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Active and Reactive Power of Bidirectional AC-DC Microgrid System for PV System Application

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Abstract: *The AC/DC hybrid microgrid, which takes into account the access requirements of AC and DC sources and loads, optimizes the structure of traditional distribution networks. The application of power electronic transformers as the core of its energy management, with electrical isolation and accurate control of the voltage, current and power flow by the control system, enables the microgrid to achieve a more flexible and stable transmission mode. Because the power electronic transformer combines the power electronic device and the high-frequency transformer, its frequent switching causes the electromagnetic transient simulation to take too long. Microgrid concept integrates large amounts of micro sources without disrupting the operation of main utility grid. This hybrid Microgrid consists of PV/wind energy sources for DC and AC networks respectively. Energy storage systems may be connected to either AC or DC Microgrids. The proposed hybrid Microgrid operates in grid-tied or isolated mode. AC sources and loads are connected to AC network, whereas DC sources and loads are connected to DC network. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature and load are additionally considered in the system model and operation.*

Keywords: *Solar Power, PV Array, Inverter, Seven Level, Cascaded Multilevel.*

1. Introduction

Increasing concern towards the energy crisis due to the depletion of fossil fuels and environmental issues like global warming has ignited a revolutionary change in the conventional power system in terms of production and outage. The conventional grid is characterized by unidirectional power flow that constitutes bulk power generation followed by transmission and distribution. The conventional power system experiences the following drawbacks stated below. Inability to meet the rising demand. Expandability of power network is minimum. Bulk power generation and outage require a huge investment. Impact of carbon emissions on the environment. Monopoly in the power sector. The inability of conventional grid to accommodate the renewable
energy sources due to unidirectional power flow and the instability problems due to variable power generation led to the concept of distributed generation with non-conventional energy sources. The potential benefits of distributed generation include proximity of the load and generation systems that drastically minimize the transmission and distribution losses, increased system-wide reliability, and easy augmentation of resources to the utility grid. The penetration of renewable energy resources like solar energy, wind energy, bio-gas etc. and other non-conventional micro sources like diesel engines, microturbines modified the demography of the power system network in the distributed generation. The capability of renewable energy sources to meet the load demand has been an encouraging prospect in

the distributed generation sector. According to the International renewable energy agency, the share of renewables in power generation is expected to increase to

33% by the end of 2019. For the enormous exploitation and effective utilization of renewable energy sources in the distributed generation environment, the multiple micro sources need to be integrated into a distribution network. The huge advent of power electronics facilitates the integration of micro sources, storage technologies and the end-user in an active distribution network.

2. Microgrid and Their Classification

The cluster of micro sources, storage devices integrated in a distributed network through a controlled power electronic interface to meet the load demand forms a microgrid (MG).

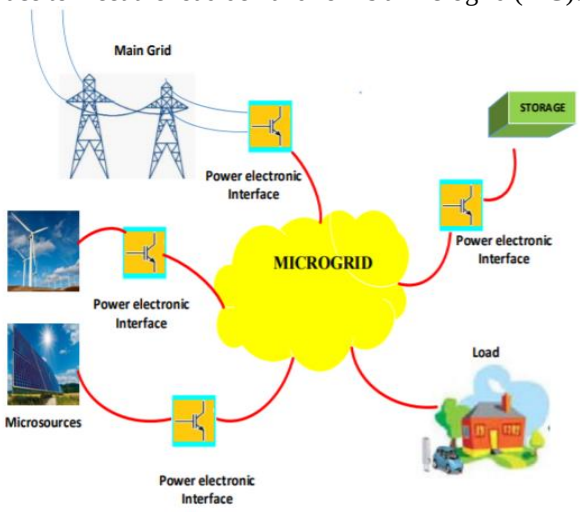


Fig. 1: Physical diagram of basic microgrid

In other words, a distributed generation environment, that consists of at least one energy source along with a power electronic interface which can either be connected to the utility grid or can act autonomously to fulfil the load demand. During the past decade, the evolution of microgeneration technologies and power electronic interface facilitates the microgrid to operate at a low voltage level. Fig 1 represents the physical structure of microgrid.

The microgrids are much popular and pave a way for significant development in the future smart grid. The microgrid has an edge over the conventional network due to the following reasons. The democratization of power at the domestic level. Reliability in supplying electric power. Reduced emissions with the penetration of renewables A tampered expense due to proximity of generation and the load The diversified power level at the output to cater to different technologies like AC, DC and both. Remote electrification in extremely rural and tribal areas. The microgrids are classified based on the connectivity, output type and application as shown in Fig. 2.

