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Practical impact of not self-disconnected VSPP during faults and unintentional islanding on distribution system reliability

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Abstract

The promotion of small-scaled distributed generation (DG), commonly known as Very Small Power Producer (VSPP) in Thailand's electric power industry, is derived from its incentive policy, energy efficiency, and environmentally friendly attribute. For this reason, distribution networks have seen a high penetration level of VSPPs powered by conventional or renewable energy resources. Although VSPPs have economic and environmental benefit of the sustainable energy, they have imposed technical barriers and established new requirements for control and protection system of the distribution networks. This paper investigates the possible negative impacts of VSPPs on control and protection systems of distribution networks located in a metropolitan area. Three case studies of real, existing VSPP in 24 kV distribution network are practically presented with short-circuit analysis and dynamic analysis primarily focusing on undisconnected VSPP during faults, and unintentional islanding. The study results show that without proper measures to address the issues on the existing control and protection system, the distribution network would be unable to maintain its integrity of electricity power supply for disturbance incidents.

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Keywords: control and protection system; distributed generation; short circuit fault; unintentional islanding

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1. Introduction

1.1. Very Small Power Producer (VSPP)

Traditionally, much of the electricity generated has been produced by large-scale, centralized power plants using fossil fuels (e.g., coal, oil, and gas), hydropower, or nuclear power. The electrical energy is transmitted over long distances by high voltage (HV) or extra high voltage (EHV) transmission lines and from there, the high voltage levels are converted to medium voltage (MV) and low voltage (LV) levels through distribution lines in the distribution system to end-use customers. Such a centralized generation pattern, however, suffers a number of drawbacks, such as a high level of dependence on imported fuels that are price-vulnerable, transmission losses, the necessity for continuous upgrading and replacement of the transmission and distribution facilities and therefore high operating cost, as well as environmental impact. In addition, as electric demand is substantially increasing as a result of economic and social growths, the construction of a large sized power plant is running into financial and technical difficulties because it is capital intensive and needs considerable amount of time to complete.

Alternatively, an ideal possibility on electric power supply to end-use loads is the installation of a small sized generation or commonly known as distributed generation (DG). Over the last decade, distribution networks have seen a large number of small-scaled DGs powered by conventional or renewable energy resources due to incentive financial policies to promote energy efficiency and renewable energy. DGs can be powered by photovoltaic (PV) solar arrays, wind turbine, fuel cells, and biomass fuel, as well as gas-fired combined heat and power (CHP), which are installed on-site, and owned and operated by customers or utilities.

In Thailand, a DG with a net injected capacity less than or equal to 10 MW is commonly known as Very Small Power Producer (VSPP). As of June 2016, there are 789 VSPPs on commercial operation with a total capacity of 4,100.78 MW or 9.99 % of 41,040 MW as total generation capacity (Energy Regulatory Commission) [1].

1.2. Impact of VSPPs on power system reliability

In power system reliability point of view, VSPPs play an important role in reducing interruption durations (i.e., system average interruption duration index: SAIDI) as a local backup generator when the main supply from grid is out of service due to faults or planned outages. It is obviously seen in this case that without an adjacent feeder to perform open-loop configuration, VSPPs can help to improve system reliability, therefore decrease electricity outage cost of customers. However, they could be useful only when intentional islanding operation was allowed by the local electric power utility.

Although VSPPs have gained many positive effects, they still have some specific, technical issues that need to be addressed before their applications in the distribution networks driven by two fundamental goals can be fully realized: 1) delivering an acceptable quality of supply to consumers under normal conditions and 2) protecting the integrity of the system when disturbed by faults. There have been a number of problems reported in literature that create complexity in control and protection system of existing distribution networks [2-4].

2. VSPP and symmetrical faults

Let us consider a balanced fault shown in Fig. 1(a), assuming that no load current is present in the system. The fault level can be calculated using an equivalent network shown in Fig. 1(b), where the generator model is represented by an ideal voltage source serried with an internal impedance Z_S and feeder impedance Z_L [5]. For a three phase fault is away from the substation with a distance of d as shown in Fig. 1, the fault current is given by

$$\vec{I}_f = \frac{\vec{E}}{Z_S + \frac{d}{l} Z_L} \tag{1}$$

When a three phase fault occurs at the end of feeder, the distance of d becomes equal to the line length of l. We can conclude that the impedance between the fault position and the source limits the magnitude of fault current (i.e., the fault current at the end of feeder is less than that near the substation).