Efficiency of that relay coordination analysis engineering essay

The main intention of any electrical utility company is to deliver power with better quality and one of the most important sections is the electrical distribution system. Selective coordination for the protective devices is really important and should be analysed for the reliability of the electrical distribution system. In this project, relay coordination analysis has been performed using ETAP software and described the whole process in details. First of all, a general one line diagram was constructed and the protective devices such as relay, fuse, and circuit breaker were implemented to the circuit. Then, to analyse the effect of relay coordination, Star - Protective Device Coordination analysis was performed and the selective coordination is identified.

Protective devices such as relay, circuit breaker and fuse are designed to assign electrical protection to the electrical network as it is sure that fault or failure will occur in the network. Therefore, these protective devices work together to protect the transmission and distribution network [1]. Protective device like protective relay must quickly identify fault occurrences in the network and shut away these occurrences from the rest of the electrical network by triggering off circuit breaker operation. The relay should act quickly as to minimize the damage to the system as well as the personnel. Other than that, the fault also will interrupt the service to the consumer. Circuit breaker will work with the relay to perform the function of detection and disconnection of the faulty region. So, the coordination of the protective devices in electrical network is a vital and must be investigated.

The combination function of protective relay and circuit breaker are designed to serve the protection for the high voltage transmission and distribution

network in electrical system. The protective relay will detect the abnormal condition and send the information to the circuit breaker to trip and clear the fault. So, in relay coordination two principles have to be applied to ensure the coordination can be applied. The first principle is the protective relay should clear the fault that only occurs in its zone protection and the second principle is the relay should not trip outside its zone protection, apart from backing up a failed protective device [2]. According to these two principles, the electrical network can ensure that the power can be delivered to the customer in a right way and the unnecessary power loss can be avoided to the other customer in another line and in case of the protection system such as protective relay and circuit breaker might fail, protection device indeed should acts as a backup to the other protective device in the same line or station with the time delay to achieve the coordination [2].

The coordination between the relay will ensure the backup protection has adequate time to let the primary relay and circuit breaker to clear the fault that occur in its zone. So, in relay coordination the circuit breaker in the downstream area of a network has to operate first prior to the fault and when it is fail to work properly the upstream circuit breaker will operate to isolate the affected area only. Thus, in relay coordination the setting of the relay play an important role in getting the selective coordination. Determining the appropriate setting for the relays is essential as it is a problem to coordinate the protective devices and the setting should met the requirement of selectivity, reliability, speed and sensitivity of a relay to be coordinated [3]. Then, each protective relay in electrical system has to be coordinated with other protective relay in adjacent to each other.

Relay coordination on the electrical network can be conducted using different types of power system software. In this project, various electrical networks have been modelled and relay coordination has been performed using ETAP 7. 5. 0. ETAP is very user friend software that delivers analysis innovation to a new level of advancement. Using this new user-oriented capability, the process of designing and evaluation of protective device coordination is significantly easier and faster. Therefore, the outcome of implementing the required power network on real life can be avoided

1. 2 Aim and Objectives

The aim of the project is to perform relay coordination on the existing conventional electrical system and an electrical network with distributed generator added to distribution network by using ETAP software. To accomplish this project, the study undergoes a list of objectives as shown below.

To understand the purpose of the relay coordination module in ETAP star protective device coordination.

Analyse relay coordination on these electrical network so that coordination can be achieved.

To identify the setting of the relay that can working at its efficient time to clear the fault from the system.

To create different types of electrical network which relay coordination is tested with this network.

To discover the impact of distributed generators to the protective relay coordination on distributor network.

All the objectives above will be evaluated using IEEE C37. 90 standard, which the relay standard and the relay system associated with the electrical power apparatus is synchronized correspondingly in ETAP software [4].