Microgrids can either be connected to the main grid or can act autonomously which classifies it as grid-connected microgrid and Islanded microgrid. Based on the output type and loads connected, the microgrid is classified as AC microgrid (ACMG), DC microgrid (DCMG) and if it could feed both ac and dc loads, it is termed as a hybrid microgrid.

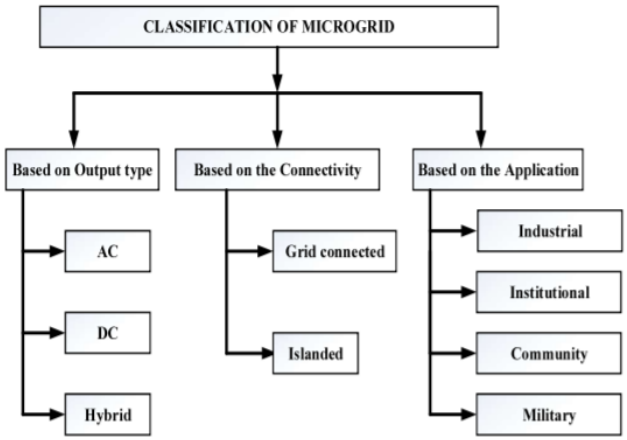


Fig. 2: Classification of Microgrids

Depending on application, regulatory prospect of microgrid it is classified as Industrial microgrid, Institutional microgrid, Community microgrid and Military microgrid. The Industrial or commercial microgrids are intended to supply power to commercial applications despite the technical difficulties due to the involvement of various private parties. The institutional microgrids supply power to set of public buildings in the public sector which are owned by the government. These microgrids ought to ensure uninterrupted power supply. So as to lighten up the remote areas, a temporary set up supported largely by the renewable generation systems are erected. Such microgrids are termed as military microgrids. The community microgrids are also known as residential microgrids since its model is intended to supply power to residential areas. These microgrids can be owned by the private parties through which the democratization of power is achieved, shattering the monopoly in the power sector. These microgrids prove to be an appropriate solution for palliate problems that arise in the low voltage level power networks. In the remote and rural areas, the electrification is carried out similar to military and community grids except for the

fact that they are incapable of integration to the main grid. These remote microgrids serve as a boon to the indigenous people of the hilly and tribal area.

3. PV System

The photovoltaic cell converts the light energy into electrical energy depending on the irradiation of the sun and temperature in the atmosphere. Basically PVC is a PN junction diode [8] [4]. But in PN junction diode DCI AC source is needed to work, but here light energy is used as a source to produce DC output. PVC is a current control source not a voltage control source. The equivalent electrical circuit diagram of PVC is shown in the Fig. 3.

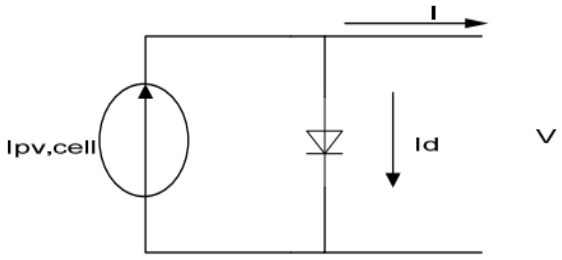


Fig. 3: Show ideal photovoltaic cell equivalent circuit

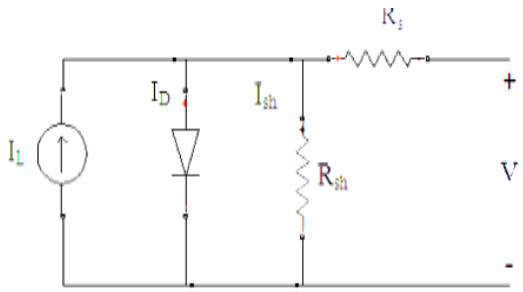


Fig. 4: Equivalent Electrical Circuit of PVC

$$I_D = I_0[\exp(V + IR_S)/KT - 1] \quad (1)$$

Therefore PVC output current is given in equation 2.

$$I = I_L - I_D - I_{Sh} \quad (2)$$

$$I = I_L - I_0[\exp(q(V + IR_S))/KT - 1] - (V + IR_S)/R_{Sh} \quad (3)$$

Where I_D the diode is current, R_{sh} is the shunt resistance, I_L is the light generated current of solar array. Solar cell is basically a p-n junction fabricated in a thin wafer or layer of semiconductor. The electromagnetic radiation of solar energy can be directly converted electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron-hole pairs proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar insolation. PV system naturally exhibits a nonlinear I-V and P-V characteristics which vary with the radiant intensity and cell temperature.

