American International University- Bangladesh

Department of Electrical and Electronic Engineering

EEE4227: Power System Protection Laboratory

Title: Study of the performance of O/C relays for backup protection and directional relays.

Performance of backup protection by O/C relyas

Introduction:

The objective of protection is to remove only the affected portion of plant and nothing else. A circuit breaker or protection relay may fail to operate. In important systems, a failure of primary protection will usually result in the operation of back-up protection. Remote back-up protection will generally remove both the affected and unaffected items of plant to clear the fault. Local back-up protection will remove the affected items of the plant to clear the fault.
The primary objective of back-up protection is to open all sources of generation to clear a fault on the system. To accomplish this objective, an adequate back-up protective system must meet the following functional requirements:

1. It must recognize the existence of all faults which occur within its prescribed zone of protection.
2. It must detect the failure of the primary protection to clear any fault as planned.
3. In clearing the fault from the system, it must
    a. Initiate the tripping of the minimum number of circuit breakers.
    b. Operate fast enough (consistent with coordination requirements) to maintain system stability, prevent excessive equipment damage, and maintain a prescribed degree of service continuity.

Theory and Methodology:

Back-up protection may be obtained automatically as an inherent feature of the main protection scheme, or separately by means of additional equipment. Time graded schemes such as over current or distance protection schemes are examples of those providing inherent back-up protection; the faulty section is normally isolated discriminatively by the time grading, but if the appropriate relay fails or the circuit breaker fails to trip, the next relay in the grading sequence will complete its operation and trip the associated circuit breaker, thereby inter-rupting the fault circuit one section further back. In this way complete back-up cover is obtained; one more section is isolated than is desirable but this is inevitable in the event of the failure of a circuit breaker.

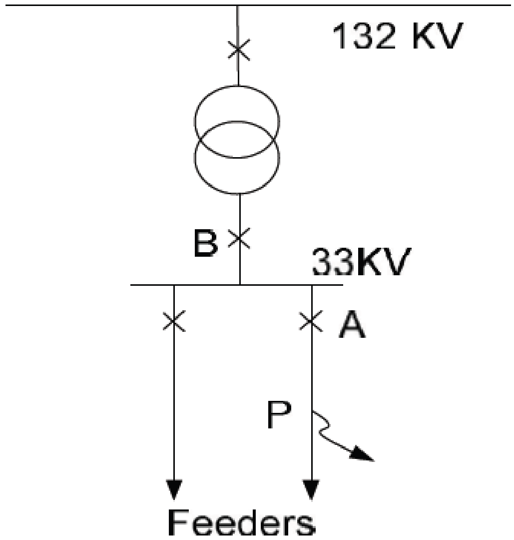
Where the system interconnection is more complex, the above operation will be repeated so that all parallel infeeds are tripped. If the power system is protected mainly by unit schemes, automatic back-up protection is not obtained, and it is then normal to supplement the main protection with time graded over current pro-tection, which will provide local back-up cover if the main protective relays have failed, and will trip further back in the event of circuit breaker failure.

Such back-up protection is inherently slower than the main protection and, depending on the power system configuration, may be less discriminative. For the most important circuits the performance may not be good enough, even as a back-up protection, or, in some cases, not even possible, owing to the effect of multiple infeeds. In these cases duplicate high speed protective systems may be installed. These provide excellent mutual back-up cover against failure of the protective equipment, but either no remote back-up protection against circuit breaker failure or, at best, time delayed cover.

Breaker fail protection can be obtained by checking that fault current ceases within a brief time interval from the operation of the main protection. If this does not occur, all other connections to the bus bar section are interrupted, the condition being necessarily treated as a bus bar fault. This provides the required back-up protection with the minimum of time delay, and confines the tripping operation to the one station, as compared with the alternative of tripping the remote ends of all the relevant circuits.