1. 3 Related Work

1. 4 Project Organization

CHAPTER 2

LITERATURE REVIEW

2. 1 History

First of all, the idea that contributes the relay to be invented was proposed and developed by several scientists. The scientists are Hans Christian Oersted, Joseph Henry, Samuel Finley Breese Morse and Thomas Alva Edison. The first industrial relay was invented by Lars Eriksson. He was the founder of the first telephone factory in Russia in 1897. So, the first manually operated telephone exchange using relay principle was innovated [5].

2. 2 Protective Devices

Protective devices are really important and are simply plugged to the electrical network to ensure the protective is served to the system, which otherwise can create a lot of problems when the protection is not installed. So, the protection is needed to reduce the damage and to ensure that a good power supplying can be established. Protection system will determine

the protection against short circuit current, overload current and temperature rise.

There are three-protection device used in electrical system

Relay

Circuit breaker

Fuse

2. 2. 1 Relay

Relay is used to protect the electrical network against the high voltage fault that will happen in the system. Relay will work by sensing the fault conditions and send the signal to the circuit breaker to trip and close the breaker to clear the fault [6].

Figure Circuit diagram of relay

The relay circuit connection to the electrical network plays an important role because it will measure the electrical quantities which are different for both normal and fault condition [7].

Relay connection can be break down as

The first part of the connection is the primary winding of current transformer (C. T) and it is connected in series with the line [7].

The second part is the relay coil and secondary winding of C. T [7].

Third part is the trip circuit of a relay and there is a source that supply the power to the circuit to trip the coil of circuit breaker to disconnect any fault that occur [7].

2. 2. 2 Circuit breaker

Circuit breaker is a mechanical switching device use to protect the electrical wiring, breaking, and carrying current under normal situation. It is also used to disconnect the power supply in case of under specified abnormal condition such as overload and short circuit (IEC 947-1) [8]. Circuit breaker is divided into two categories that are low voltage circuit breaker (LVCB) and high voltage circuit breaker (HVCB). A circuit breaker will serve the following functions to the customer [9].

Motor protection

Short circuit protection

Protection of installation

Disconnecting fault

Tripping indication

Remote switching

Circuit breakers have the capability to interrupt the short circuit current. So, this capability is divided in categories depending on the type of construction, and their capability to limit the short circuit current. Hence, the circuit

breaker can be classifies under current limiting type of circuit breaker and current-zero interrupting type of circuit breaker [9].

Figure A diagram of circuit breaker

2. 2. 3 Fuse

The fuse is an initial protective device. The fundamental component of a fuse is the link. The link of a fuse is a metal strip or wire that can melt to disconnect the supply of power to activate a safety system [10]. The fuse link is constructed so that heat produced for a normal current can be hold by the fuse's link and will melt when the current rise to a higher temperature [11] [10]. As the voltage and power magnitude in electrical appliances increase, fuse protection become deficient. So, this leads to the new development of more reliable protective devices such a relay and circuit breaker [12].

Figure Current and voltage during the operation of fuse [13]

In Figure 3 is the current characteristic of a fuse. So, let through current smaller than the peak current meaning there is current clamping. The operating time of the fuse is the added up of melting fuse time and arcing fuse time [13] [14].

2. 3 Principle types of relays

Protective relay is a protective device that measures the current, voltage, frequency and other electrical power quantities from the source to detect any abnormal condition [15]. There are two type of common relay that are electromechanical relays (EMR) which the contact of the relay opened or

closed by a magnetic force and the other type is the solid state relay (SSR) which there is no contact on the relay and switching is all done electronically [16] [17]. So, electromechanical relay has been used wide to serve the protection to the electrical network and are based on few basic operating principles [12] . Generally, electromechanical protective relay operates using either magnetic attraction or magnetic induction principles.