4. Power Quality

Power quality for the most part manages the interaction among the clients and the utility or it can be likewise said that it gives an interaction between the power system and the separate load. A definitive objective of power system is the supply of electric energy to its clients. Over the most recent 50 years or somewhere in the vicinity, as a result of the broad development of enterprises power request has massively expanded which has prompted establishment of numerous power generation and distribution grid. The interest for expansive measure of power for modern and local utilize expanded the weight on the generation. Electrical utilities working today are functioning as a subsystem of a vast utility network that are entwined with a specific end goal to shape an unpredictable grid. Every one of these factors have put the power system under the necessity of a power quality.

A powerful quality is the primary point of the business facility design, alongside "prosperity," "trustable administration" and "low start and working costs". Issue in power quality is generally alluded to any electrical issue faced in the frequency, voltage or current deviation which prompts mal-activity of the client's equipment. Frequently when we discuss nature of power we actually mean the nature of voltage since it is the voltage which is controlled the greater part of the circumstances. The term power quality can be connected with dependability of the system by the electrical utilities. The most troublesome thing is upkeep of the electrical power quality so it will exist in as far as possible. There are numerous drawbacks of poor and low power quality. It might prompt higher power losses, anomalous and uncommon conduct of electrical hardware, and impedance with the adjacent correspondence lines, poor voltage profile, harmonics, hang and swells in the voltage, poor and low distortion and displacement factor.

In the current time power electronic and electronic hardware are winding up increasingly touchy when contrasted with their partners couple of years back. The hardware which is

especially defenseless to this variety or debasement of power quality is the delicate loads. Unadulterated sinusoidal voltage is required for its legitimate task. Alongside the expanded affectability of the gear, the developing affectability of organizations towards the creation loss on account of diminishment in the edge of benefit has likewise included to the weight the nature of power. From ages power has been considered as an essential right in the household life and it will dependably be there. Because of this very reason even a little intrusion in the supply prompts overwhelming grievances, regardless of whether no harms are identified with it.

Tripping of the electrical equipment on account of aggravations in the supply voltage is as often as possible depicted by customers as "horrendous power quality". Then again utilities regularly observe agitating impacts on account of the end customer hardware as the standard power quality issue. The inconvenience in assessing power quality concerns is elucidated by the method for interaction among the nature of power and the gear. What is "incredible" power quality for one gear could be "terrible" power for another. Two unclear gear may react differently to a similar power quality parameters due to contrasts in their gathering. Present day electronic gear isn't in charge of voltage agitating impacts; it moreover causes aggravations for various buyers. The principle guilty party behind this poor power quality is the utilization of power electronic devices that are for the most part the gear driven by converters and rectifiers like PC, speed drives and so forth that acts as non-direct load.

5. Proposed Methodology

In the present trend, Renewable energy sources are attractive choices for providing power in the places where an association to the utility network is either not possible or unduly costly. As electric distribution technology steps into next century, several trends have become noticeable which will modify the necessities of energy delivery. The ever-increasing energy consumption, soaring value and exhaustible nature of fossil fuels, and also the worsening international environment have created enhanced interest in green power generation systems. Renewable sources have gained worldwide attention because of quick depletion of fossil fuels in conjunction with growing energy demand.

Microgrid concept integrates large amounts of micro sources without disrupting the operation of main utility grid. This hybrid Microgrid consists of PV/wind energy sources for DC and AC networks respectively. Energy storage systems may be connected to either AC or DC Microgrids.

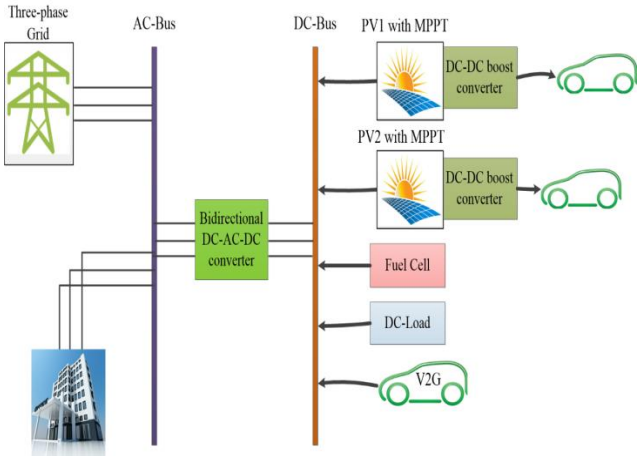


Fig. 5: Representation of cascaded PV to grid connected system

The proposed hybrid Microgrid operates in grid-tied or isolated mode. AC sources and loads are connected to AC network, whereas DC sources and loads are connected to DC network. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature and load are additionally considered in the system model and operation. Representation of microgrid system shown in fig. 5.