The extent and type of back-up protection which is applied will naturally be related to the failure risks and relative economic importance of the system. For distribution systems where fault clearance times are not critical, time delayed remote back-up protection is adequate but for EHV systems, where system stability is at risk unless a fault is cleared quickly, local back-up, as described above, should be chosen.

In this experiment, the back up protection of a radial feeder as shown in the figure is considered.



Normally for fault at P on one of the two feeders, the O/C relay at A and relay at B should pick up the fault but CB at A should be clear the fault first. Here the fault is being sensed by the relay at A correctly but the CB at A fails to clear the fault. So, after some delay the relay at B closes its contacts and CB at B will clear the fault. It means the relay at B provides the back up protection for breaker failure at A.

Pre-Lab Homework:

Study and clear concept of relay characteristics, primary protection and backup protection.

Apparatus:

1) Relay Module
2) Instruction Manual

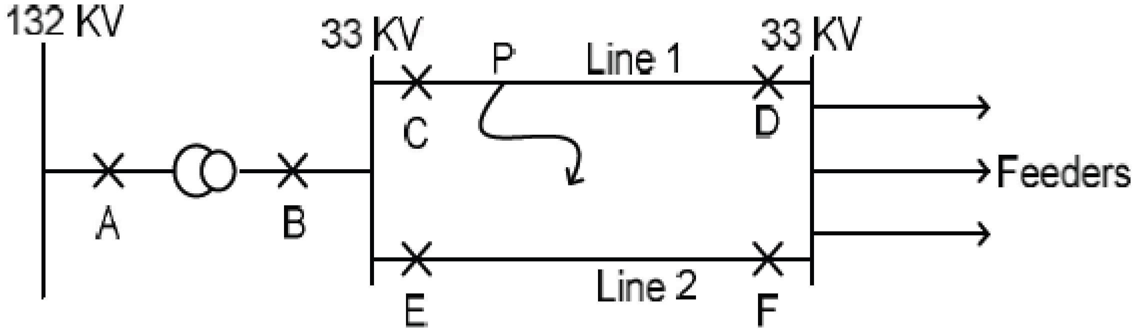
Precautions:

1) Do not touch the bare conductors or connecting junctions.
2) Do not switch on/off anything in the circuit without following the hierarchy.
3) Be careful of handling small equipment /instruments inside the relay module if necessary.

4) Be careful when power is supplied to the module and any casing is kept open.

Experimental Procedure:

A section of the power system, set up by the test bench in the lab, is shown in figure:



The line 2 is de energized by opening the CB E and F at the two ends of the line. Then apply a ground fault at P on the line 1. O/C relay at B and C detect the fault. But the breaker at C should clear the fault first. Since the breaker at C is deliberately disabled, the relay at B, after some delay will be operated and trips the breaker at B.

Performance of directional relays

Introduction:

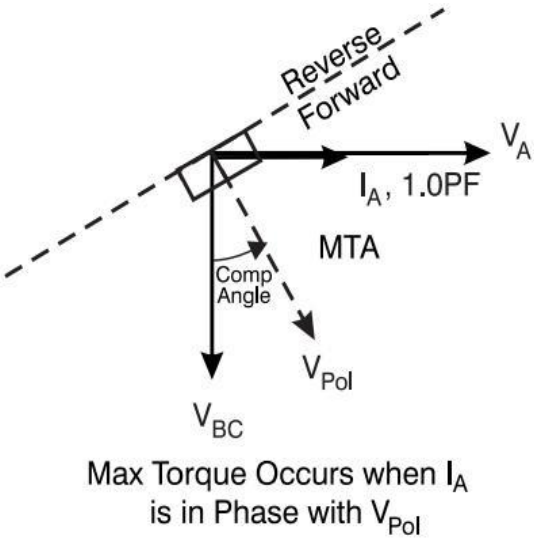
In some medium voltage distribution lines and almost all high voltage transmission lines, a fault can be in two different directions from a relay, and it can be highly desirable for a relay to respond differently for faults in the forward or reverse direction.