Following are the types of electromechanical relays:

Attracted-armature relays

Moving-coil relays

Thermal relays

Induction relays

Static relays

2. 3. 1 Attracted-armature relays

This relay operates both with a. c as well as d. c and this type of relay is the simplest type of relay. This relay operates using the movement of a piece of iron into the magnetic field produced by a coil on the relay [18]. In attracted armature relay type, there is a laminated electromagnet and a coil. This coil will produce a magnetic field which will attract the armature or a moving iron and the coil is energized by an operating quantity which is proportional to the current and circuit voltage [19]. The restraining force is produced by the spring to make the armature vibrate. As the force produced is proportional to the square of current, that is why this relay can be used with a. c and d. c

source [19]. In the abnormal situation, current through the coil will increase above the pre-set limit of a fault condition and the armature will attract. During this situation, the armature will make contact with the contacts of trip circuit and the circuit breaker will operate to clear the fault [19].

In a. c. electromagnetic relay, the electromagnetic force is divided onto two fluxes different in time phase but working simultaneously. If the electromagnetic force produced is always greater than the restraining force, then the armature will not vibrate. So, this problem can be avoided by providing shading in the electromagnet [17]. Other than that, this problem also can be settled by providing two windings on the electromagnet as the electromagnet will have a phase shifting circuit [17]. In order to re-set the back to normal after an operation, the current of the coil must be reduced to an appropriate amount. The ratio of operating to re-setting current level is known as the 'drop-off to pick-up ratio' or 'returning ratio' and formerly known as differential ratio [20].

Usually attracted-armature relays are used for:

Auxiliary relays

Signal relays [17]

Typical type of attracted armature relays

Hinged armature type

Plunger type

2. 3. 2 Moving-coil relays

A current carrying conductor in a magnetic field will produce a moving mechanism and acts as a 'motor' [18]. This is the basic of a relay and moving coil instruments. The moving coil instrument which is a rotary movement comprises of a coil. It is pivoted or suspended on an axis in its plane in order to rotate easily between the poles of permanent magnet [18]. So, the movement of the coil is very sensitive which is a little of energy only required to create operating force. The magnetic force usually is constant over the operating arc, so that the operating torque will be constant when a current is given and is independent of the coil position [20].

In general moving-coil relays are used for [12]:

To provide a high drop-off/pick up ratio.

In high speed protection schemes.

2. 3. 3 Thermal relays

The thermal relay has a heat sensitive element that connected in series with the motor load circuit and an overload heater. So, using this relay the higher the overload current, the quicker the heat sensitive element to be heated up and the faster the relay operates [5]. In the protective thermal relay for high current fault, an additional heater and a direct current are applied to the bimetal element. Sometimes, a current transformer also is used to supply the heat to the element. This action will break the circuit through the operating coil of the main contactor as the heat sensitive clement to open the overload relay contact and disconnects the power supply from the motor.

Since, the bimetal element takes time to heat up, the inherent time delay is used by the thermal overload relay to draw current at start without tripping the motor [21].

Induction relays

Basic induction motor principle is applied to the relay to operate base on induction principle. The moving conductor is placed between two magnetic fields to produce the torque displaced both in phase and time [20]. The torque is produced when there is an interaction of one alternating flux with another alternating flux that induced eddy current in the rotor. These two fluxes have same frequency but are displaced in time and space. So, this type of relay only uses a. c. quantities.

The types of the induction relays are:

Shaded pole type

Watt hour meter type

Induction cup type

The torque produced is proportional to the product of upper and lower fluxes and the sine of the angle between these two fluxes [19].

- Torque equation for induction type relay [19]

A maximum torque is produced when the angle between the fluxes is, proportional to and. The disc will continue to accelerate when the torque is

applied without control and only limited by friction. The disc can be controlled using two methods [12]:

Using a permanent magnet that will produce a braking force proportional to the disc speed which is its field passes through the disc. So, this controls the time characteristic of the relay.

Using a control spring which produces a torque proportional to disc angular displacement. This will determine the relay setting and control disc speed at low values of torque [12].

