IMPACT OF ROOFTOP SOLAR SYSTEM ON POWER GRID

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ABSTRACT
Any research work foundation depends on literature survey. Based on the studies carried out by several researchers and their contribution to research field motivates for further scope of research. In this paper firstly review of several research papers by various authors and technical reports has been discussed. Then suggest the simulation model of Grid connected PV system for reducing the impact of PV system on the Grid. The whole model is simulate in MATLAB software for demonstration of small scale power generation like rooftop solar system.

Index Terms:- Microgrid, DG, PCC.

INTRODUCTION
The traditional electrical power grid is unidirectional in nature, where the electricity lows from power generation facilities to end users. This system has served well for the last hundred years. Recently, however, it has been subjected to government deregulation and has suffered from several technical, economic, and environmental issues. Modern society demands this system to be more reliable, scalable, and manageable while also being cost effective, secure, and interoperable [1]. The next-generation electric power system, known as the “smart grid” [2], is a promising solution to the long-term industry evolution. The smart grid is expected to revolutionize electricity generation, transmission, and distribution by allowing two-way lows for both electrical power and information [3]. Moreover, it can complement the current electric grid system by including renewable energy resources, such as wind, solar, and biomass, which is environmentally cleaner as compared to the fossil fuels used in many bulk electric power generation facilities. Furthermore, each of these new power generating systems can be relatively small and can be distributed around the load centers to increase the reliability and reduce the transmission loss, which adds another degree of flexibility while also increase the complexity to the current power system. The definition and description of the smart grid are not necessarily unique, as its vision to the stakeholders and the technological complexities can be different [4]. For example, the Ontario Smart Grid Forum has defined the smart grid as follows.

“A smart grid is a modern electric system. It uses communications, sensors, automation and computers to safety of the electricity system. It offers consumers increased choice by facilitating opportunities to control their electricity use and respond to electricity price changes by adjusting their consumption. A smart grid includes diverse and dispersed energy resources and accommodates electric vehicle charging. It facilitates connection and integrated operation. In short, it brings all elements of the electricity system production, delivery and consumption closer together to improve overall system operation for the benefit of consumers and the environment” [5].

In general, a smart grid is the combination of a traditional distribution network and a two-way communication network for sensing, monitoring, and dispersion of information on energy consumptions. An example of communication architecture in a smart grid is shown in Figure 1. A typical smart grid consists of numerous power generating entities and power consuming entities, all connected through a network. The generators feed the energy into the grid and consumers draw energy from the grid. The ad hoc, dynamic and decentralized energy distribution are hallmarks of the smart grid.

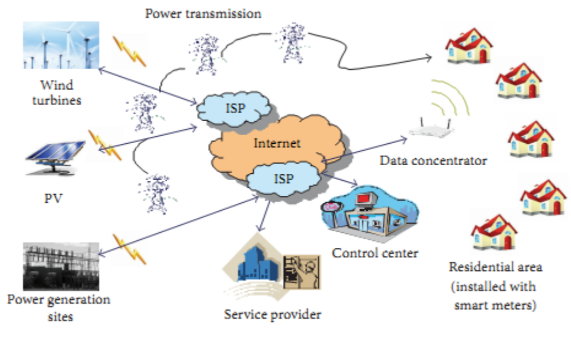

Figure 1: An example of communication architecture in smart grid.

Recent technological advancement on distributed energy resources management helped creating a new grid paradigm, the smart micro-grid distribution network [6]. A micro-grid is an electrical energy distribution network that includes a cluster of loads, distributed generators (e.g., renewable energy sources such as solar panels and wind turbines), transmission, and energy storage systems. A micro-grid can dynamically respond to the changes in energy supply by self-adjusting the demand and generation [7]. Controlled and reliable integrations of distributed energy resources and micro-grids are extremely important to ensure an uninterrupted power supply in the most efficient and economic configuration.

