Analysis of Power Distribution System with PV Integration

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Abstract— This paper presents a review on the analysis of power distribution system with the integration of PV. It is essential because it is the backbone of power system analysis and design. There is high requirement for the analysis of power distribution system. It is highly essential that the Power distribution systems should meet demands such as high reliability, efficiency, and penetration of renewable energy generators. Since PV integration is intermittent in nature, it is a challenging task to integrate these renewable energy resources into the power grid infrastructure. This will provide standby service during utility outages and when operated during peak load hours, potentially reduce energy costs.
Key words: Distribution System, Grid Connected PV, Distributed Generation, PV Technology

I. INTRODUCTION

The inevitable transformation of the electrical grid to a more distributed generation configuration requires solar system capabilities well beyond simple net-metered, grid-connected approaches. Time-of-use and peak-demand rate structures will require more sophisticated systems designs that integrate energy management and/or energy storage into the system architecture. Controlling power flow into and from the utility grid will be required to ensure grid reliability and power quality. Alternative protection strategies will also be required to accommodate large numbers of distributed energy sources. The objective of this program is to develop the technologies for increasing the penetration of PV into the utility grid while maintaining or improving the power quality and the reliability of the utility grid. Distribution systems have been designed to operate in a radial fashion, and it is well known that the interconnection of distributed generation may cause impacts that need to be studied and planned. PV systems generate energy with minimal environmental impact. However, a simple PV system without storage provides power only when the sun shines. It does not produce power in the evening when loads can be high, and the power output from a PV system can increase or decrease rapidly due to cloud passages. While the markets for grid-connected residential and commercial PV systems are growing rapidly, the total contribution of PV systems to the nation’s power supply is small and currently has no significant effect on the operation of the nation’s power systems.

However, as the quantity of energy generated by solar and other distributed energy systems becomes significant, these systems have the potential to adversely impact utility system operation. To mitigate these impacts, changes are likely to be made to utility/PV system interface requirements and to utility rate structures, which in turn may alter the value of these systems.

II. ORGANIZATION

Rest of the paper is organized as follows: Section III describes about the theory related to distribution infrastructure. Section IV describes about the related work in the field of analysis of distribution system with PV integration. Section 5 tells the issues, challenges and solutions related to the analysis. Section VI consists of future work of this analysis. And lastly, in section VII, we concluded about the whole paper.

III. DISTRIBUTION INFRASTRUCTURE

Distribution systems have traditionally been designed to operate in a radial fashion, and it is well known that the interconnection of distributed generation may cause impacts that need to be studied and planned. In this section, approaches to enabling high penetration of PV into the current distribution infrastructure while maintaining or improving PV system value and utility system reliability are discussed. Due to the variability caused by passing clouds, PV-PV can significantly affect volt/var control, power quality, and system operation. Some of these impacts can only be investigated through dynamic/transient studies that include the time-varying behavior of fast-acting generation (inverters), load, and automatic voltage-control devices on the feeders.

Given the complexity of such studies and the fact that the proliferation of this type of PV is fairly recent, the body of work in this field is sparse, impacts and mitigation measures are more difficult to identify, and utilities are less prepared to deal with them. Furthermore, for small-scale PV-PV, studying the problem is increasingly complex because of uncertainty about the location and timeline of market penetration as well as the potential interactions with emerging active loads such as electric vehicles (EVs). Impact studies are generally intended for quantifying the extent of the issues and providing utilities with guidelines, tools, and processes with which to manage the expected steady-state and dynamic transient impacts of PV-PV.

Most important, these studies can assess mitigation measures for any problems discovered and determine the cost and effectiveness of alternative solutions. The proliferation of PV-PV is expected to continue through the next decade and beyond; therefore, it is critical for distribution utilities to understand the associated impacts of integrating PV-PV plants on distribution system planning and operation. Depending on the degree of PV-PV deployment, impacts can be local (e.g., at individual feeder or substation level) or system wide (e.g., affecting several feeders and substations across the utility’s service territory and including sub-transmission and transmission facilities).

IV. RELATED WORK

2015	Analysis of Distribution System with PV System Generation on Probabilistic Power Flow
2014	Distribution Networks with Single-Phase Connected Photovoltaic Generation
2013	Effect of PV Power Injection in Unbalanced Distribution Systems
2010	Power System Reliability Analysis with Distributed Generator
2007	Solar Energy Grid Integration System
2002	Impact of Large-Scale Integration of Distributed PV with the Distribution Network
1998	Guidelines for Large Photovoltaic System Integration
1994	Evaluation of Interconnection Capacity
1989	Distribution System Power Quality Problem
1962	Load Flow Analysis of Distribution System Including Solar

Table 1: Related Work

V. Issues and Probable Solutions

Unlike centralized power plants, the PV units are directly connected to the distribution system most often at the customer end. The existing distribution networks are designed and operated in radial configuration with unidirectional power flow from centralized generating station to customers. The increase in interconnection of PV to utility networks can lead to reverse power flow violating fundamental assumption in their design. This creates complexity in operation and control of existing distribution networks and offers many technical challenges for successful introduction of PV systems. Some of the technical issues are islanding of PV, voltage regulation, harmonic distortions, increase in system fault level protection and stability of the network. Some of the PV technologies produce DC power; power electronic interfaces are required to connect them to the load as well as the distribution power network. These additional devices introduce new control issues. The salient issues of the PV plant interconnection are outlined below:

- Power quality and stability
- Power factor and voltage regulation
- Frequency control
- Transient analysis and post steady state

Potential technical problems can be addressed regardless of the type of the PV generation system, provided proper analysis and design is performed at early stages. Utility may consider following points:

- The PV plant developer should be responsible to provide adequate steady state and dynamics models of the PV plant to utility where PV plant will be interconnected
- The models should be updated when commissioning the PV plant if any model structures or parameters are substantially changed between the planning and commissioning phase of the plant
- Field verification tests or studies should be performed to demonstrate that the PV plant meets all of the requirements set forth by interconnection policy of the utility. In particular, the low-voltage ride-through capability of the PV should be demonstrated either through detailed modeling of the PV controls, or by field/ factory tests.
- For the purpose of continued understanding and analysis of distribution system with PV system operation and control, utility may consider requiring that each interconnection be equipped with a disturbance monitor and automatic voltage regulators and other safety and controlling equipments.

VI. Future Work

In the coming next 5-10 years, there will be scenario of distributed energy generation at a large scale and hence there will be a dire need for the proper and in-depth study of the distribution system along with PV integration. So, it has a wide scope of research regarding the various parameters. On integrated analysis of production-distribution systems, there are important areas where further research is needed. By integrated analysis we understand analysis performed on models that integrate decisions of different production and distribution functions for a simultaneous optimization.

VII. Conclusion

Photovoltaic (PV) generation is an attractive source of renewable energy due to their relatively small size and operation. We have seen the various aspects related to this analysis and integration of PV to distribution system. The intent of this review paper is to objectively discuss the issues and concerns related to the integration of PV generation into the utility power system. The outcome is a series of recommendations, all technically feasible and viable, for possible incorporation into broader standards for interconnecting PV plants to the utility system. The goal of any such standard will be to establish minimum technical requirements for connecting PV plants to the power systems at transmission and/or distribution levels - this in the end will help to ensure greater utilization of our natural renewable resources helping to safe guard our environment.

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