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# Adaptive PV Module Integrated Converter Operated in Standalone and Microgrid Connected Modes using Hysteresis control

**S.M.S. Swaroop | B. Rakesh | M. Prasunna | D. Ravi Kishore**

Department of Electrical & Electronics Engineering, Godavari Institute of Engineering and Technology (A), JNTUK, Kakinada.

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## ABSTRACT

*Micro grid interconnected solar system has demand in the market due to zero fuel cost. But the drawbacks of low efficiency due to dc-to-dc converters and high switching frequency results in aging effect in the input. To compensate the above problems a new method is introduced for dc to dc converts which can be replaced by interleaved converter. The interleaved converters perform high dc conversion and also switching frequency modulation. module integrated converter (MIC) which controls the converter for smooth operation. This project focus on maximum power point tracking (MPPT) based DC-DC convert for power control. An adaptive control scheme is used for better power control. Switching frequency control is adapted for faster control and to increase the output voltage. The switching frequency is optimally modulated as a function of solar irradiations. Variation in the solar irradiation is optimally control for and output power is regulated. DC-DC converter is operated as module integrated converter (MIC) for high voltage generation. A Hysteresis controller is used to reduce the output ripples and to increase the output voltage level. This project is carried out using MATLAB/SIMULINK software.*

*KEYWORDS:***Micro** *grid, MPPT, Solar Energy, Hysteresis Controller.*

## 1.INTRODUCTION

Most of the world's energy consumption is currently met by fossil fuels such as petroleum, coal, and natural gas, which are rapidly depleting. One of the most serious challenges of global warming is carbon dioxide, which is produced by the combustion of fossil fuels and poses a serious threat to life on our planet.

Among all Renewable energy sources, PV array system plays a vital significant role in renewable energy production. Solar systems transform sun energy into electrical energy as dc. These systems generate lower voltage. Step-up dc/dc converters are used in vast applications, including wind power, fuel cells, and solar systems. Due to the increasing requirement on electricity, and less availability and big cost on non-renewable sources, the solar energy conversion has become an alternative as it is wind power, freely available and has low maintenance cost. Therefore, the use of solar cell energy systems has to be improved for grid-connected and as well as standalone modes. Photovoltaic (PV) as a renewable energy resource naturally is not stable by location, time, season cost for installation should be considers and also the material [1]. A very important consideration in improving the efficiency of solar systems is to operate the sloar system at maximum power point (MPP) which obtains the maximum power of solar array.

Maximum power point tracking are also used to increase PV system performance, and a high output converter trying to separate the most power from a PV panel is often considered. In most circumstances, the V-I graph will have a single position, known as the Maximum Power Point (MPP), where the entire PV system will function at maximum efficiency and produce its maximum power production. The operating point of the PV array is kept at the exact area where maximum power can be produced using Maximum Power Point Tracking Techniques (MPPT). The literature has covered the Perturb and Observe (P&O) strategy, the Incremental Galvanic skin (lC) method, the Artificial Neural Network method, the Proposed Hysteresis method, and others. P&O and IC are the most commonly used methods. The perturb and observe approaches are among the MPPT techniques investigated in this project.Several advancements in electricity transmission technologies will affect energy delivery requirements because as twenty-first century unfolds. Both the need for improved energy availability and efficiency and the supply side's requirement to handle the integration of distributed generation and peak-shaving technology are driving these changes [1]. The MIC is a boost converter with a filter and an SFM. Ripples were also decreased in order to maintain a consistent voltage and improve power quality. Due to dust, dirt, and other particulates on the PV panel, conversion efficiency is lowered by 20%. Dust particles in the surrounding environment reduce conversion efficiency by 30% in desert settings.