II MICRO GRID AND INTEGRATION OF ENERGY SOURCES

Recently, distributed generation (DG) has become extremely important due to the growing global interest in reliable and sustainable electric power supply, to incorporate more renewable and alternative energy sources and to reduce the stress and loss in existing transmission system [8]. In DG, different energy resources can be incorporated to form an energy system that can meet the demand of local users. The emphasis in distributed generation is increasing as it can also conveniently support electrical energy needs in remote and rural areas [9], where no main utility power grid exists or is unreliable. A micro-grid, in this context, refers to a controlled system of a cluster of loads and distributed micro-energy sources that can provide electrical power to its neighboring areas [7, 9]. It can effectively coordinate different types of distributed energy resources through local power managements.

The U.S. Department of Energy has defined a micro-grid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid (and can) connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode." A micro-grid is considered to be the building blocks of future smart grids [10] with participation of multiple small-scale renewable energy sources. A conceptual illustration of a micro-grid within the context of a smart grid is shown in Figure 2.

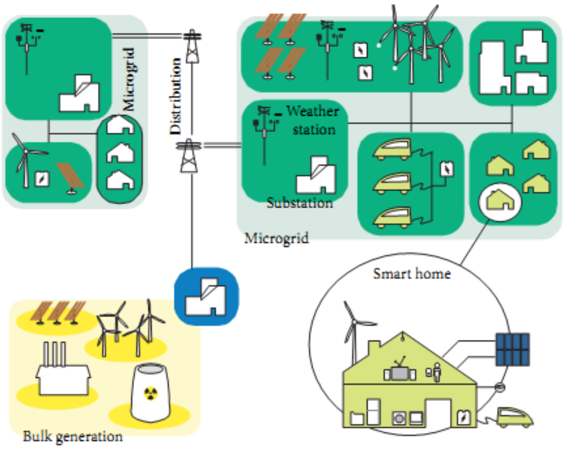

Figure 2: A conceptual illustration of a micro-grid.

Electric power can be generated at a distribution level in a micro-grid. It usually includes a variety of small power generating sources, as well as energy storage systems such as batteries, flywheels, and super capacitors [8, 13]. The power generating sources may include renewable sources such as solar panels and wind turbines, which are typically located close to the consumer sites [8]. A micro-grid can be coupled with the utility power grid through a single connection, known as point of common coupling (PCC). The electrical energy can low in either direction through this coupling, based on the available energy generated within the micro-grid and the demands of the consumers within the micro-grid. A micro-grid, when disconnected from the main grid, is known as an "islanded micro-grid." In an islanded micro-grid operation, DGs continue to power the users of the micro-grid without requiring obtaining electric power from the utility grid [10, 11]. To connect and disconnected processes in a micro-grid are specified by the PCC.

Traditional power system is not designed to incorporate power generation and storage at the distribution level. It is also not designed to allow the distributed energy sources to supply the power to the customers directly [11]. Interconnecting and integrating distributed energy sources to power grid, therefore, is a challenging task. Due to the involvement of significant and critical technical issues associated with such integration, it has attracted significant research attention [11].

Power electronic can play an important role in micro-grid integration. Distributed energy sources can interface with a micro-grid through rotating machines or through electronically coupled units that utilize power electronic converters to provide the coupling media with the host system [12]. The interfaces between the micro-grids and prime movers can be based on power electronic converters acting as voltage sources (or voltage-source inverters in AC micro-grids) [13]. These power electronic converters are connected parallel through a micro-grid. In order to avoid circulating currents among the converters without the use of any critical communication between them, droop control method is generally used; however, it suffers from load-dependent frequency and amplitude deviations, which can be resolved by installing a secondary controller, implemented in the micro-grid central control [13].

The output voltage of distributed energy resources can be DC or AC with a variable frequency. Unregulated output voltage and intermittent nature of renewable energy sources require the use of power converters for integration of the energy sources to the utility grid [14]. Voltages sourced converters (VSC), coupled with isolating transformers, are commonly used for this [14]. Designing grid connected VSC systems may face issues, leading to a distorted line voltage. In [14], modeling and control system design for a three-phase VSC system is investigated. After presenting a model for control system design, simulation, and stability analysis, a control strategy that regulates active/reactive power generation and mitigates the effect of grid voltage distortion on line currents is proposed in [14].

