Transmission and distribution line protection and performance of network splitting

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Abstract - In this paper, a protection scheme for transmission and distribution lines is presented and also discuss about fault in transmission line, effects, causes and overcurrent protection of transmission and distribution line. This paper also presents network splitting which have more potential for fault level reduction in short term as it is relatively economic and moreover it has accuracy, also mention about fault level reduction technique and test networks and input data. The analysis shows that the fault current is sensitive to closure the normally open point (NOP). In urban area the fault level rating of installed equipment is a common restriction on the expansion of distributed generation (DG). For reducing fault level the network is to split at selected point by, for example opening bus section circuit breakers which are normally run closed. It studies performed to evaluate the reduction technique and impact of network splitting such as reliability and power quality.

Keyword :- Distributed Generation, Time and Current Grading, Network Splitting, Coordination Delay time

Introduction

A reliable power system network is designed with the ability to withstand any crisis (single or multiple outages) occurring with the system. Although, certain crises may contribute to severe cascading failure in the transmission line system that cause the system to split and form few unbalanced islands. This occurrence is known as unintentional islanding. Without proper planning of network splitting, such islanding will trigger instability issues in the system and consequently lead to partial or total system blackout.

Most severe blackout cases which occur in many countries around the world are caused by cascading events intimated by single or multiple events. The fault level management problems are particularly acute in large conurbations where fault levels are already close to the design limits of switchgear. The connection of distributed generation (DG) in these areas requires some action to be taken to ensure that fault levels remain within the design limits of existing plant. This is an important safety issue which if unresolved would severely limit the amount of DG that can be connected. Where fault levels are already high, as is often the case of urban areas, any additional contribution from DG may necessitate the potentially expensive replacement of switchgear.

Transmission and distribution lines:-

(i) Transmission lines are used to transmit the electricity from a power plant or Power Station to the various substations whereas Distribution lines are used to deliver the electric power from the transmission system to the consumers.

(ii) Transmission line carries electricity at very high voltage i.e. 11KV whereas distribution line carries electricity at very low and safe value level i.e. 220 volt.

(iii) The thickness of the transmission lines are more as compared to the distribution line.

(iv) Transmission line carries power(electricity) in 3 phase supply system whereas distribution system needs a single phase supply system for carrying power.

Brief review of the fault in transmission line

The transmission lines can have fault because of short circuit between phase or phase to ground.

From this point of view the faults of the power system are mainly classified into two types :-

1. **Symmetrical fault :-** This is the most severe type of fault and this is also dangerous because when symmetrical fault occurs all the three phases short circuited. They may be short circuited with or without involving the ground.This is called balanced or symmetrical(L-L-L or L-L-L-G) fault because the network remains electrically balanced at fault condition.

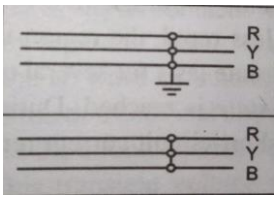

Fig 1 :- Symmetrical fault

2. **Unsymmetrical fault :-** The unsymmetrical faults are further classified as -

(i) line to line(L-L) fault - When a short circuit occurs between lines, the fault occurs in this condition is called line to line(L-L) fault. This can occur because of either ionization of air or physical contact between lines(because of breakdown of insulation).

In transmission lines almost 5 to 10% of faults are line to line faults.

(ii) Line to ground(L-G) fault - When a short circuit between one line and ground occurs generally because of physical contact(due to lightning or other climatic effects), this type of fault is called L-G fault.

In transmission lines about 65 to 70% of faults are line to ground faults.

(iii) Double line to ground fault (L-L-G) - In this type of fault two lines come into contact with each other and the ground(due to storm damage), so it is called Double line to ground fault.

In transmission lines about 15 to 20% of faults are line to ground faults.

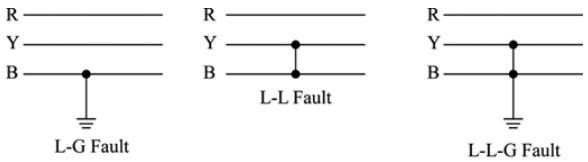

Fig 2 :- Unsymmetrical fault

Causes of transmission and distribution line faults

- Overvoltage because of switching surges.
- Lightning effect.
- Insulation breakdown.
- Because of more external and internal stresses on the conductor.
- Falling of trees on the transmission line.
- Heavy rain, snowfall and wind.
- Perching of birds.
- Accidental short circuit because of string or snakes.
- Accident of vehicle with poles of Transmission lines or Towers.
- Chemical pollution.