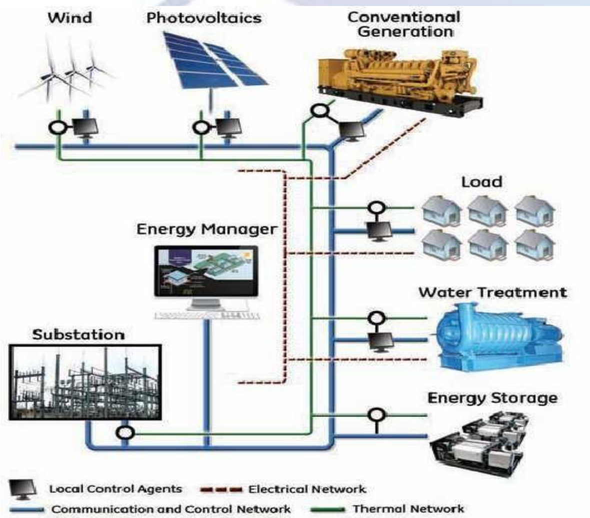


Fig 1.1 Microgrid power system

## 2. SOLAR ENERGY

*A. Introduction*

Solar cell is one way of producing electricity that includes converting solar radiation into direct current electricity using photovoltaic semiconductors. Solar panels with a number of cells containing a photovoltaic material are used in photovoltaic power generation. Monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide are currently employed in photovoltaic's [1]. Solar cell and photovoltaic array production has evolved significantly in recent years as a result of the increased need for renewable energy sources.

Solar photovoltaic generates electricity in over 100 nations as of 2010, and is the world's fastest growing power-generation technology, but accounting for only a small portion of the 4800 GW total global power-generating capacity from all sources. Grid-connected PV System capacity expanded by 60% of annually average of 2004 to 2009 is 21GW. Building Combined Photovoltaics or BIPV for short are installations that are either ground-mounted or sometimes integrated with farming and grazing embedded into the roof or walls of a building. An extra 3–4 GW comes from off-grid PV.

Since the first solar cells were developed, the cost of photovoltaic has gradually decreased due to breakthroughs in technology and increases in manufacturing scale and sophistication. Solar PV installations have been aided by net metering and financial incentives such as favorable feed-in prices for solar-generated electricity in various nations.

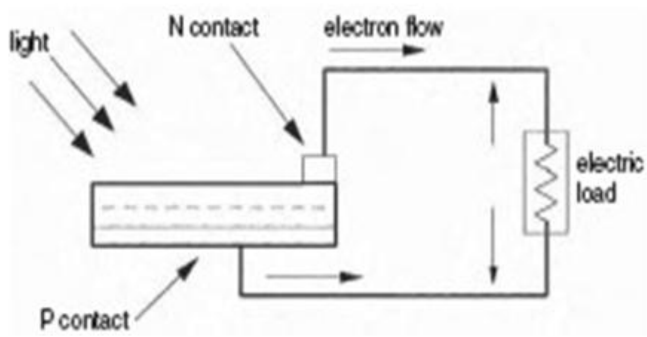


Fig 2.1: PV converts the photon energy into voltage across the p-n junction

The photovoltaic effect occurs when a substance is exposed to light and generates a voltage (or a corresponding electric current). Though the photovoltaic and photoelectric effects are related, the two processes are distinct and should be differentiated. Electrons are ejected from a material's surface when it is exposed to sufficient energy radiation in the photoelectric effect. The photovoltaic effect differs in that the produced electrons are moved across various bands inside the material (i.e., from the valence to conduction bands), leading in a voltage buildup between two electrodes. The radiation used in most photovoltaic applications is sunshine, which is why the devices are called solar cells. In the case of a p-n junction solar cell, illumination causes the generation of an electric current as excited electrons and the remaining holes are swept in various directions by the depletion region's built-in electric field, as seen in figure 2.1.Alexandre-Edmond Becquerel discovered the photovoltaic phenomenon in 1839. The largest photovoltaic (PV) power plants in the world as of October 2010 are the Sarnia Photovoltaic Power Plant (Canada, 80 MW), the Olmedilla Photovoltaic Park (Spain, 60 MW), the Strasskirchen Solar Park (Germany, 54 MW), the Lieberose Photovoltaic Park (Germany, 53 MW), the Puertollano Photovoltaic Park (Spain, 50 MW), the Moura Photovolta (Germany, 40 MW).

2.1.1 In Buildings:

Buildings are frequently associated with photovoltaic arrays, which are integrated into them, placed on them, or mounted close on the ground. Arrays are frequently retrofitted into existing structures, either on top of the existing roof structure or on the existing walls. Alternatively, an array can be positioned outside of the building but connected to it by cable to provide electricity to the structure. More over four-fifths of Germany's 9,000 MW of solar PV capacity was installed on rooftops in 2010.

2.1.2 InTransport:

PV has long been used in space for electric power generation. PV is rarely utilized to generate motive power in transportation applications, but it is becoming more common in boats and cars as an auxiliary power source. A self-contained solar car would have limited power and utility, however a solar-charged vehicle would allow transportation using solar power. There have been demonstrations of solar-powered automobiles.

