Impact of Photo Voltaic Cells on Hybrid Microgrid

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Abstract

In order to reduce the green house gas emissions all over the world the investment on renewable energy infrastructure is increasing particularly in the distribution network. It is also observed that the power generated by distributed system is not only supplied through distribution system but also fed to the grid by appropriately transforming the voltage. It has the advantage that the power generated through distributed generation system is utilized in the grid for other users. The PV cell generates voltage at the distribution level. At the end of distribution line a 1 MVA three phase load is connected. In the absence of the generation from the PV cells, the voltages and currents at various lengths of the line are calculated with a single load of three phase 1 MVA. With the inclusion of PV cells, the improvement in voltage dip is also estimated. This estimate provides the power supplied by the PV cell and improvement in voltages. In order to determine the effect of additional load on voltage profile, a three phase load of 1 MVA was connected to intermediate point in the transmission system. This causes the dip in voltage at various nodes of the distribution line. Several combinations of source and loads have been examined to determine the effect on voltage and power. The above work has been carried out using Electro Magnetic Transient Program (EMTP), free version developed by university of British Columbia, Canada and made available through Indian EMTP user group.

In order to simulate the system, 8.98 kV 5 km long line is divided into 5 sections of 1 km each. The sections are represented in the form of Pi-network by its series inductance, resistance and capacitance to ground. Loads are represented by R and L of appropriate magnitude and through EMTP program the calculations are done. The PV cell is represented by a source stepped up to 8.98 kV system. Both single phase and three phase lines have been examined through the above program. The results obtained for various conditions are presented in the paper.

Keywords: PV-Inverter; Harmonics; Islanding mode; IEEE 1547

Introduction

Issues related to power conditioning or grid interconnection device

It is often said that the success of a distributed energy resource will depend mostly on the power conditioning used. The DC output current of the solar module array has to be transformed to AC current and synchronized to grid conditions in order to be useful and safe to the distribution system. Most of the available devices rely on high power semiconductor technology to perform this task. It is important to understand that no device is able to perfectly convert energy from one form to another, yet a set of minimum requirements can be pre-determined to guarantee compatibility between the PV system and the local distribution network. Standards have been created that specify the minimum operational requirements for grid interconnection equipment. The IEEE 1547 is one such standard. This standard unifies the requirements for different interconnection technologies in one universal document. Following standard guidelines guarantee system designers that the equipments chosen will not have negative impact on the distribution system (or will at least maintain negative impacts within a tolerable margin).

The most important requirements are discussed in detail in the PV inverter section of this document. The issues to consider from a distribution system operation perspective are:

Harmonics

These are parasitic currents and voltages at frequencies different than the fundamental system frequency (50 Hz in Europe or 60Hz in America) that are commonly created by non-linear loads or power electronic equipment such as the inverters used to convert DC currents to AC currents in PV systems. The frequencies are typically multiples of the fundamental frequency, hence the term harmonics. These are a normal and necessary by-product of power electronic energy conversion equipment, yet the harmonic content of equipment output currents can be minimized using appropriate switching frequencies and filtering networks.

Islanding

This happens when a section of the distribution network is disconnected from the utility network due to abnormal operating conditions, but a DG continues to unintentionally feed current to the network. This can cause a safety hazard to maintenance personnel servicing the faulted section and could cause damage to DG and sensitive loads. The probability that an event like this happens for an extended period of time with PV inverters is quite small due to the required protection functions for these devices, and the ideal load to generator conditions that must exist for the island to remain energized.

Fault current contribution

The IEEE 1547 sets the operational requirements for grid-tied inverters under fault conditions, yet inverters that follow the standard may still contribute fault currents to the distribution network for small time frames. Fault contributions by inverters are typically of very short duration and limited to twice the rated current capacity due to internal
protection functions. These currents could increase the required instantaneous short-circuit withstand capability of some distribution equipment and may interfere with reclosing protection schemes and protection device coordination time. The DG system should not actively regulate the voltage profile, hence power factors close to 1 are necessary. The DG should act as a current source hence the operating voltage must match the grid voltage in-phase and magnitude.