A micro-grid is desirable to have a simplified operation capability so that an entity, for example, energy storage system, or a controllable load can be added without requiring a system level reconfiguration. Proper control or energy management system is imperative to ensure system stability, reliability, and deficiency while integrating multiple energy sources, storages, and controllable loads. The measurements taken from different components of micro-grids need to be communicated to the control system that can then decide on optimal operation for each component, based on the available information of the current states and the operating conditions [15].

III IMPACT OF PV SYSTEM ON GRID

Photovoltaic systems were first used as stand-alone systems to provide electricity to rural areas where no other sources of energy were present. The advances in the technology and the concerns about global warming are encouraging both utilities and customers to expand the use of grid-connected PV systems. However, the intermittent nature of the output power of these systems might impose some challenges on the operation of the electric network. The aim of this chapter is to explore the pros and cons of installing grid connected photovoltaic systems and to present some of the methods that can be used to study the impacts of these systems on the electric network. For utilities, the gains of installing PV systems are mainly operational benefits, especially if the PV system is installed at the customer side on rural feeders. For example, PV systems can be used to decrease the feeder losses, improve the voltage profile of the feeder, and reduce the lifetime operation and maintenance costs of transformer load tap changers (LTCs). Moreover, if the peak output of the PV system matches the peak loading of the feeder, then the loading of some transformers present in the network can be reduced during peak load periods.

In order for all the aforementioned benefits to become effective, a number of conditions must be satisfied, including:

1. Strategic placement of the PV system,
2. Proper sizing of the PV system, and
3. Suitability of the output power profile of the PV system.

The negative impacts of Grid-connected PV systems on the network operation did not receive much attention until lately, after the noticeable increase in installation of these systems. The work done in this area can be classified under three main categories:

1. Impacts on the generation side,
2. Impacts on the transmission and sub-transmission networks, and
3. Impacts on the distribution networks.

Impact of PV system on the generation side

Severe fluctuations in the output power of large PV systems might affect the generation in electric utilities. This is mainly due to the fact that the utilities have to follow these fluctuations in order to compensate for any rise and fall in the generation of PV systems. Hence, the generating units that are scheduled to operate during the generation period of PV systems should have ramping rate capabilities that are suitable for the fluctuations of these systems. Moreover, the power fluctuations from the PV system make it difficult to predict the output power of these systems, and thus, to consider them when scheduling the generating units in the network.

The study suggested some solutions that can be applied to the cases where the severity of the changes in the output power of the PV system is beyond the ramping capacity of the system. These solutions include:

1. Increasing scheduled tie-line power,
2. Bringing more generating units online to increase the overall ramping capacity of the system, and
3. Decreasing the output power of the PV system.

In general, the generation side of an electric utility can be affected by the PV system if the penetration level of the PV system is comparable to the size of the generating units.

Impact on transmission and sub transmission networks

PV systems might cause problems in the transmission and sub-transmission networks if their sizes are large enough to affect these networks. The problems arise mainly due to power fluctuations of these systems which might lead to:

1. Power swings in lines,
2. Power reversal,
3. Over and under loading in some lines, and
4. Unacceptable voltage fluctuations in some cases.

Impact on distribution network

The impacts of PV systems on the performance of distribution networks are currently one of the main issues for electric utilities. This is because the size and location of the installed PV systems mainly influence these networks. The operational problems introduced by PV systems are similar to those imposed by distributed generators that produce constant active power, such as diesel generators and fuel cells. These problems arise mainly due to the installation of generators at the customer side in a feeder designed for unidirectional power flow. They include malfunctioning of protective relays, voltage regulation problems, reverse power flow, as well as overloading or under loading of some feeders. Other problems arise due to the use of interfacing electronics that lead to harmonic distortion and parallel and series resonances if a large number of inverters are installed in a certain area. Moreover, the fluctuation of the output power of PV systems adds to the problems faced by the system operator and can deteriorate the power quality of the network. The impact of small PV systems installed on rooftops of houses has received the attention of many researchers during the last few years. This is mainly due to the increase in installation of these systems due to the incentives provided by governments to residential customers. Typical ratings for PV systems installed on rooftops of houses range from 1 to50 kW.