Designing of AC bus

In the proposed microgrid system design AC bus which is connected with three phase grid so it is suitable to power supply to the bus. As shown in figure 4.1 microgrid system have AC load at the AC side and it is directly connected to the AC-bus. AC side load and grid simulation diagram shown in figure 5.

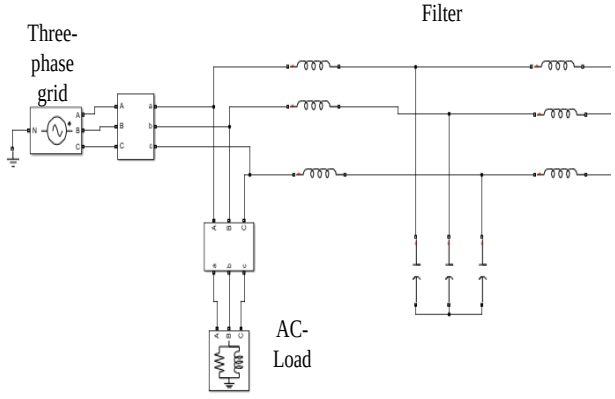


Fig. 6: Simulation of AC side load and grid

Grid Synchronization

The number of PV installations has an exponential growth, mainly due to the governments and utility companies that support programs that focus on grid-connected PV systems. In a general structure distributed system, the input power is transformed into electricity by means of a power conversion unit whose configuration is closely related to the input power nature. The electricity produced can be delivered to the local loads or to the utility network, depending where the generation system is connected.
One important part of the distributed system is its control. The control tasks can be divided into two major parts:

(1) Input-side controller: Its main property is that it can extract the maximum power from the input source. Naturally, protection of the input-side converter is also important to be considered.
(2) Grid – side controller: It performs the following:

(a) It controls the active power generated
(b) It controls the reactive power transfer between the PV and the grid
(c) Control of the dc-link voltage is done by the grid-side controller
(d) It ensures high quality of the injected power

The items listed above for the grid-side controller are the basic features this controller should have. In addition to the above, auxiliary services like voltage harmonic compensation, active filtering or local voltage and frequency regulation might be requested by the grid operator.
The necessity of voltage feed forward and cross-coupling term is the major drawback of the control structure implemented in synchronous reference frame. In addition to that the phase angle of the grid voltage is a must in this implementation. In the case of control structure implemented in a stationary reference frame, if PR controllers are used for current regulation, the complexity of the control becomes lower compared to the structure implemented in dq frame. In addition to that, the phase angle information is not a necessity, and filtered grid voltages can be used as templates for the reference current waveform.

6. Simulation Result

The proposed Microgrid operates in grid-tied or isolated mode. AC sources and loads are connected to AC network, whereas DC sources and loads are connected to DC network. Figure 6 shows the three-phase grid voltage and grid current. Which used to connect to AC bus by using LCL filter. This three-phase voltage and current stabilised unity power factor at the grid side and also its have lower harmonics.