Typical application of the induction relays:

Shaded pole type

Wattmetric type

Overcurrent relay

Over/under voltage relay

Static relays

In this type of relay, all the function measurement and comparison are performed by static circuit and there is no moving part like electromagnet relay [22]. The static circuit uses components such as transistor, diodes, resistor, and capacitor and so on [23]. So, the change from the electromechanical relays to static relays is very slow because of the relative costs.

There are three terms for the static relays [22]:

Static relay - in this relay the designed response is developed by magnetic and electronic without mechanical motion.

Static relay with output contacts - this relay has a contact in one or more of its output circuit.

Static relay without output contacts - this relay has no contact in its output circuit.

2. 4 Fundamental requirement of protective relay

The principle function of protective relay is to clear the fault quickly when there is abnormal condition happened. In order for the protective relay to perform this function satisfactorily, it should have the following qualities:

Selectivity or discrimination

Sensitivity

Speed

Reliability

Stability

Simplicity

Economy

2. 4. 1 Selectivity or discrimination

It is the ability of the protective system to select correctly the fault location of the power system only and leave the healthy part without disturbing the

rest of the system. The discrimination quality is the property of the relay to locate only of the faulty section of a power system [24]. In order to provide selectivity to the system, usually the entire system is divided into several protection zones. So, the system can be divided into the following protection zones [7]:

Generators

High-tension switchgear

Transformer

Transmission lines

Low-tension switchgear

2. 4. 2 Sensitivity

It is the ability of a protective relay to operate with minimum value of actuating quantity such as current, voltage and power. The relay should be very sensitive as possible meaning it should start to operate for low value of fault current [24]. So, with this quality, the relay will operate reliably when required and under the actual condition that produces the least operating tendency [25]. The smaller the input required to start the relay operation the more sensitive is the relay [7].

2. 4. 3 Speed

The relay should clear the faulty section as fast as possible for the following reason:

Electrical appliances may be damaged if the fault current stays on them for a long time.

A failure to the system will create problem to the consumer motor and the generators on the system may become unstable.

So, the relay should disconnect the fault as quickly as possible to improve quality of service, increase the stability of operation and avoid danger to life and property [26] [27].

2. 4. 4 Reliability

It is the ability of the relay to must ready to operate under the pre-determined conditions at all times. The correct design, maintenance and supervision can increase the reliability [28]. The need for the reliability is very important because incorrect operation can be attributed to one of the following classification:

Incorrect design/setting

Incorrect installation/setting

Deterioration in service

2. 4. 5 Stability

A protective relay should remain stable to withstand a large current that flows through its protection zone although the fault does not in its zone and for example through load current and external fault conditions [24] [29].

2. 4. 6 Simplicity

As for the construction and good quality of the relay, the relay system must be simple so that it can be easily maintained [28]. The simpler the protection scheme, the greater will be its reliability and reliability is closely related to simplicity [24].

2. 4. 7 Economy

The most important factor in the choice of a particular protection scheme is the economic aspect. Sometimes it is difficult and economically unjustified to achieve an ideal scheme of protection and a compromise method become necessary [28]. As a rule, the protective gear should not cost more than 5% of total cost. Too much protection is as bad as too little and the relay engineer must strike a sensible compromise due to the practical and situation [28]. However, when the apparatus to be protected is of utmost importance such as generator, main transmission line, economic considerations are often subordinated to reliability [7].

2. 5 Protective relay application in electrical network

A wide variety of protective relays and protective relay function are available and are in the following:

Phase overcurrent relay

Ground overcurrent relay

Time overcurrent relay (51)

Instantaneous overcurrent relay (50)

Overvoltage relay (69)

Directional overcurrent relay (67)

Differential Relay

Distance relay

2. 5. 1 Phase overcurrent relay

This relay is used to avoid operation on all those normal operation to which the relay may be subjected [12].

2. 5. 2Ground overcurrent relay

This relay is advantage of utilizing a current source that supplies little or no normal current to the relays [12].