Directional relay senses direction of power flow by means of phase angle between V and I. When this angle exceeds certain predetermined value, the directional relay operates if, of course, the current in the relay current coil is above pick up value. A directional relay is a double actuating quantity relay with one input as current I from CT and the other input as voltage, V from PT.

With the electromagnetic directional O/C relays, discrimination is affected when the voltage drops down to a low value due to faults close to the location of PT. With static or digital directional O/C relay, the static relay can function well up to 1% of the system voltage.

Theory:

The classic electromechanical and solid state relay, as well as some common numeric relays, determines the direction to fault by comparing the phase angle relationship of phase currents to phase voltages. If only per phase watt flow is to be considered, the basic concept would be that if IPh is in phase with V_{Ph-N} (0°, ±90°), then power flow on that phase is indicated as forward (or reverse, depending on one's perspective). However, for a phase to ground fault, the V_{Ph-N} may collapse to 0, and I may be highly lagging, so that V_{Ph-N} x IPh may be mostly VAR flow, and thus prevent the relay from making a correct directional decision. To resolve the low voltage issue, quadrature voltages (i.e., V_{BC} vs. I_A) are commonly used. To resolve the issue that fault current is typically highly lagging, the relay current vs. voltage detection algorithm is skewed so that the relay is optimized to detect lagging current conditions rather then 1.0 power factor conditions. One approach is to phase shift the voltage signal so that the relay's internal voltage signal ($V_{Polarity}$, abbreviated as V_{Pol}) is in phase with current when current lags the 1.0 power factor condition by some setting, typically between 300 and 900. The angle setting is commonly referred to as the maximum torque angle, MTA. In some designs of this concept, the current signal is skewed rather than the voltage signal. In some designs, other phase voltages are used. For instance, I_A could be compared to V_{AB}, V_{CA}, V_{BN}, or V_{CN}, and the detection algorithm would work, though the quadrature voltage V_{BC} gives the most independence of the voltage signal from the effects of an A-N, A-B, or A-C fault.



Classic $V_{Quadrature}$ Directional Element

The response to a phase to ground fault is fairly apparent because the quadrature voltages are assumed to be relatively unaffected by the faulted phase currents. However, for a phase to phase fault, the quadrature voltages are affected.

Pre-lab Homework:
Study and clear the concept of directional relay protection characteristics.

Apparatus:

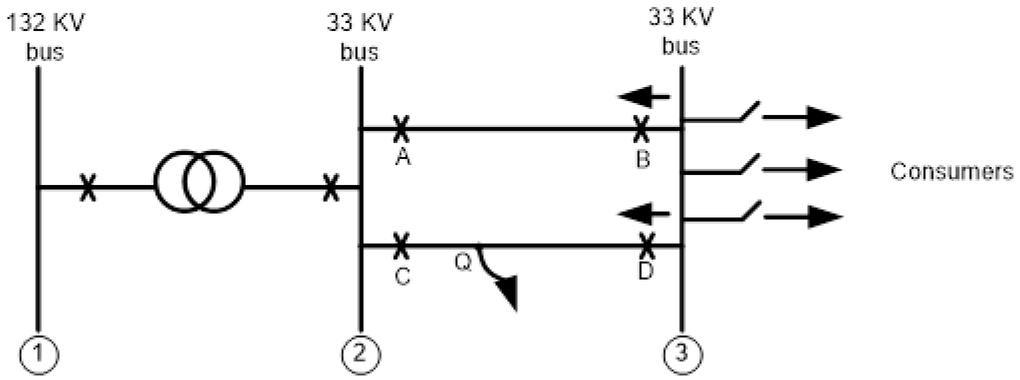
- Relay Module
- Instruction Manual

Precautions:

- Do not touch the bare conductors or connecting junctions.
- Do not switch on/off anything in the circuit without following the hierarchy.
- Be careful when power is supplied to the module and if any casing is kept open.

