ABSTRACT

Today integration of solar photovoltaic (PV) plants through power electronics converters into the grid has proven to be a promising solution in mitigating environmental challenges. Such plants, having fault current limitations are governed by country-specific control requirements which modulate the fault voltage and current patterns differently than synchronous machine based sources. Therefore, the existing protection principles cannot be good enough for distribution systems in the presence of inverter-interfaced PV plants.

In this thesis, algorithms are developed to improve protection reliability in PV plants connected systems. A high-speed time-domain directional relaying method using only phase fault current is proposed to overcome the issue with the uncommon phase shift of current from voltage with PV plants presence. A quadrature-axis transform components-based scheme is proposed for line protection, which is accurate even when the magnitude of fault current is at par with the rated current. This scheme uses the communication channel to transfer the direction information to other end for the decision. A positive sequence component-based method using local data is proposed which addresses the varying current contribution of PV plants. The method resolves the protection coordination issue of distribution systems with PV plants. An adaptive distance relay setting using local prefault data is proposed addressing the change in PV source impedance during fault. A combined distance and voltage-restrained overcurrent relay based approach is proposed to reduce the overall operating time of protection systems.

The proposed methods can be implemented in any numerical relays without additional hardware requirements and are cost-effective solutions for line protection. Using DigSilent PowerFactoy and MATLAB/Simulink, the proposed methods are tested for the standard distribution systems, including the CIGRE system with PV plants, and found to be applicable for relays on PV plant-side as well as grid end. Hardware-in-loop testing using OPAL-RT simulator as a system, Arduino UNO/NANO microcontroller as a relay, and IEC 61850 protocol as a communication channel validates the proposed method in real-time.

Keywords: *Distribution system, Solar photovoltaic plant, Time-domain protection, q-axis component, Hardware-in-loop testing, IEC 61850 protocol.*