IV PROPOSED WORK

In this paper we discuss the Rooftop solar system with grid connected. The whole simulation is divided into three parts. The first part is based on the designing of the PV module. Second is for designing of the control strategy of the PV power. Third is the interconnection with the grid. Figure 3 is the basic module of the PV system.

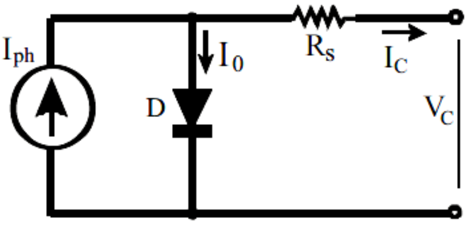

Figure 3: Simplified equivalent circuit of PV Cell

The PV cell output voltage is a function of the photocurrent that mainly determined by load current depending on the solar irradiation level during the operation.

$$V_c = \frac{AkT_c}{e}\ln\left(\frac{I_{ph}+I_0-I_c}{I_0}\right)-R_sI_c \qquad [1]$$

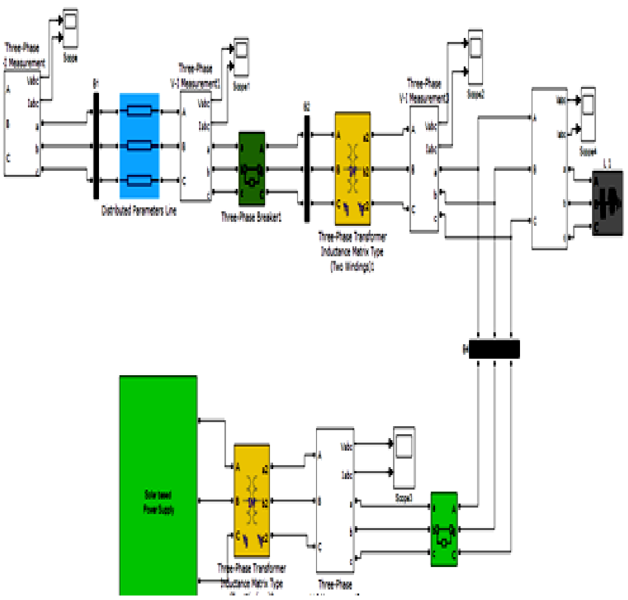

Figure 4: Simulink Model of PV Based grid connected system.

Where the symbols are defined as follows:

e: electron charge ($1.602\times10^{-19}\,C$)
k: Boltzmann constant (1.38×10^{-23} J/oK).
I_c: cell output current, A.
I_{ph}: photocurrent, function of irradiation level and junction temperature (5 A).
I_0: reverse saturation current of diode (0.0002 A).
R_s: series resistance of cell (0.001 Ω).
T_c: reference cell operating temperature (25 °C).
V_c: cell output voltage, V.

BOTH K AND T_C SHOULD HAVE THE SAME TEMPERATURE UNIT, EITHER KELVIN OR CELSIUS. THE CURVE FITTING FACTOR A IS USED TO ADJUST THE I-V CHARACTERISTICS OF THE CELL OBTAINED FROM FIGURE (3) TO THE ACTUAL CHARACTERISTICS OBTAINED BY TESTING. EQ.(1) GIVES THE VOLTAGE OF A SINGLE SOLAR CELL WHICH IS THEN MULTIPLIED BY THE NUMBER OF THE CELLS CONNECTED IN SERIES TO CALCULATE THE FULL ARRAY VOLTAGE.

