils to indicate CB Close. CB Open is indicated by Green LEDs, keeping it in series with their respective NC contacts. Thus status of both CBs can be known.

PB3 and PB4 is used to manually open C1 and C2 respectively. Opening of C1 and C2 through relay can be accomplished by operating C3 and C4 contacts respectively. When CB Open / TRIP command is given, C3 energises making C1 open. When TRBU (Back Up trip) command is given C4 energises making C2 open.

PB5 is used to demonstrate Main CB Failure i.e., pressing PB5 and giving relay command to trip C1, should not trip C1 at all as now C3 remains de-energised and would not open C1. In this case TRBU command is used that open C2 (Upstream Breaker). This is known as CBPF i.e., Circuit Breaker Failure Protection. When PB5 is pressed it is shown by Amber LED (ILPB).

Timer connections are made in such a way so as to have any one time out of relay operating time, CB operating time and CBFP time, which is achieved by Timer Selector Switch. Moreover, Relay Healthy and Unhealthy conditions are indicated by White LED (connected between 5 & neutral) and Amber LED (connected between 4 & neutral) respectively.

V. TESTING

Before doing final panel mounting and hardware connections, control circuit is tested at first. Here control circuit is first connected roughly, then single phase 50Hz AC power supply is given to the control circuit after which circuit is tested for following actions.

- C2 and C1 open
- C2 close and C1 open
- C2 and C1 close
- Main CB (C1) Failure

C2 and C1 open: - CB open is indicated by green LED (see control circuit). Here supply is given to the control circuit and neither of PB1 or PB2 is pressed i.e., both C1 and C2 is off (open).

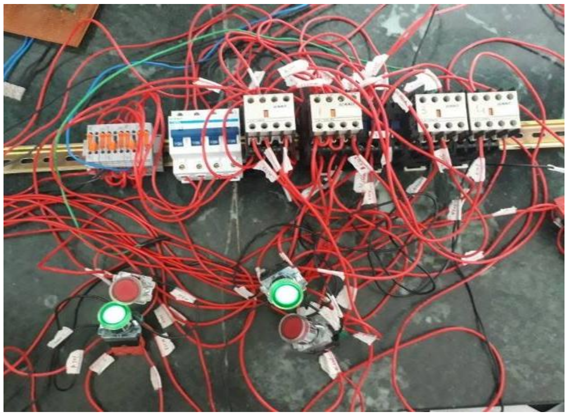

Figure 6. Control Circuit with C2 and C1 open

C2 close and C1 open: - CB close is indicated by red LED (see control circuit). Here PB2 is pressed once, so that upstream breaker C2 gets closed (ON).

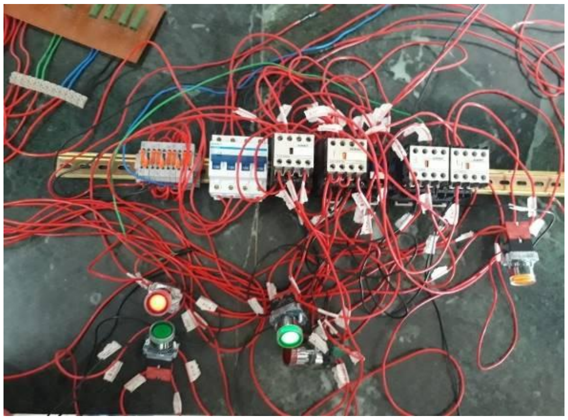

Figure 7. Control Circuit with C2 close and C1 open

C2 and C1 close: - As C2 is closed, now PB1 is pressed, so that C1 also gets closed and now both CBs are in service, making injection ON to relay

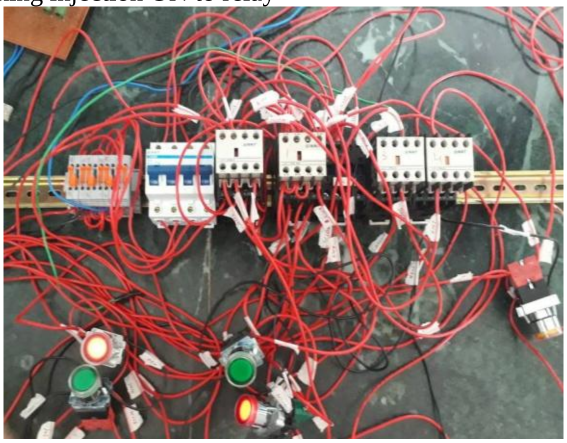

Figure 8. Control Circuit with C2 and C1 close

Main CB (C1) Failure: - Main CB is made fail to operate even when relay gives signal, by pressing PB5 (see control circuit).

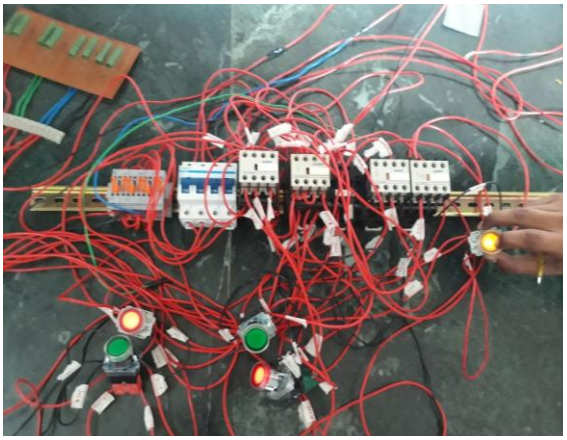

Figure 9. Control Circuit with C1 fail

VI. HARDWARE

Now after doing testing, mounting of components is done on wooden panel.

