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Directional overcurrent and earth-fault protections for a biomass microgrid system in Malaysia

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ABSTRACT

Over-current protection is principally intended to counteract excessive current in power systems. In distribution systems in Malaysia, non-directional over-current protection is adopted because of the radial nature of the power system used. Relay typically used in distribution network are designed to cater for current flow in one direction, i.e., from transmission network to load. However, with the forecasted increase in generation from renewable sources, it is important that adequate codes are in place with regards to their integration to sub-transmission/distribution network. Distribution network dynamically changes from "passive" to "active" network. With distributed generation connected to distribution network, power flows bi-directionally. Hence, directional over-current protection is adopted along the line between the transmission grid and the distributed generation. The bi-directional flow of power also complicates the earth fault protection. This is due to the presence of the distributed generation that will cause the line near the delta side of the transformer to be still energized after the operation of earth fault relay during single-phase-to-ground-fault. This paper investigates the directional over-current and earth fault protections used to protect the microgrid (biomass generator) in Malaysia. In this study, under-voltage relays are adopted at the delta side of the transformer to fully clear the single-line-to-ground fault, which cannot be cleared by earth fault relay. Three-phase-balanced fault and single-line-to-ground-fault at all possible locations in the network have been simulated. Simulation shows good coordination and discrimination between over-current relays.

1. Introduction

One of the main objectives of most utilities is to provide secure and reliable supply to their customers. However, the occurrence of short-circuit fault affects the reliability and quality of power supply [1]. Radial system is the most common configuration in distribution systems. In this type of configurations, only one source feeds a downstream network [2,3]. Most protection systems for distribution networks assume power flows from the grid supply pointing to the downstream low voltage network [4]. Normally, protection is done using overcurrent relays with settings selected to ensure discrimination between upstream and downstream relays [5]. In the event of electricity outage due to fault, fast isolation and restoration are required to minimize customers lost.

With the presence of distributed generators (DG) in distribution network, the complexity of protection relay coordination, control and maintenance of power distribution systems increases. With the connection of DG, in case of fault, the system can lose the radial configuration since the DG sources contribute to the fault. Therefore, the system coordination could be lost. High penetration of DGs will have unfavourable impact on the traditional protection methods because the distribution system is no longer radial in nature and is not supplied by a single main power source [6]. Power flows bi-directionally and ordinary non-directional over-current relay will not be able to fully clear the fault. When DG is present in the system, an additional power flow appears from the load side to the source side and vice versa. Hence, the opening of the main feeder breaker does not assure that the fault is cleared. The short circuit rating of the power system also changes with the installation of DG. If generation is embedded into the distribution system, the fault current seen by the relay may increase or decrease, depending on the location of the relay, the fault and the distributed generators [7]. In a fault situation, distributed generators modify the current contribution to the fault and therefore, it influences the behavior of the network protection.

Distributed generations have posed some problems to protection, which are false tripping of feeders (sympathetic tripping), nuisance tripping of production units, blinding of protection, increased or decreased fault levels, unwanted islanding, prohibition

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of automatic reclosing and unsynchronized reclosing [8]. Earth fault happening at the delta side of the transformer will not be fully cleared by the earth fault relay with the presence of DG because there are more than one power source in the network. When the main utility service provider is the only sole power source provider to the customer load, the earth fault that happens between the utility source substation and delta-wye transformer can be fully cleared or completely isolated by the tripping of the utility-source line breaker alone. Hence, when there is another generation source (probably a distributed generator) being added in parallel with the utility power system at the customer load site, beyond a delta-wye transformer, the transformer becomes a source of fault current for faults on the utility source line [9].

This paper examined the use of directional over-current relays along the line connecting the two power sources in order to fully clear the fault. Characteristics graph of relays were plotted and the tripping time of the primary protection and back-up protection were recorded. The study also investigated the use of under-voltage relay at the delta side of the transformer to fully extinguish the earth fault.

2. Over-current protection

Two types of over-current protections are discussed here, the phase over-current and the earth fault over-current protections. It should be noted that the earth fault protection should not operate for any phase to phase fault because there is no zero sequence current flowing [10]. However, the phase over-current protection may operate when earth fault happens. Hence, coordination and discrimination should be done properly to ensure no nuisance tripping of relays.

