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Fault contribution from large photovoltaic systems in building power supply networks

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ABSTRACT

This paper presents a detailed analysis for determining the impact of adding large three phase photovoltaic (PV) systems in secondary (building) power distribution networks. The analysis highlights the protection relay coordination problems arising due to the increase in network fault levels caused due to the contribution from PV generators. A typical distribution network for power supply to large buildings with multiple apartments in a housing complex has been modeled and used as a test network. Simulation result shows that the magnitude of fault current contribution from PV system depends on a number of different factors, not only on the size of the PV system. The analysis emphasizes the requirement to review protection settings of similar installations prior to connection of PV generators to the network and suggests a method of protection coordination to minimize the requirement of reviewing the protection setting every time a new PV system is connected to the distribution network. It is found that fault current contribution from PV systems, depending on the size, can cause significant relay coordination problems in terms of discrimination and thereby reduce system reliability.

1. Introduction

PV systems are considered to make very minimum contribution to network in terms of fault current. It is therefore expected to make minimum impact on protective device coordination. The industry rule of thumb for fault current contribution from PV systems considered for studies and modeling is twice [1] the inverter rated current. This can however, vary between 1.2 -2.5 times the inverter rated current depending on different types and manufacturers of inverters for PV systems. The fault current contribution time generally varies from 4 cycles to 10 cycles [5]. The low fault current contribution from PV system does not necessarily mean that evaluations of existing relay coordination is not required when PV systems are added to network. Study carried out in the past indicates that an increase in the order of 7% in fault current magnitude [2] can be caused due to PV systems integrations in **distribution** network. The magnitude of fault current contribution depends on the size and number of PV system installed in a particular network. Therefore, the level of penetration of PV system in a particular size of network determines the impact of PV system on protection coordination.

Most literature, available in this area, analyses protection problems in network caused by fault contribution from synchronous generators, which can feed substantial fault current and cause protection issues like fuse recloser coordination problems [10] and out of phase closing of recloser during a fault. Such issues are more relevant for high voltage power distribution networks as recloser is generally used in high voltage transmission networks. Some literature is available on fault current contribution from PV systems but to the authors have mainly focused on high voltage power networks [4]. A detailed investigation of protection and voltage regulation issues caused by high penetration of PV systems in low voltage network has been discussed in some literature [11,12]. However these papers focus on the protection issues in high voltage side of network caused by high PV penetration in the low voltage side of network. Not much literature is available on protection coordination issues in low voltage network due of high penetration of PV system in low voltage. Presently a number of large three phase PV systems are connected to low voltage networks, in particular **to large buildings with multiple apartments in a housing complex** or in commercial and industrial premises, which can cause protection problems in low voltage network. The objective of this paper is to present a detailed investigation of the effect of increase in fault current with high penetration of large PV systems in typical low voltage power supply networks on protection coordination of low voltage network and thereafter define the factors that should be considered for determining effective contribution of fault current from PV systems during faults. The

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paper also suggests preferred method of adjustment of time current coordination settings in order to avoid repeated adjustment of protective setting each time when a new PV system is added to the distribution network.

The organization of the paper is as follows: Section 2 presents a detailed description of the power network used in this paper for simulations, Section 3 – provides the power system model, Section 4 includes case studies and observations and Section 5 provides analysis of results which is followed by conclusions of this study.

2. Description of network

A typical power distribution network for providing power to buildings with multiple apartments has been considered as a test network for the analysis. The single line diagram of the network is shown in Fig. 1. Three phase power at 11 kV is supplied via overhead line (OHL) from main substation to pole mounted 11/0.4 kV Transformer (T1). The transformer is protected by drop out fuse on the high voltage side and the secondary side is connected to a ground mounted low voltage distribution board using a cable. The low voltage distribution board comprises one off 630 A incoming air circuit breaker (ACB) and four off 160 A outgoing feeder (moulded case circuit breakers – MCCBs). The outgoing MCCBs are connected to building main distribution board (MDB) using a cable. To allow connection from the grid and PV system, the MDB has two incoming switches. The utility side incomer is provided with over-current protection devices. The incoming power from the PV source is protected and switched by PV system's integral switching and protection device. Specifications of the components for the network in Fig. 1 are provided in Table 3 in Appendix. For the purpose of this study, four buildings, each made up of ten apartments have been considered. Considering a maximum demand of 5 kVA per apartment, each building shall have a maximum load of 50 kVA. A roof top photovoltaic system of 50 kVA for each building has been considered.