Effects of fault

- Because of the fault a very heavy fault current is produced which is very large and magnitude and this current can damage the equipment of the power system network.
- The condition of overheating and mechanical stress in the conductor is caused by a very high amount of fault current because it produces heat.
- Due to arcing caused by the heavy current there is a danger of Fire and if the fire remains for a long time then this fire can be spread in the other parts of the Transmission and distribution system.
- Because of overheating the insulation of the conductor weakens and it reduces the life of the insulation.
- Fault reduces the reliability of the system.
- Fault affects the stability of the system.
- Due to unbalanced Currents and voltages, generators may lose their synchronism and the condition of total shutdown or blackout can occur.

Thus determining the fault in the Transmission and distribution line and clearing it is very important for the proper functioning of the power system.

Protection principles of transmission and distribution line

For the protection of Transmission and distribution line we use four protection principles-

- Overcurrent.
- Directional overcurrent.
- Distance.
- Differential.

  - Overcurrent protection is the simplest and most economical principle.
  - It is limited to radial lines.
  - This type of protection has wide used in distribution and industrial systems
  - In order to increase the operating speed we use distance protection in many transmission lines.

Overcurrent protection of transmission and distribution lines

Below Figure shows three substations.

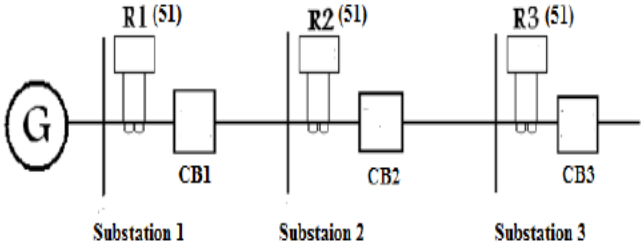

Fig.3 - Radial line supplying three substations.

In order to provide the desired selectivity the relay operation must be coordinated with respect to each other. This is called relay coordination.

There are three methods for obtaining relay coordination-

- Discrimination by current
- Discrimination by time
- Discrimination by both time and current

Discrimination by both time and current

It is also called time current grading method. In this method to achieve the time current grading we use the relays which have inverse time overcurrent characteristics.

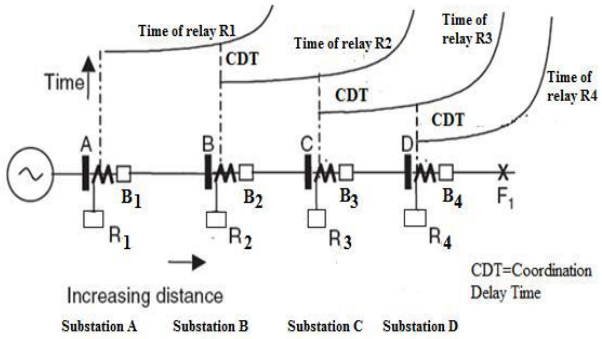

Fig 4:- relay coordination principle.

The above figure shows the application of time delay overcurrent relays for the protection of radial transmission line with multiple section. It illustrates how time coordination is achieved between the inverse time overcurrent relays it is breaker location.

- The coordination between the relays for fault at F1 is necessary. The relay R4 tripping breaker B4 operates quickly at time T1, followed by the relays controlling B3, B2 and B1 so that B4

operates before B3, B3 before B2 and B2 before B1.

- Therefore the operating time T2 of relay R3 can be expressed as

T2 =T1+ CDT

where CDT is called the coordination delay time (CDT), which is the minimum interval that permits a relay and its circuit breaker to clear a fault in its operating zone.