2. 5. 3 Time overcurrent relay function (51)

A time overcurrent relay is a relay that has an inverse time characteristic meaning that when the higher the fault current the faster the relay operates. This relay operate when input current of the relay exceeds a pre-set pickup current value for a pre-determine amount of time as described by a time-current curve (TCC) [30].

2. 5. 4 Instantaneous Overcurrent relay (50)

Instantaneous overcurrent relay is a relay that has no intentional time delay when it operates with its input current exceeds a pre-set pickup current value [30]. In order for this relay to operate, the pickup current needs to be specified and CT ratio also needs to be determined. Instantaneous

overcurrent relays will complete its function every time pickup current exceeds the pre-determined pickup value to open instantaneously [30] [31].

2. 5. 5 Overvoltage relay (59)

This relay is a relay that operates when input voltage exceeds pre-determine pickup value. This overvoltage relays will operate either as instantaneous or time-delay devices. In order to set a time overvoltage relay, its pickup voltage and time dial need to be assigned and voltage transformer (V. T.) ratio also needs to be determined [30]. Overvoltage relay will operate and close the output contact when the time of the overvoltage exceeds the time delay described by the time voltage curve [30].

2. 5. 6 Directional overcurrent relay (67)

This type of relay compares the phase angle relationship of phase currents to phase voltage to locate the direction to the fault. In high voltage transmission lines and medium voltage distribution lines, a fault location can be in two different directions from a relay. So, the relay needs to respond quickly and differently for fault in forward or reverse direction [32] [33].

2. 5. 7 Differential Relay

This relay is well known in the field of protection. Differential relay operates by measuring and direct comparing of the phase and magnitude of the current entering and leaving the protected zone [22]. So, Current transformer having a suitable ratio of transformation intervened in the circuit between both the end of the protected equipment [22]. By the way, the zone of differential relay is limited by a part of the electric circuit between the current transformers and where the relay is connected [5]. In addition,

differential relay protection is also used to protect power network from current overloading by localizing the insulation damages in high-voltage equipment [5].

2. 5. 8 Distance relay

A distance relay measures the apparent impedance derived from the current and voltage that have been measured. The impedance of a transmission line is usually distributed constantly all over its length. Therefore, a distance relay can distinguish with relatively good accuracy between a fault that is internal to the line and one that is external by measuring the apparent impedance during a fault by providing the protection [34].

2. 6 Important terminologies

In relay coordination there are important terms that must be known.

The following terms are:

Time/ Plug setting multiplier (PSM)

Time setting multiplier (TSM)

Current setting---

Pick up current

2. 6. 1 Time/ Plug setting multiplier (PSM)

Plug setting multiplier (PSM) is defined as the ratio of the current through the operating coil of the relay and the plug setting current [35] [36].

Other than that PSM can be calculated in terms of line current:

Therefore, the current plug setting multiplier and operating time in seconds are used to draw the time-current curve along the X-axis and Y-axis respectively [35]. Figure 90 show the curve.

Image = time current curve characteristic

2. 6. 2 Time multiplier setting (TMS)

Time multiplier setting is generally provided for relay the control to adjust the time of operation. Time multiplier setting also is called as time dial setting. This time multiplier setting also used to adjust the time delay before the relay operate whenever the fault current reaches the equal value to, or greater than the pickup current setting of a relay [36]. The time multiplier setting is used to calculate the actual time of operation of a relay derived from TCC curve. So, the actual time of operation is calculated by multiplying the time obtained from the TCC curve of a relay with the time setting multiplier [7] [36].