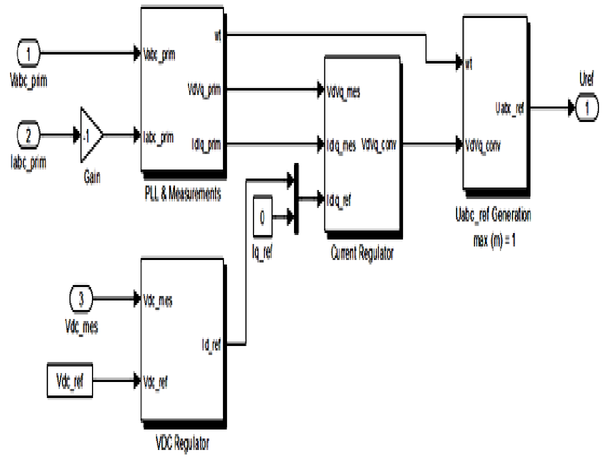

Figure 5: VSC control Block.

Figure 5 shows the control block for the voltage source converter system. Most grid side converters adopt the VSC topology with a current controller to regulate the current injected into the grid.

Control issues related to the use of gird connected converters are mainly the control of the DC voltage and the control of the AC power. The AC power can be controlled with the aim of either feeding the main grid or feeding standalone loads or a micro grid. The DC voltage can be subjected to transient conditions due to change of power. DC voltage control is necessary to compensate for voltage variations during power changes. DC voltage control is achieved through the control of the power exchanged by the converter with the grid. This is achieved by injecting/absorbing power to/from the grid, thus changing the value of the reference for the AC current loop. The control of the DC voltage through the AC current can result in the identification of two loops, an outer DC voltage loop and an internal current loop. The internal loop is designed to achieve short settling times while the outer loop is designed to achieve optimum regulation and stability. The output of the DC voltage regulator (VC) produces a demand for the current control which is used to vary the magnitude of the controlled current. The voltages at the point of common coupling (V_a, V_b, and V_c) are measured and fed into a unity amplitude sinusoidal waveform template. The sinusoidal waveform template is in phase with the grid phase voltage. The output of the DC voltage controller is then multiplied by the sinusoidal waveform template outputs. The results are used as the reference currents (I_a*, I_b*, I_c*) which are compared with the measured currents (I_a, I_b, I_c). Three individual current regulator (CC) are used, one for each phase, to generate the voltage demands V_a' V_b' and V_c', which are then passed to the PWM generator. The desired voltage at the front-end is generated according to the controlled PWM signal. The advantage of this scheme is its simplicity which means it can be implemented with an analogue circuit, thereby improving the speed response of the control scheme as there are no sampling or processing delays. The main disadvantage is an inherent tracking error resulting from the controller trying to follow a constantly changing reference value. This problem can be resolved with a high switching frequency and high current controller bandwidth. However at high power levels, the switching frequency and the current controller bandwidth will be constrained and the current errors due to the inherent tracking delay will become significant.

V RESULT ANALYSIS

In this section we discuss the result generated with the simulation of the proposed work. The whole proposed work is simulated in the MATLAB/SIMULINK environment to produce the result of the impact of solar system on the grid. Figure 6 & 7 shows the voltage and current transmitted and distributed by the grid. Figure 8 shows the power generated by the PV module.

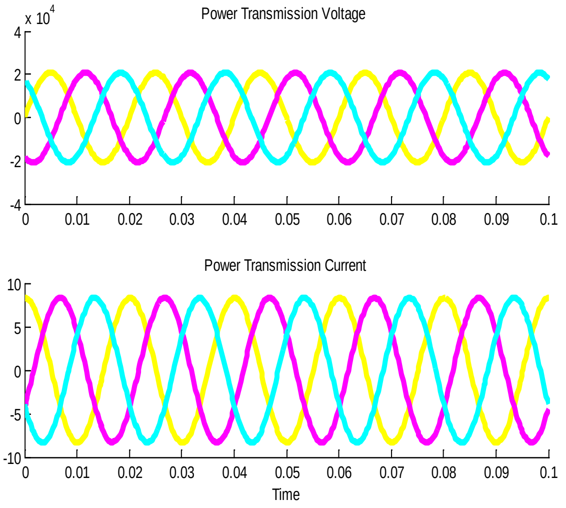

Figure 6: Grid Voltage and current for transmission.