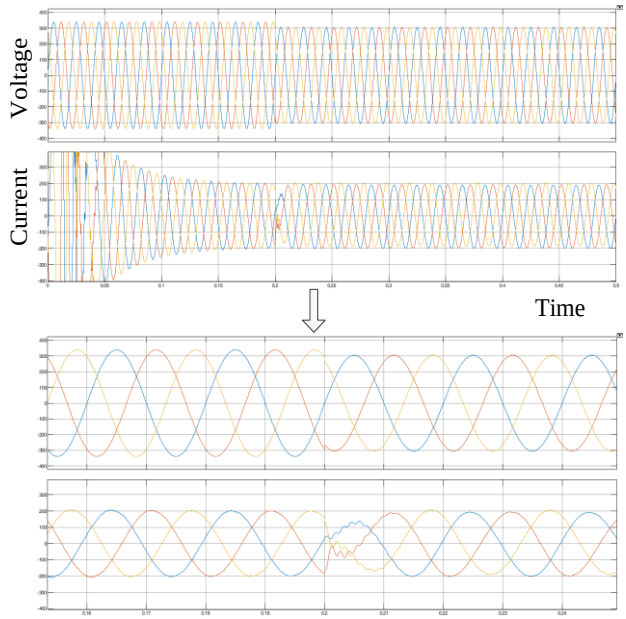


Fig. 7: Three phase grid voltage and current

By creating some disturbance through grid at time of 0.2 sec it reduces a voltage by 10%. So, it created a sudden disturbance at this time renewable energy sources perform a role so it maintains this voltage to the same condition. In fig. 7 voltage reduces by 10% but current maintain same peak to peak amplitude.

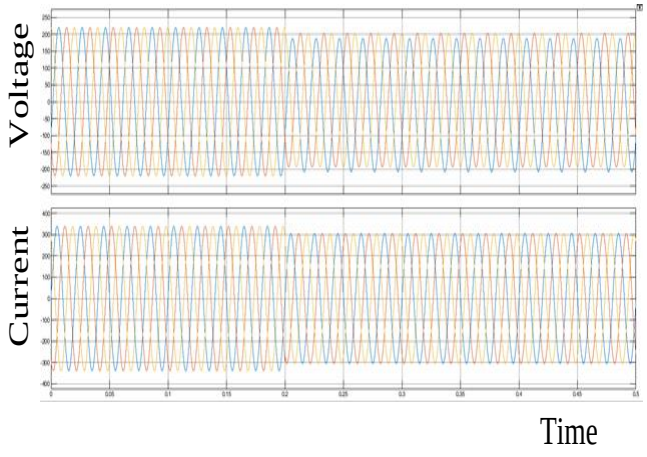


Fig. 8: Three phase AC load voltage and current

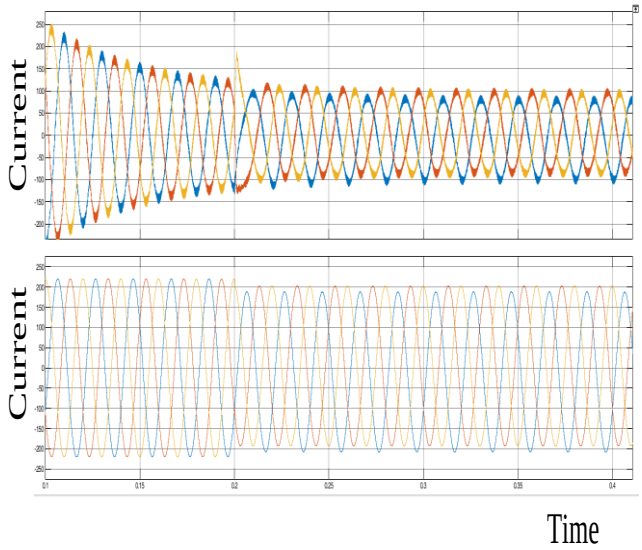


Fig. 9: Three phase AC inverter current and load current

By the sudden change the grid voltage peak reduces simultaneously for the AC load. By the design of the filter which is perform a specific role in connected with AC and DC bus, load voltage and current are ripple free which is shown in fig. 8 and also, fig. 9 shows the inverter current and load current.

Before the time t<0.2 second there is not have any problem in the grid so at this time PV module charge a battery or use as any DC load but DC bus voltage same as 800V its not change after 0.2 sec. Charge state of DC-bus battery shown in fig. 10.