Experimental Procedure:

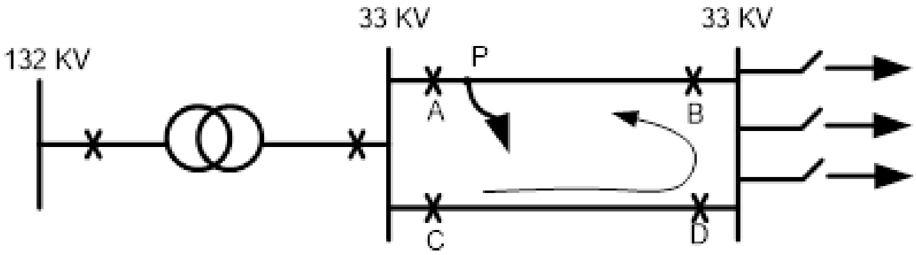
The following figure shows the single line diagram of a power system which feeds 33 KV consumers of bus 3. The bus 3 is fed from bus 2 at 33 KV through two circuits in parallel. There are two breakers and associated relays at the two ends of each circuit. These relays are A & B and C & D as shown in the figure. Of these, A&C are non-directional O/C relays whereas B and D are directional O/C relays.



When the fault current flows through the relays B and D in the direction of arrow as shown in the figure, the relays operate and trip associated breakers.

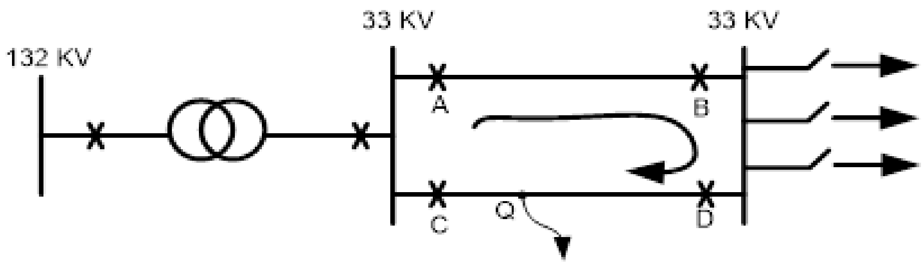
Case I

For a fault at P on one of the circuits, the direction current flow is as shown in the following figure.



Under this fault condition, the non-directional relay A and directional relay B operate and trip the associated breakers to isolate the fault.

Case II
For a fault at Q in the other circuit, the direction of current flow is as shown in the following figure.



Under the fault condition, the non-directional relay C and the directional relay D operate and trip the associated breakers to isolate the faulty circuit.

Conclusion:

The preliminary purpose of this experiment is to present the current ideas and practices used in providing backup protection using over-current relays on modern electric utility systems. A circuit breaker or protection relay may fail to operate. In important systems, a failure of primary protection will usually result in the operation of back up protection. Back up protection generally removes both the affected items of plant to clear the fault. For distribution systems where fault clearance times are not critical, time delayed remote back-up protection is adequate but for EHV systems, where system stability is at risk unless a fault is cleared quickly. Another prime objective of the expperiment is to observe the functionality of directional relay. To percive the secondary objective of directional relay one parallel feeder is beign selected and intentional faults are applied nd it has been verified that due to the presence of the directional relays appropriate line is being cleared.In lab, one single module is used to fulfill the overall goals of the experiments. The module displays the occurrence of a fault and the scenario after the faults have been cleared. Students are advised to observe these processes carefully since numerical calculations are absent in this experiment.

Report:

1. Explain your observation about the performance of the relay.
2. Explain how close up faults affects the relay operation.
3. If one of the terminals of the PT supplying relay Voltage coil, is open what will happen?
4. Explain why there are two actuating quantities in a directional relay.

References:

[1] John Horak, “Directional Overcurrent Relaying Concepts”, Basler Electric, April 2005.

[2] “Switchgear Protection and Power Systems” by Sunil S Rao

[3] PSP previous lab sheet

[4] Internet

[5] “Electric Power Systems: A Conceptual Introduction” by Alexandra Von Meier