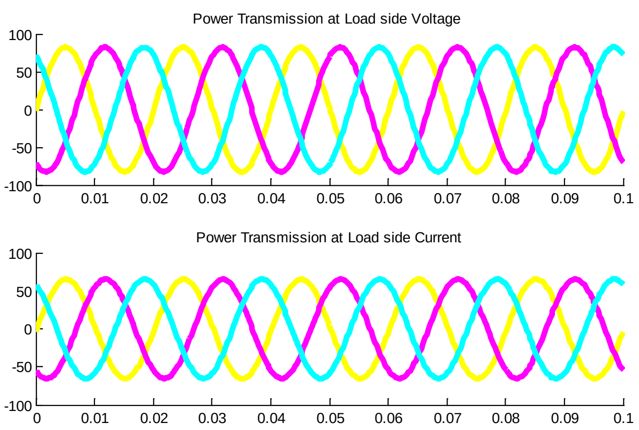

Figure 7: Grid Voltages and Current for Distribution.

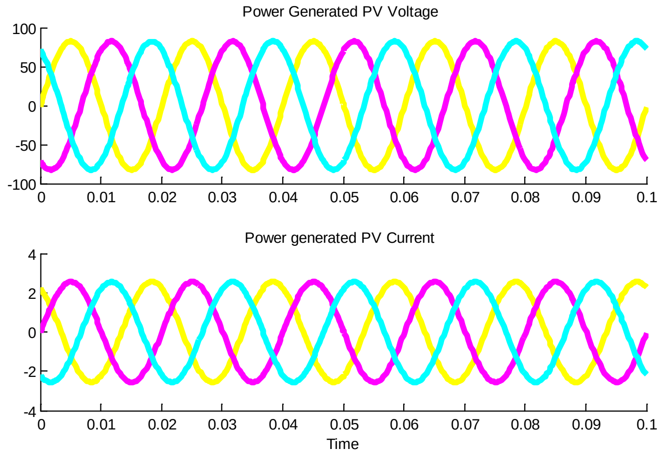

Figure 8: Voltages and Current Generation of PV System.

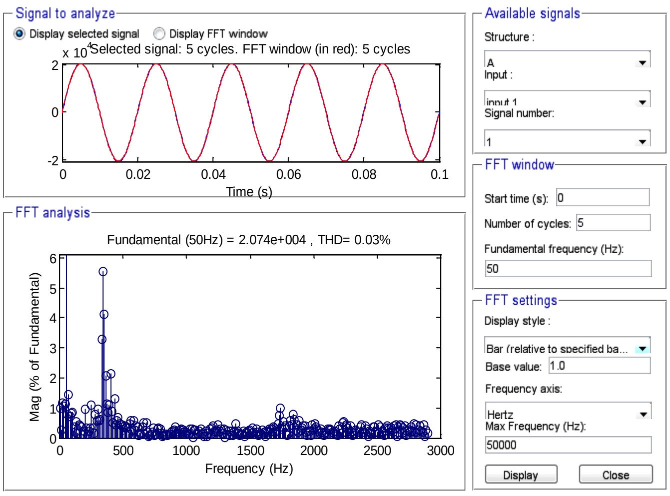

Figure 9: FFT of Voltage at Load

Figure 9 shows the FFT of load voltage. In the FFT analysis we see that the total harmonic distortion (THD) is 0.03%. it shows that the variation of the solar PV module has no impact on the grid.

VI CONCLUSION

After carrying out the literature survey the research work had one orientation towards the impact of PV system on the grid. In this paper deals the different impacts caused by the PV system on the grid. This paper focused on the simulation of the small scale PV generation for reducing impact of the PV generation on the grid side.

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