

Fault Tolerance and Protective Schemes for DC Distribution Network

Abstract

The integration of distributed generation such as renewable energy at the distribution is considered as the better option to cope with the rising demand of electrical energy. The storage system is also introduced to act as an additional power buffer to the power system due to the intermittent supply of energy from the distributed generation. With the addition of these 2 DC energy systems, the DC distribution system can achieve a better system efficiency than the AC system. This is due to the reduction in power conversion stages such as the power factor correction and a rectifier circuit. Of the advantages, the fault protection is the major obstacle for the DC system to move forward. Hence, a research topic is brought out with the major aim is to develop an effective fault tolerance solution to increase the resiliency of the DC distribution system. A complete fault tolerance and protection process with the sequence is: 1) fault detection, 2) fault isolation, 3) fault identification, 4) fault recovery.

In the DC system, a fast tripping speed of the circuit breaker can reduce the consequences of high fault current sourcing toward the fault point. A T-source circuit breaker is used as the device for the fault detection and isolation in the DC system. The T-source circuit breaker is a kind of impedance-network based circuit breakers which provide a high-speed breaking capability and no sensor is required. It also has the benefit of preserves a common ground, zero reflected source current, and provide a low-pass filter behaviour. The redesign of T-source circuit breaker based on fast tripping speed and low output surge current are presented. A T-source circuit breaker model is derived using the transformer low and mid-frequency modelling. An optimal component sizing design of the T-source circuit breaker is done based on the proposed design flow associated with the desired circuit breaker current rating, the wire current rating, and the SCR device minimum turn-off time. A manual tripping circuit modification for the protection of SCR device in the T-source circuit breaker is also presented. The component of the modification circuit is selected based on the optimal value between the capacitor charging speed and the minimum value of the instantaneous capacitor charging power.

A high accuracy fault identification solution can ease the task for inspection, maintenance, and the repair work. High accuracy can also speed up the restoration service and possesses the merit of less maintenance cost. The probe power unit injection method is chosen as the solution for fault location identification. It has a benefit of single end injection which does not require multipoint measurement, no high data acquisition needed, and can be used as the fault point tracking in the offline whereby the fault current from source has interrupted completely. The logarithm decrement technique is introduced to obtain the damping constant of the damping injection current. The logarithm decrement technique has the advantages of high accuracy, less data reading needed, and fast processing speed. The component selection of the probe power unit with the inductor and capacitor pair value is based on a low damping ratio and high Q-factor bandwidth. A modification probe power unit circuit associated with the proposed multipath fault identification flow can determine the exact fault segment line. This fault identification solution provides an information for the fault segment isolation for a complex network such as a meshed network.

A fault recovery is a final step for the fault protection process which recovery the non-faulty system back to normal operation. Instead of the modular multilevel converter as the only type power converter in the DC network, a low voltage microgrid has various power converters for different

facilities. The common facilities in the microgrid include grid interfacing system, storage system, and photovoltaic system as the distributed generation system. Each converter functions differently and has a different consequence over the system reconfiguration. The minimum transient of the reconfiguration step is chosen. The reconfiguration step is the order of action between the activation of the power converter and the reclose of DC circuit breaker. The sequence of reconnecting each facility back to the DC network is demonstrated. The reconnection is presented with a stable voltage and power equilibrium.

As above mentioned, the main reason for introducing fault tolerance and protection scheme into the DC system can increase overall system reliability. The scheme can prevent a harmful high current triggered by a fault which can damage the non-fault device or facilities attached in the DC system.