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Demand side management in a microgrid to reduce the peak consumption cost

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ABSTRACT

Microgrid stands for the participation of renewable sources such as solar and wind in the existing energy system in order to increase the availability and reliability of energy for consumers and to make the atmosphere carbon-free by reducing dependence on the main grid. However, the non-linearities inherent in the nature of the microgrid and network components make the programming process complex. Therefore, the efficient but linear model for microgrid resource planning algorithms is gaining interest today due to its simplicity and computational speed. On the contrary, for demand-side management, reducing the peak demand price by using different methods such as load trimming and valley filling by varying the use of flexible loads on the consumer side, which is an easier option for microgrid operators, rush hour price for consumer satisfaction. This paper gives an idea of the above purpose by designing an average model of a solar microgrid with the implementation of the maximum power point tracking (MPPT) algorithm method for stability of the system frequency and a battery storage system with a controller. You then plan the microgrid using the demand side management (DSM) method in order to reduce the cause of the price spikes.

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1. INTRODUCTION

Microgrids have multiple distributed sources and local loading centers with low-voltage delivery networks, regardless of the presence or absence of backup storage components. The regional load demand cannot be promoted, regardless of the collaboration of the main grid [1]. Bidirectional energy flows when the main grid is connected. There is an individual or more intelligent control unit for the control and management of all components and power flow in the micrograph. In the consumption and management of loads, that is, the management of demand is very essential for the functionality of the stability and ease of the network. If the load consumption or the generated value is underestimated, the grid operation and stability can be dangerous due to an in-line insufficient rotation reserve. If the load consumption and the generated value are overestimated, a large number of units are sent and operating costs increase [2]. Therefore, the demand side management (DSM) on the demand side plays the interface between the microgrid and the end user. Different operating modes of a microgrid have been proposed to harness maximum power. A boost converter was used to track the maximum power point tracking (MPPT) of the PV array by regulating terminal voltage and the surplus energy of the system was sent to the utility grid. For a suitable control mechanism, the conventional three-phase power system should be converted into a rotating (dq) frame so that the control in both axes is decoupled and independent of each other. This dq frame control requires a synchronization mechanism which is provided by phase locked loop (PLL) [3]. From this reference we got that microgrid is a mini-scale power system comprised of distributed energy resources (DERs), storage devices, and loads [4] and microgrid applications are used in various areas such as inverter analysis and control [5], [6]. Numerous technical obstacles still need to be removed in order to successfully integrate renewable DERs, so that the current reliability levels are not severely impacted, and the potential advantages of distributed generation are fully harnessed. MPPT method provides uplift in the tracking abilities of MPPT and at that time it reduces steady-state oscillations [7]. From this reference, we got that microgrid produces DC voltage we have inverters to convert DC to AC since, household loads are mainly ac loads and it also interlinks the system with the grid, and to get the maximum output of the solar panel we connect a boost converter with MPPT algorithm which redirects the system to operate at maximum power point [8], [9]. For a suitable control mechanism, the conventional three-phase power system should be converted into a rotating (dq) frame so that the control in both axes is decoupled and independent of each other. This dq frame control requires a synchronization mechanism which is provided by PLL. Since we are here applying DSM we implement here battery charge and discharge controller instead of charging it every time to avoid a large storage system.

Earlier societies are not so developed and were not adapted to electrical appliances as well as the generated electricity couldn't easily meet the demand of the consumers. So, now renewable energy generators like solar microgrids are preferred with the main supply to meet the demand [10]. It also gives the availability of energy every hour as the microgrid includes a storage system that provides energy during the lack of generation from a renewable source and main supply. But to meet the peak demand, more energy is required. So larger installation of the solar panel is required which will lead to high expenses and there is a waste of energy when the demand is less [11], [12]. To avoid the above and make smooth coordination between generation and consumption we have implemented DSM. The immediate purpose of the paper is to meet the peak demand and to eliminate the extra cost that is caused to cover the peak demand. Firstly, we collect the load data that is consumed by the user within 24 hours of the period as it remains almost the same every day. We also collect the power generation profile for a day in the respective microgrid. Then we try to model the system so that to interlink the generation and consumption. We store the excess power during the valley and supply it to the user during the peak hour [13]. Here we have presented an insight into the basic features of a microgrid [14], [15]. It emphasizes on modeling of the microgrid and the interlinking converter. Then we have provided simulation results and an analysis of the control technique proposed. And lastly, we have underlined the conclusion and future scope of the research.