2.1. Need of directional element in over-current relay

Directional over-current protection is used against fault current that could circulate in both directions through a system element and when non-directional over-current protection could produce unnecessary of disconnection of circuits [11–13]. This situation can happen in a ring circuit and a circuit with a number of infeed points. When distributed generator (DG) is present, there are multiple power sources and the opening of the utility breaker only does not guarantee that the fault will be cleared. Hence, the nature of distribution network changes with multiple DG units and directional relays are needed in the network [6]. Directional relays should be placed along the line that links the main grid and the DG. For the branch that does not link the two power sources, non-directional relays could be used.

2.2. Relay characteristics

2.2.1. Definite time

This characteristic makes use of time delay element to provide means of discrimination [14]. The relay, which is installed at the furthest substation away from the source, is tripped in the shortest time. The remaining relays are tripped in sequence having longer time delays, moving back in the direction of the source. For the purpose of this study, definite time characteristic is used for directional earth fault protection. This characteristic has advantage

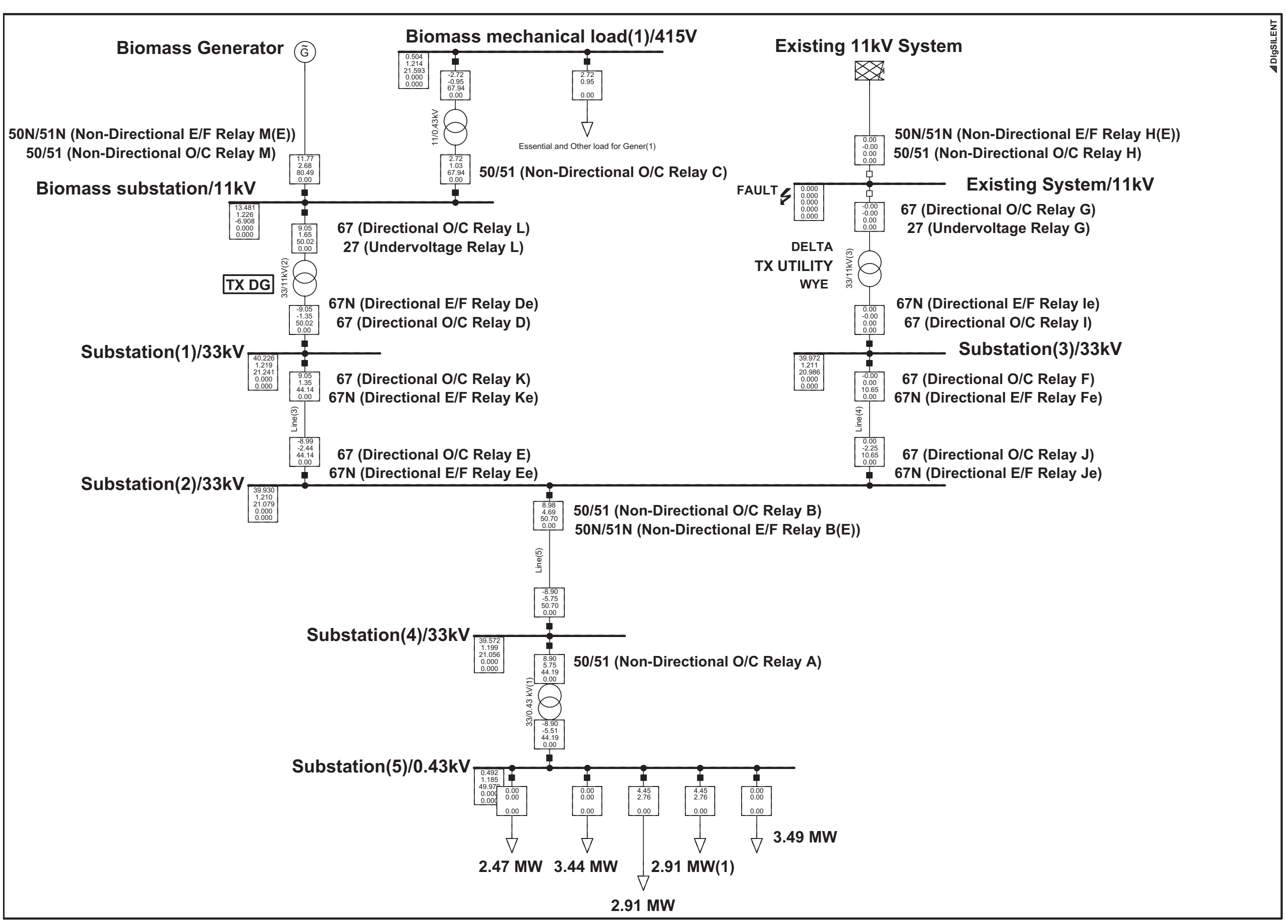

Fig. 1. Network model.