The development and use of proper system planning techniques is of great importance to guarantee the safe and reliable operation of a power system, yet it is equally important to follow proper methods when designing and constructing the PV system. The incorrect use of PV equipment could tarnish the reputation of renewable energy technology; hence only qualified engineers or technicians should design and install them. The improper matching of PV components could cause the malfunction of otherwise good components. Often grid-tied inverters are matched with undersized or oversized PV arrays reducing or impeding the expected power outputs. Inverters should be sized considering the loading and fault current limits of distribution system equipment like: transformers, cables, switches and fuses. The behavior of grid-tied inverters under fault conditions is discussed in the PV inverter section of this document [1-3].

The array solar cells are made up of semiconductor devices which are used to convert solar energy into electrical energy in Photovoltaic system. Solar cells generate at low voltages less than 0.5 Volts of DC electric power [4]. A single cell produces small amount of power as its size is very small approximately less than a square centimeter. In Photo voltaic system the number of cells are arranged in series or parallel. So as to produce higher voltage solar cells are connected in series and to produce higher current the cells are connected in parallel. To obtain Maximum Power Point Tracking (MPPT) using photovoltaic cells a DC/DC converter is used at the output end of Figure 1. This will extract maximum available power through a given insulation level, as the voltage level will be maintained as close as possible to the maximum power point [4]. As there are no moving parts, PV system requires less maintenance.

**Micro-gas turbines**

Micro-gas turbines are simple, robust and compact devices which are used in distribution generation system. It uses gas instead of steam to rotate the rotor of turbine and generate electricity. Mostly these turbines acquire their intake air from a recuperator. It is a device which manages heat from the turbines and exhaust to pre-heat the intake air which also raises the turbine internal temperature [4-6]. The recuperator is a type of heat exchanger or radiator which transfers heat from the exhaust to the incoming air. Micro-gas turbine system are equipped with air bearing which runs at speed range of 50,000-90,000 rpm. These systems can be mass produced at low cost of 25-100 Kw [4]. Figure 2 shows micro gas turbine system without integrating with the AC grid. The generated voltage is DC voltage so it must be rectified using a diode rectifier.

**Design Model of Distribution Networks**

- Circuit diagram of a single phase distribution line (Figure 3).
Simulation Output

- Circuit diagram of a three phase distribution line (Figure 4).
- Single source and single load (Figure 5)
- Single source and 2-loads (Figure 6)
- Two sources and 2-loads (Figure 7)
- Three-Phase Single source and single load (Figure 8)
- Single source and two loads (Figure 9)
- Two sources and two loads (Figure 10).

Conclusion

A distribution system of power generation is modeled using Electro Magnetic Transient Program (EMTP) software. The distribution system

Figure 3: Circuit diagram of a single phase distribution line.

Figure 4: Circuit diagram of a three phase distribution line.
Figure 5: Single source and single load.

Figure 6: Single source and 2-loads.

Figure 7: Two sources and 2-loads.
consists of a number of sources in the form of regular power supply and supply through photo voltaic cells. Load flow studies are carried out on 11 kV, 5 km distribution line to find the various parameters to determine the impacts of solar PV cells. Increase in load increases the voltage drop at various distances from the supply point. This in turn is compensated by PV cells generated power thereby showing positive impact on losses and voltage profile i.e., reduction in power losses and improvement in the voltage profile of the system. PV cells are introduced in the distribution network to obtain additional power. Since PV cells are connected in the system they provide required a large amount of power by load and also meet peak demand. The main source is connected at node 1 and a PV cell is introduced at node 22. When symmetrical load is applied on a 3 phase system then there is no difference in phase to phase voltages, whereas if unsymmetrical load is applied, then there is difference in the voltages. This is improved by using another source i.e., through PV cells.

References