2. METHODOLOGY AND MODELLING PROCEDURE

A microgrid consists of various renewable sources installed locally and supplies energy to the local loads which are initially synchronized with the conventional AC supply. A microgrid beneficiary has many advantages over the consumer who only relies on the main AC supply [16]. Like when the main supply is under maintenance or out of order, the microgrid can independently supply electricity avoiding interruption of work. As an energy storage system i.e., battery banks are very essential for a microgrid. They play different roles at different times. Like when there is no supply from the main and microgrid as well, the battery acts as a backup [17], [18]. As microgrid produces DC voltage we have inverters to convert DC to AC since household loads are mainly AC loads and it also interlinks the system with the grid. To get the maximum output of the solar panel we connect a boost converter with the MPPT algorithm which redirects the system to operate at the maximum power point.

2.1. Modelling of MPPT

The circuit diagram for the implementation of MPPT has been depicted in Figure 1. MPPT is a method used in a PV systems and wind turbines to extract maximum output from them at all conditions [19]. The efficiency of output power depends on the conditions like temperature, irradiance, and type of load. As these vary the highest power transfer efficiency varies [20]. To optimize the transfer the load characteristic should operate at maximum power efficiency. This work is done by the MPPT mechanism, it redirects the load characteristic to the highest efficiency condition at all conditions. MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out [21]. The boost converter consists of a switch, an inductor, an output diode, and an output capacitor which converts input voltage variation to a higher output voltage. The metal oxide semiconductor field effect transistor (MOSFET) is known as the switching device since it can be easily structured by using a pulse width modulation (PWM) signal developed by a controller.

When the switch is turned on, the inductor will store some amount of energy during on time period whereas when the switch is turned off, the polarity of that inductor is reserved. The amount of energy stored in the inductor is then transferred to the output capacitor through the connected diode which causes the output voltage higher than the input voltage [22]. The function of the PI controller is to reach the maximum power point tracking by analyzing the voltage and current of the photovoltaic (PV) array. It also adjusts the duty cycle and regulates an operating point in a system [23]. The duty cycle in MPPT is used for creating switching signals in a boost converter. The purpose of switching signals is to allow a boost converter to conduct a solar PV system at a favorable voltage and current so that maximum power extraction takes place.

In the modeling of a boost converter, a boost converter is a DC-to-DC converter that steps up the input voltage to get a desired DC voltage output [24]. Where D is the duty cycle and is the voltage generated from the solar cell. Thus, the boost converter makes the input PV voltage an ideal output voltage so that this can be applied in the MPPT algorithm to work.

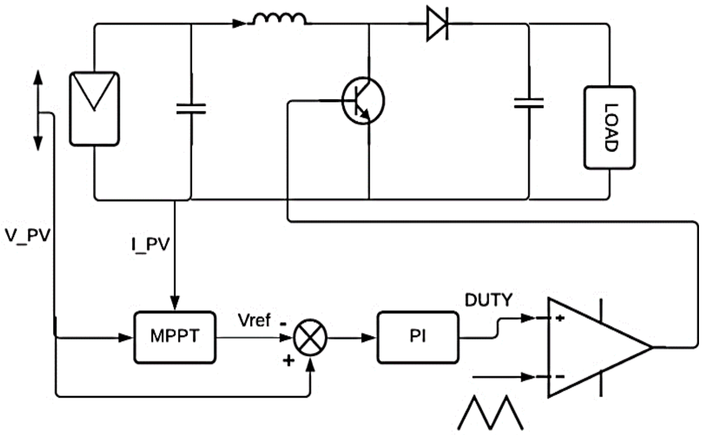

Figure 1. Circuit diagram for implementation of MPPT

2.2. Modelling of inverter

An inverter is a power electronic device that is used to change the power source from DC to AC at the required frequency and voltage output. It could be classified according to the power supply and the related topology in the power supply circuit. Therefore, they are divided into two types i.e., voltage source inverters (VSI) and current source inverters (CSI). The VSI has a DC voltage source with small impedance at the input end of the inverter [25], [26]. The CSI-type inverter has a high-impedance DC current source. We know that inverters convert direct current into alternating current. We have talked about many varieties of investors. The three-phase inverter is used to change the DC voltage to a three-phase AC power source. Now we have connected the VSI three-phase inverter to the DC output of the solar panel which interlinks the solar panel with the grid.