*2.1.3 StandaloneDevices:*

PV was widely used to power calculators and other novelty devices until about a decade ago. Improvements in integrated circuits and low-power LCD displays allow such gadgets to operate for several years between battery changes, making PV less prevalent. Solar-powered remote fixed devices, on the other hand, have recently gained popularity in areas where grid electricity is prohibitively expensive due to high connection costs. Water pumps, parking meters, emergency telephones, trash compactors, temporary traffic signs, and remote guard posts and signals are only a few examples of such uses.

2.1.4 RuralElectrification:

Photovoltaics have been popular in developing countries because many communities are more than five kilometers from grid power. A rural lighting programme in India has been delivering solar-powered LED illumination to replace kerosene lamps in distant regions. The solar lamps were offered for roughly the same price as a few months' worth of kerosene. Cuba is aiming to deliver solar power to off-grid locations. These are regions where the societal costs and benefits make a strong case for going solar, however the lack of profitability may limit such efforts to humanitarian purposes.

2.1.5 Solar Roadways:

A 45 mi (72 km) section of roadway in Idaho is being used to test the possibility of installing solar panels into the road surface, as roads are generally unobstructed to the sun and represent about the percentage of land area needed to replace other energy sources with solarpower. Now total technology was mainly on solar system because it is pollution free, easy maintenance. Recent days in roadways solar system is implementing for better utilizing of power.

2.1.6 Solar PowerSatellites:

Large solar power collection satellites have been the subject of design research for decades. The concept was first presented by Peter Glaser, then of Arthur D. Little Inc; NASA performed a long series of engineering and economic feasibility studies in the 1970s, and interest has recently resurfaced in the early years of the twenty-first century. The launch cost appears to be the most important issue for such satellites from a practical economic standpoint. Development of space-based assembly techniques will be another factor, but they appear to be less of a barrier than the capital cost. These will be lowered as the cost of solar cells falls or the efficiency of the cells rises.

### 2.2 Performance:

2.2.1 Optimum Orientation of SolarPanels:

Terrestrial PV systems strive to spend as much time as possible facing the sun for optimal performance. Solar trackers work towards this goal by shifting PV panels to follow the sun. In the winter, the rise can be as high as 20%, and in the summer, it can be as much as 50%. The Sun path can be used to optimize static mounted systems. Although most panels are set at a latitude tilt or an angle equal to the latitude, performance can be enhanced by altering the angle for summer or winter.

2.2.2 Irradiation:

Irradiation is the process of exposing something to radiation. The exposure might be planned, sometimes for a specific goal, or it can happen by chance. In general usage, the word refers to ionizing radiation and a dose of radiation that will serve that specific function, rather than radiation exposure to typical levels of background radiation or abnormal levels of radiation as a result of an accident. Non-ionizing radiation such as microwaves or low frequency (50/60 Hz power supply) and high frequency (50/60 Hz power supply) are also included in this category (as cellular phones, radio and TV transmissions).

2.2.3 Insolation:

*Solar radiation energy received on a given surface area in a given period is measured as insolation. Average irradiance is often given in watts per square meter (W/m2) or kilowatt-hours per square meter per day (kW·h/ (m2•day)) (or hours/day). In Photovoltaics, it is often expressed as kWh/(year/KW) (kilowatt hours per year per kilowatt peak rating).A planet, a terrestrial object inside a planet's atmosphere, or any object exposed to sun rays outside of an atmosphere, including spacecraft, could be the specified surface. The sun's rays will be absorbed to some extent, while the rest will be reflected.*

*2.3 Solar cell:*

A solar cell is a solid-state device that uses the photovoltaic effect to turn sunlight directly into electricity. Solar modules, commonly known as solar panels, are made up of cell assemblies. Solar power, or the energy created by these solar modules, is an example of solar energy.

The difference in the chemical potential, known as the Fermi level, of the electrons in the two isolated materials is the source of the PV potential. The junction approaches a new thermodynamic equilibrium when they are linked. Only when the Fermi levels in the two materials are equal can such equilibrium be achieved This is accomplished via the flow of electrons from one material to the next until a voltage difference between them is produced, with a potential just equal to the Fermi level's initial difference. The photocurrent in the PV circuit is driven by this potential.