2.1. Test network model

The test distribution network, shown in Fig. 1, has been modeled in PSCAD software environment (a simulation software developed by Manitoba HVDC centre). The power system model has been first developed and validated to check its accuracy without introducing the PV system. Fault current magnitude calculated in accordance with Australian Standard AS 3851 [8] has been compared with simulation output for faults at different points in the network. Fig. 2 shows the points (A, B, C, D) in the power system at which fault has been placed and analytical values have been compared with simulation outputs. A fault level of 9.15 kA at 11 kV has been used as a source fault level for the study. This is based on a zone substation transformer rating of 15 MVA (33/11 kV, Z=8.6%). The high voltage side protection has not been included in the model as the high voltage protection device had no influence in the study done. For ease of modeling, without effecting overall accuracy, only two out of four buildings have been modeled and cumulative effect for fault contribution from PV systems installed in other two buildings has been considered in this study.

Table 1 lists the difference between analytical (calculated) and simulated value of fault currents. Simulated results are very close to the analytical results which prove the accuracy of the network model used for simulations.

Balanced load flow for the network without a PV system has also been validated. The PV system has then been introduced in the test network. Section 2.2 describes the PV system modeling in further details.

The test network model of the power system described in Section 2 is shown in Fig. 3 complete with PV systems connected.

2.2. Modeling of PV System

As described in Section 2, transformer T1 provides power to the low voltage distribution board. The low voltage distribution board powers the MDB of each building using a 160 A feeder. Each feeder (MCCB with connected cable) is sized to cater for 86 kVA per outgoing circuit. This study investigates the effect of adding a 50 kVA roof top mounted PV system to each building. Table 4 in Appendix lists the values used for modeling the PV system connected to MDB of individual buildings.

Fig. 4 shows the power distribution arrangement at the building MDB and the load sharing between the PV and utility. For the purpose of this investigation PV system has been modeled as a constant voltage source behind an impedance. For a short circuit study in PV connected distribution feeders done in the past, PV systems have been modeled as a voltage source behind an impedance [4]. The impedance is sized to limit the fault current contribution from the voltage source to the maximum possible short circuit current of the PV system (i.e. approximately 2 times the rated current of the PV system). In another similar study related to fault analysis with PV system connected, the PV system

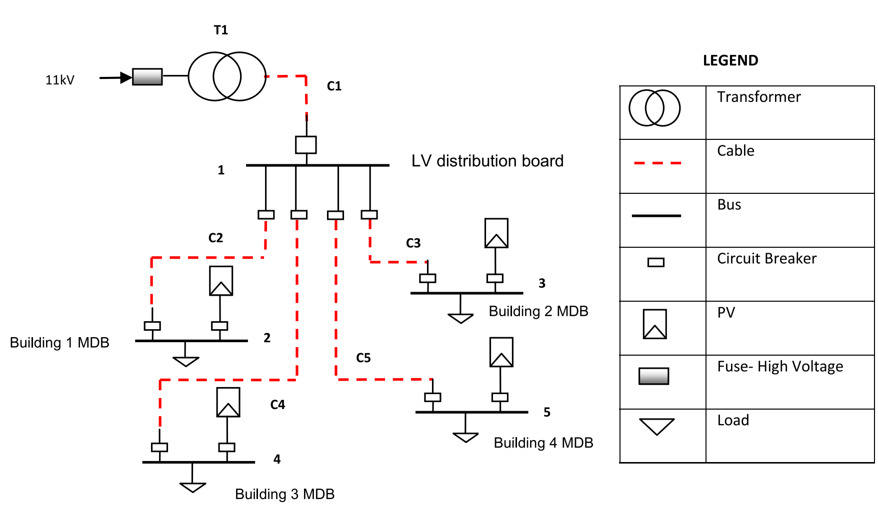

Fig. 1. Power distribution network – Power supply for buildings.