3. RESULTS AND DISCUSSION

3.1. PV array characteristics

The photovoltaic array on the right is the linked collection of a photovoltaic module that makes up a solar array. Multiply connected photovoltaic (PV) cells make up each PV module. Solar energy is transformed into direct-current electricity by the cells. In this model we have used 10 series modules and 47 parallel strings of solar arrays which have an open circuit voltage of 36.3 V i.e., the current is zero there and the maximum power is achieved at 213.15 V. The P-V and V-I curves have been obtained at changing solar irradiation levels and temperatures. The V-I and V-P characteristics of the solar PV module are shown in Figure 2.

3.2. Output of the boost converter with MPPT

When all the parameters are constant, the higher the irradiance, the greater the output current and a result greater the power generated. As the working principle of MPPT was discussed earlier, it helped to get the maximum power every time with respect to irradiance and temperature. The output power increased with an increase in irradiance and decreased when irradiance decreased. The behavioral graph is given in Figure 3.

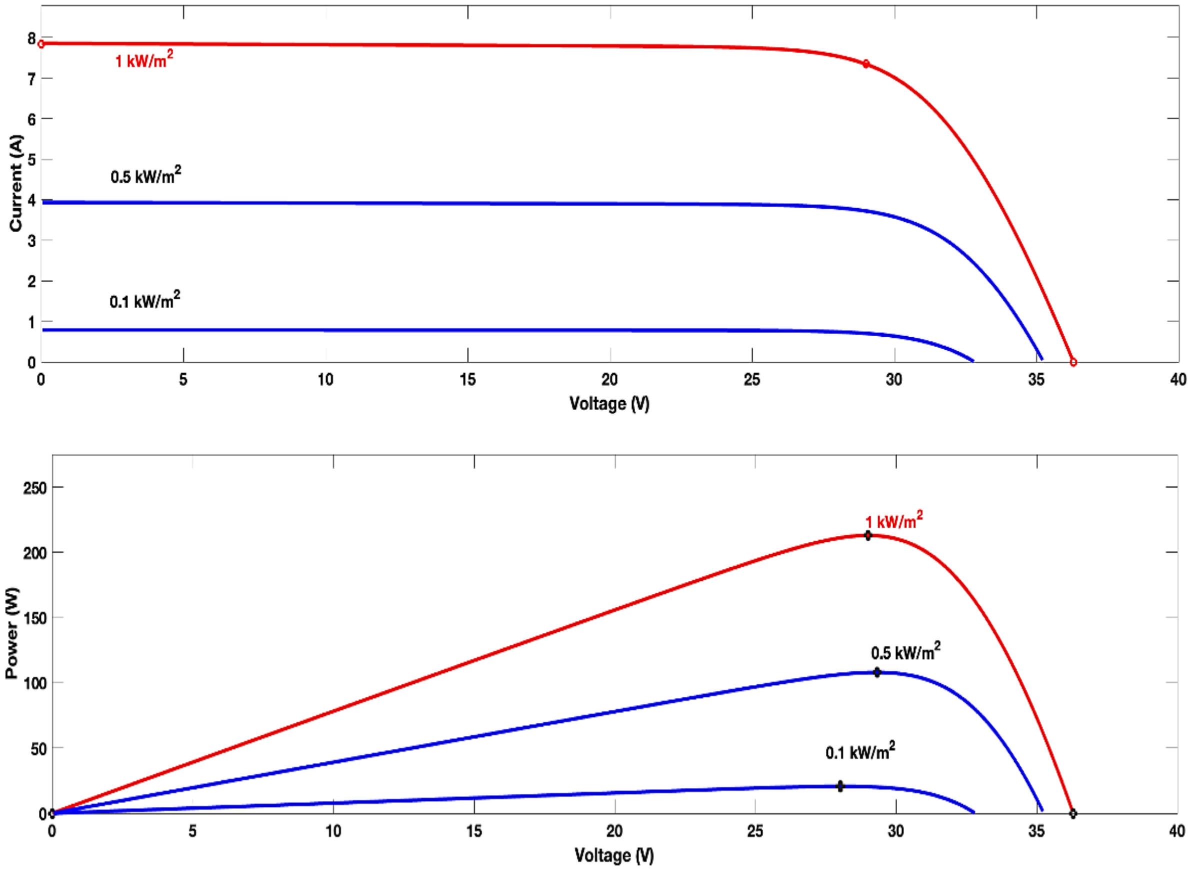

Figure 2. V-I and V-P characteristics of the solar PV module

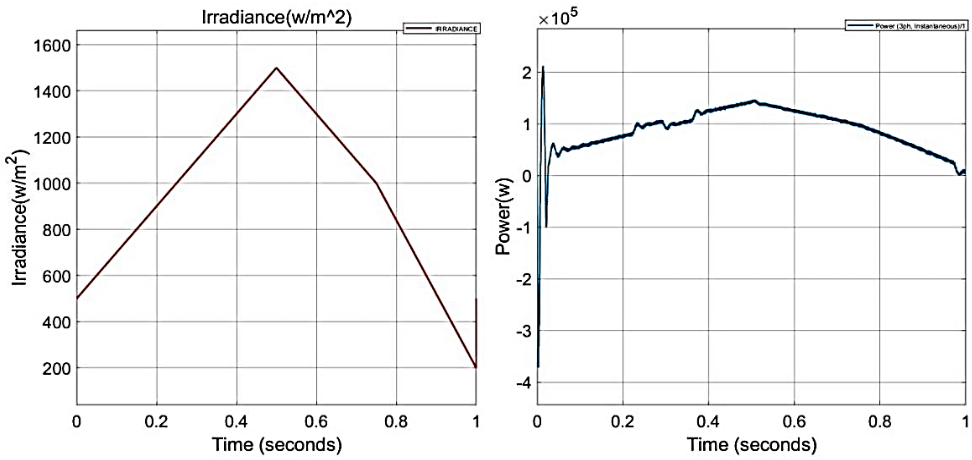

Figure 3. Irradiance and power output of PV array

An output voltage boost converter always has a higher output voltage than an input voltage. The inductor saves some energy by creating a magnetic field when the switch is closed (the "on-state"). Current flows through the inductor clockwise in this condition. The current is given in Figure 4. It shows so much fluctuation in the boost converter and the DC output voltage remains constant irrespective of changes in irradiance as shown in Figure 5.

3.3. Output voltage and current of the three-phase inverter

The boost converter output is connected to the VSI three-phase converter which converted the DC voltage to three-phase AC voltage and supplies three-phase AC current. The voltage remains the same with a change in Irradiance but, the current changes with a change in irradiance as shown in Figure 6. As a result, it converts the DC voltage into three phase AC supply.