Time multiplier setting also can be calculated for any backup relay as below [19]:

2. 6. 3 Current setting

The number of turns of the operating coil can be changed to adjust the coil current at which the relay will pick up [35]. So, there is a number of tapping on the current coil used to achieve the desire current setting and a shorting plug has to be inserted in the plug setting bridge in order to change the number of turns. This plug bridge is used to alter the number of turns on the relay coil. This also will change the torque on the disc and the time operation

of a relay [7]. Hence, the current required for the relay to operate will change when the effective numbers of turns is changed [35]. The more the number of the turns, the lesser the current will be required to operate and vice versa. Therefore, for a current setting of 100%, the effective number of turns is twice for a current setting of 200% and is half that for a 50% setting [7] [35].

2. 6. 4 Pick-up value

Pick up value is the minimum value of an actuating quantity in the relay coil at which the relay to start operate [36]. So, as long as the pickup current is less than the pickup current value, the relay will not operate and the circuit breaker will not open its contact. However, if the relay coils current is greater than or equal to the pickup current value, the relay will operate to energize the trip coil which opens the circuit breaker [7].

2. 7 Protective relaying

Protective relaying is the fundamental form of electrical automatic equipment and is essential for normal dependable operation of modern electrical power distribution system [12]. So, the trip coil will be energized to operate the automatic opening of a circuit breaker under fault or any abnormal condition [35]. A relay in a protective zone of the system will continuously monitor the condition of the system and will sense any fault or an abnormal condition that exist in any section of protection zone [35]. The significance of the protection zone is that any fault that occurred within a zone will energized the relay coil to cause the opening of circuit breaker located within that zone [37]. So, no part will be left unprotected and the components which are in the protection zones such as:

Generators

Transformers

Transmission lines

Bus bars

Cables

Loads

Image protection zone [37]

2. 7. 1 Primary and Backup Protection

The protection system can be divided into two categories as following:

Primary protection

Backup protection

2. 7. 1. 1 Primary protection

The primary protection is the first line of protection and responsible to protect all the electrical systems equipment from all type of faults [37]. The backup protection will play the role to protect the electrical system when the primary protection system fails to do its protection [37]. The arrangement of backup protective devices must be such that the failure in primary protection should not cause the failure to the backup protection as well. This can be done by setting up the primary protective relaying and backup protective relaying to do not have anything in common. Hence, backup protection

should be located in different zone from the primary protection. The backup protection is provided as the main protection can fail due to many reasons such as [37]:

Failure in protective relay

Failure in tripping circuit

Failure in d. c. tripping voltage

Failure in circuit breaker

Loss of current and voltage supply to the relay

2. 7. 1. 2 Backup protection

The concept of the backup protection is to trip only if the primary protection fails to operate properly. The important requirement of backup relaying is that it should operate with sufficient time delay in order to allow the primary relaying the chance to operate first. If any fault occurs, both type of the relay will start the relaying operation but the primary relaying is expected to trip first and backup relaying will then reset to the normal without having time to complete its relaying operation [37]. When the given set of relays provides the backup protection for adjacent system equipment, then the slowest primary relaying of any of those will determine the necessary time delay for the backup relay [37]. Hence, there are various methods used for the backup protection as classified below:

Relay backup protection

This is a kind of a primary relaying which an additional relay is introduced for the purpose of backup protection. In this scheme, a single circuit breaker is used by both primary and backup protection but the principle of operation for both of the protective relaying is different and is desirable [37]. They should be supplied from potential and current transformers [38].

Breaker backup protection

In this type of protection, two different of circuit breakers are provided for the primary and back up relaying. Both of the circuit breaker is installed at the same station [37]. This type of a backup is essential for a bus bar system where a number of circuit breakers are connected to it [38]. When a protective relay start to operate when a fault is detected but the circuit breaker is failed to trip, the fault is a bus bar fault. In this situation, all other circuit breaker on the bus bar should trip. After a time delay, the backup protective relay closes the contact of the backup relay which will trip all other circuit breakers on that bus if the proper circuit breaker does not trip within the specified time after its trip coil is energized [38].

Remote backup protection

In this method, different circuit breakers are used for the primary and backup protection. These two types of circuit breaker are at the different zones and are completely independent and isolated o