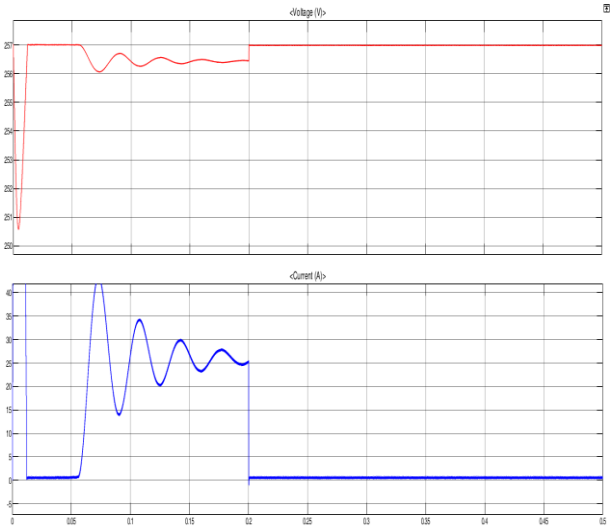
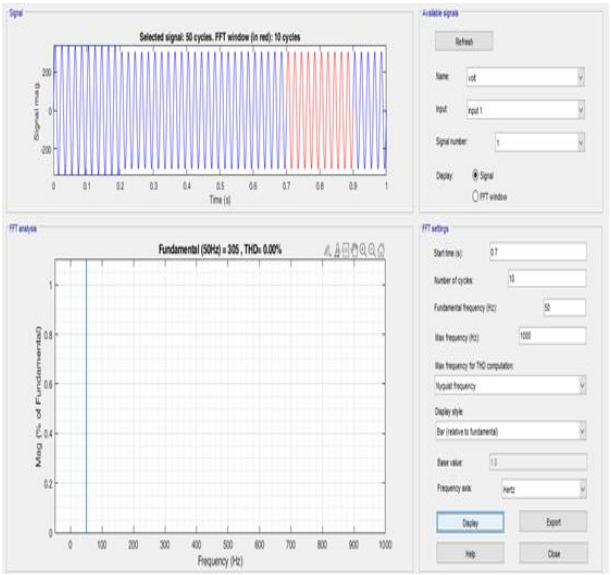


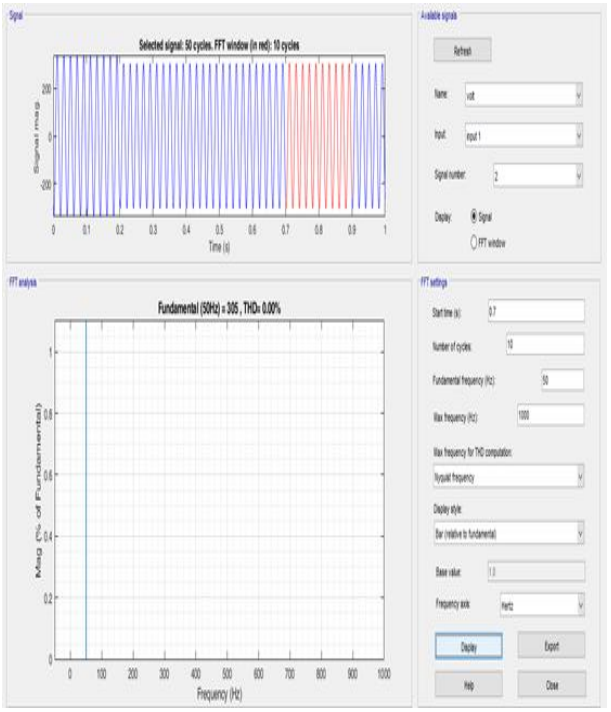
Fig. 10: Charge state of a battery

Comparison Result

THD profile of voltage-1



THD profile of voltage-2



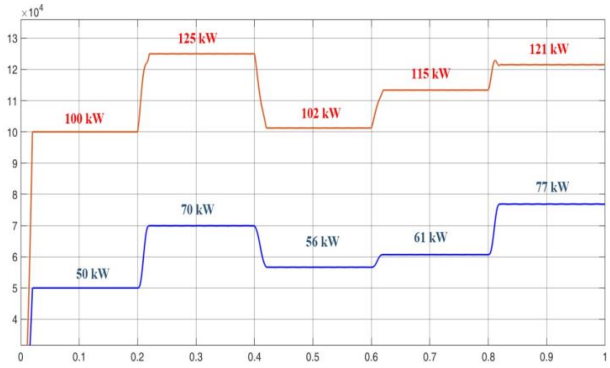


Fig. 11: Active and reactive power using load variation

7. Conclusions

In this work PV simulates at a 2 KW power rating and use a PV module as 1 parallel and 6 series connected string at specific module. Also, specified 290 maximum dc output voltage.

Maximum PV output voltage is set to 290 according to the PV module and this voltage has approximately 50V peak to peak ripple. This high voltage ripple can damage a system and reduces the efficiency also increases the losses of the system. DC voltage of the PV output.

For reduction of this ripple and increase the dc voltage required a DC-DC boost converter. Output voltage of DC-DC boost converter is ripple free and high voltage as 400V so it can be easily connected to the single-phase grid by using inverter. This DC-DC boost converter also useful for MPPT (Maximum Power point tracking) which is performed by perturb and observe method. This converter worked as a first stage of our system and work on a 5KHz Switching frequency.

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