Fault level reduction method

Fault level is a measure of network robustness . A higher fault level is a good indicator for the strength of the system proposing close presence to generating stations or a highly interconnected system. Higher fault level intimate low impedance between source and load and hence is allied with good system voltage profile and low magnitudes of voltage dips when they occur. It is also beneficial for the speed of operation of protective devices under fault conditions. As we see on the whole a high voltage level is not a bad thing. But these benefits come at a price as high fault levels require switchgear and other equipment with high rupturing capacities, which is expensive. In the event that the connection of DG causes the fault level to rise above the existing switchgear rating, it becomes necessary to find ways to reduce the fault level as a cheaper alternative to replacement of the switchgear, which in most cases is a costly solution.

There are several methods that can be used to reduce fault level in power systems. Some of the notable ones are listed below:

- Current limiting reactor
- Is – limiter
- Superconducting fault current limiter
- Solid-state fault current limiter
- Network Splitting

Network splitting

In operation, a larger extent common and less expensive near to fault level reduction is network splitting, as shown in figure 6.

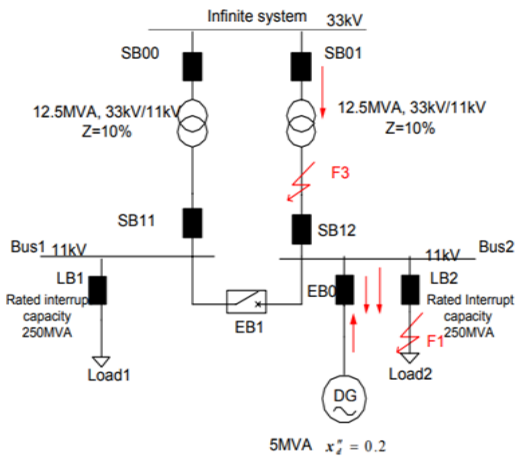

Fig. 6 – Network spitting

The network splitting design shown in figure . It uses the bus-section circuit breaker EBI between Bus 1 and Bus 2. By splitting the network in this way, the impedance between the 33kV and 11kV systems increases from 5% to 10%, reducing the fault current coming from the public supply (33kV) considerably

However, this design may decrease the flexibility of DG . When busbar Bus 2 needs maintenance, the DG has to be disconnected to the network, and therefore an alternating network splitting arrangement that avoids this problem is shown in figure.

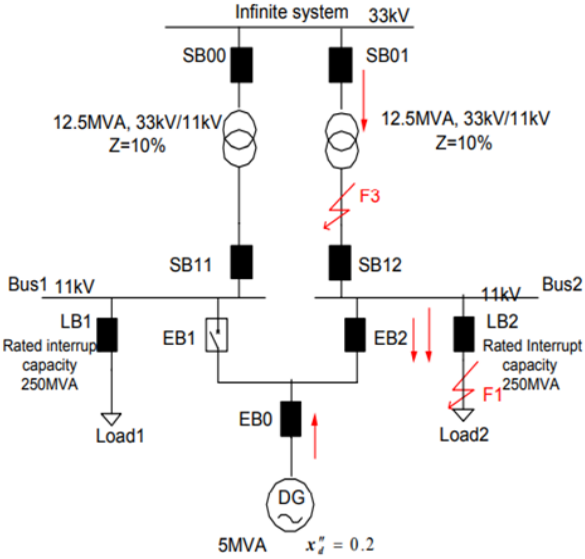

Fig.7 – An alternative network splitting method

Figure 7 shows that one more circuit breaker EB2 is needed. Under normal operation the circuit breaker EB1 is open separating the 11kV busbar into two parts, Bus 1 and Bus 2.

For a fault F1, LB2 can safely interrupt fault current within its rated capacity.

For a fault F3, the DG and the Load 2 ca be switched to Bus1 by closing EB1 after fault clearance. when busbar Bus 2 needs maintenance, the DG can be switched to Bus 1 by closing EB1.

Conclusion

In this paper, protection of transmission and distribution line use protection principles like overcurrent, directional overcurrent, distance and differential or discussed about faults of the power system.

The result of the studies showed the basic principles underlying the methods that can be used to reduce fault levels as well as their typical application. There are five main methods namely current limiting reactor, Is-limiter, superconducting fault current limiter, solid-state fault current limiter and network splitting have been discussed.

The spitting was found to have a greatest potential for fault level reduction in the momentary as it is relatively inexpensive and it also has high reliability and flexibility.

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