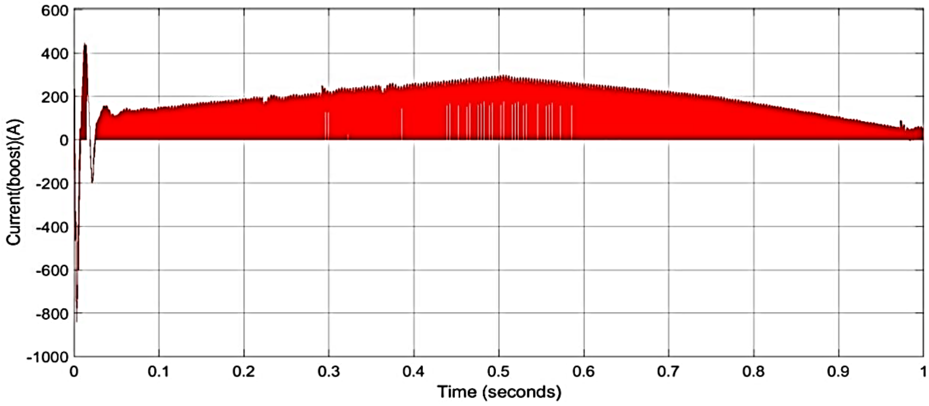

Figure 4. Boost converter output current

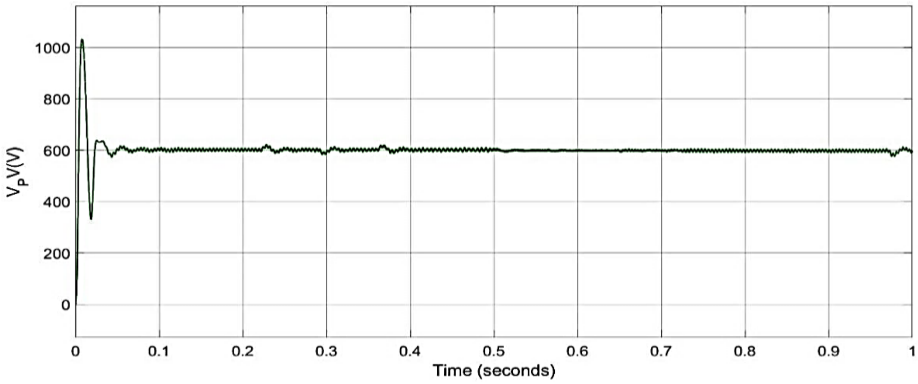

Figure 5. The output voltage of the boost converter

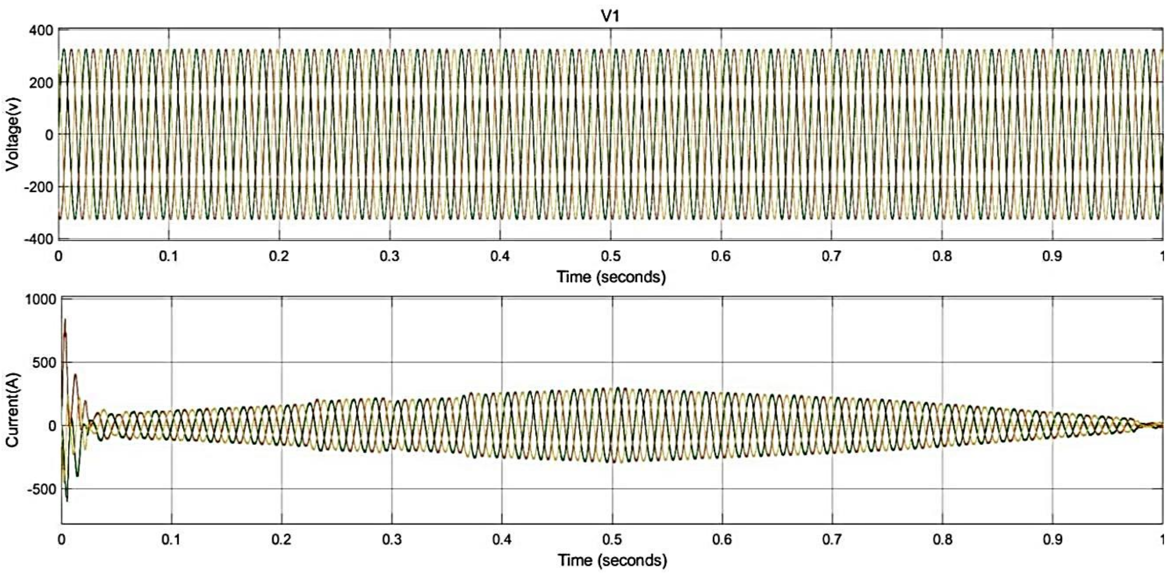

Figure 6. Three-phase voltage and current of the inverter

4. CONCLUSION

The MPPT algorithm succeeded to track the maximum power point and extracting this power from the photovoltaic system. It has been seen that the generated power depends upon the irradiances and temperature as shown above. When the irradiance varied the power also varied. The three-phase voltage generated after passing the DC voltage through the inverter circuit remains the same irrespective of the change in radiation and temperature, but the current changes as shown below, From the above we got that the Demand Side Management system with demand response plays a most important role in effectively managing the wastage of energy on the consumer side. Here we store the extra energy generated by the solar module during lesser load demand and supply it during peak which will eliminate the requirement for larger solar panels installations to meet the peak demand. So, it ultimately reduces the cost. Hence in this paper, we give a free and distributed energy consumption optimal scheduling scheme for reducing the maximum demand and total energy price. This configuration has uniformly given consumers load over the entire day and balanced the domestic load in a particular scene where many kinds of people are connected to a single power supply source. Simulation results confirm that our researched demand side load management method is efficient because of the declination in the peak demand and energy cost. In future work, our technique can be used to expand the unification of renewable energy resources available at users' places and the addition of feed in cost. Second, it is interesting that our model can be modified for adaptive and user-friendly requirements.

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