Push buttons, variable pot, supply terminals, meters, selector switches, bypass switches, relay is kept in front side of panel whereas contactors, MCBs, CTs, D-Link, Terminal Block is kept at back side.

Figure 10. Component Mounting on Panel

Now as mounting of components is done, final wiring of power and control circuit is done at back side. Power Wiring is done by 1.5 sq. mm wire while Control Wiring is done by 0.75 sq. mm grey wire, as is done in Industrial Control Panel.

Ferrule numbers are also provided according to circuit diagram so as to have ease of connections and to minimize chances of mistakes during wiring. Ferrule numbers of Power Wiring and Control Wiring is differentiated by providing alpha-numeric values starting with 'k' to the control circuit.

At last all wiring is enclosed in PVC channel also known as Trough. See fig below.

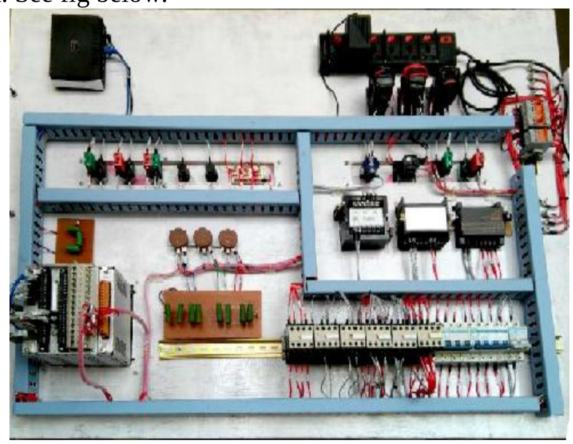

Figure 11. Final Connections at back side of Panel

VII. RESULTS AND DISCUSSION

At first CT Ratio is set i.e., primary to secondary current. Then set values for respective protection functions is set in terms of their nominal values.

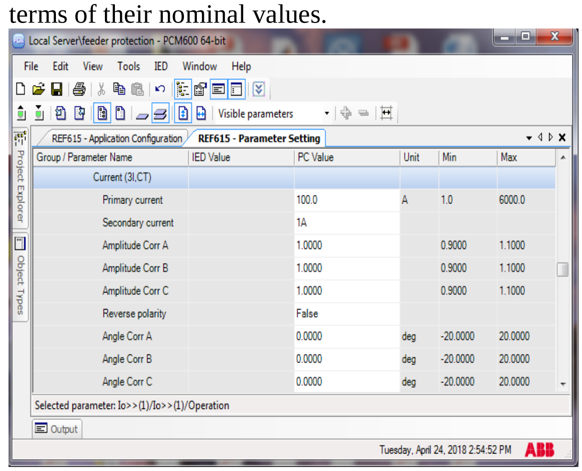

Figure 12. CT Ratio

Here relay configurations are set by PCM600 tool. CT Ratio as well as set values can be set through this software tool also.

For current protection, in order to have results (to trip CB for overcurrent) it is necessary to give current value above set point which is given by variac and trip current value & time taken is noted

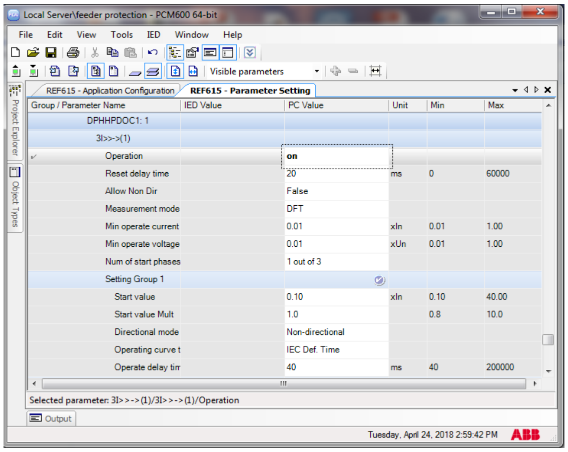

Figure 13. OC Set Values

Figure 14. OC Fault Record

VIII. CONCLUSION AND FUTURE SCOPE

With the help of this project, we can demonstrate major fault that occur in the power system i.e., overcurrent. In addition to this, relay status can also be known. Moreover, back up protection scheme in case of Main CB failure is also available.

Main component of project is Numerical Relay. Different characteristic curves like Inverse, IDMT, Definite etc., all for different standards like IEC, ANSI etc. is available in Numerical Relay REF615. The setting can be done in local HMI, web HMI or through PCM600. Start value, current & voltage ratio, time delay and many more can be set according to system requirement.

Thus, modern numerical relay offer innumerable features as compared to static and electromechanical protection system. These are given below.

- Protection is enhanced due to their complex, multiple protection characteristic.
- Self-check feature improves the protection system reliability.
- Communication capability makes the numerical protection system more intelligent and provides valuable information to the user.

Hence for complex, reliable, multi-functional requirement numerical relays shall be used.

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