Though term is commonly used exclusively to refer to the generation of energy from sunshine, Photovoltaics is the subject of science and study connected to the practical application of photovoltaic cells in creating power from light. When the light source isn't necessarily sunshine, cells are classified as photovoltaic cells. These are used to detect light or other electromagnetic radiation in the visible range, such as infrared detectors, or to measure light intensity.

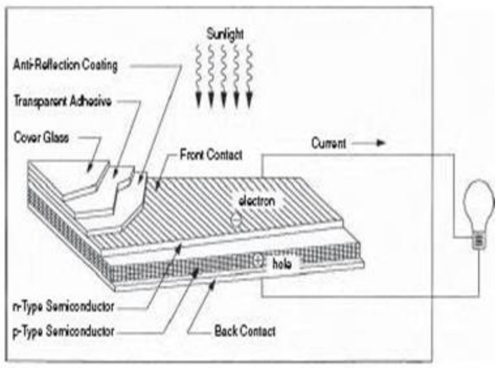


Fig 2.2: Basic construction of PV cell

## 3. HYSTERESIS CONTROLLER

Hysteresis current control is a method of controlling a voltage source inverter so that an attempt current is generated which follows a reference current waveform. This method controls the switching in an inverter asynchronously to ramp the current through an inductor up and down so that it follows a reference. Hysteresis current control is the easiest control method to implement. This method also exhibits robustness feature A low-cost current regulator using hysteresis is shown in Fig.(1). In this controller the desired current of a given phase, say Ia* , is summed with the negative of the measured, Ia.

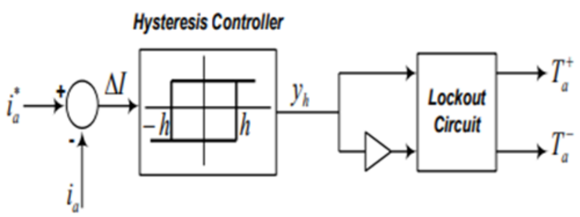


Fig 3.1 Hysteresis Current Controller

The hysteresis controller, being nonlinear, does not demonstrate the weaknesses of linear control; there is neither phase lag nor gain. Within the error of the hysteresis band and the ability of the power converter, the hysteresis controller follows the command and rejects disturbances perfectly, except that delays in the feedback device and power converter slow response. The weaknesses of the system are also evident. The loop never reaches a quiescent state; it is forever moving from full on to full off. The frequency of operation is not predictable; a furnace turns off and on at a higher frequency when the outside temperature is lower. Also, the error is never driven to zero but can always roam within the hysteresis band.

With hysteresis there is no process of tuning to achieve the optimal combination of stability and response. The key adjustment is setting the hysteresis band, which is a trade-off of how often the plant changes state against how much error can be tolerated. The tighter the hysteresis band, the higher the frequency of cycling power to the plant.

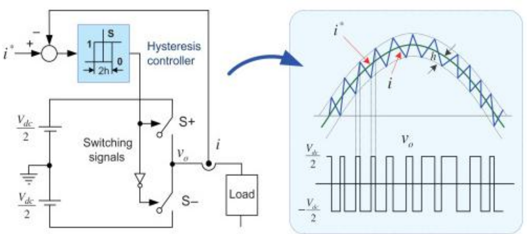


Fig 3.2 power switching using hysteresis control

## 4. IRRADIANCE ADDAPTIVE PV-MIC SYSTEM

The use of optimal SFM in PV systems is broken down into three sections: DC Microgrid integration, irradiance-adaptive SFM, and SFM scheme optimization.

As shown in fig. 4.1, the adaptively controlled MIC is designed for module level integration into a DC microgrid. The MIC's input voltage is adjusted for MPPT, and the DC bus voltage control units determine the output voltage. As a result, each PV-MIC pair acts as a current source. As a result, the MIC must have input and output ratings that are compatible with typical PV modules and DC microgrid bus voltages.

With increasing at solar irradiation, the PV current becomes stronger. The PV-fed MIC can run in CCM (continuous conduction mode) for a broad load range at high irradiation. In that situation, low switching frequencies can contribute to high efficiency without changing the converter's operation mode to discontinuous conduction mode (DCM). The converter may switch to discontinuous conduction mode where the irradiance is low and the supply current is low. When the inductor current is zero in DCM [14], the instant power drawn from input sources is zero. The switching frequency can be increased to keep the system in CCM mode

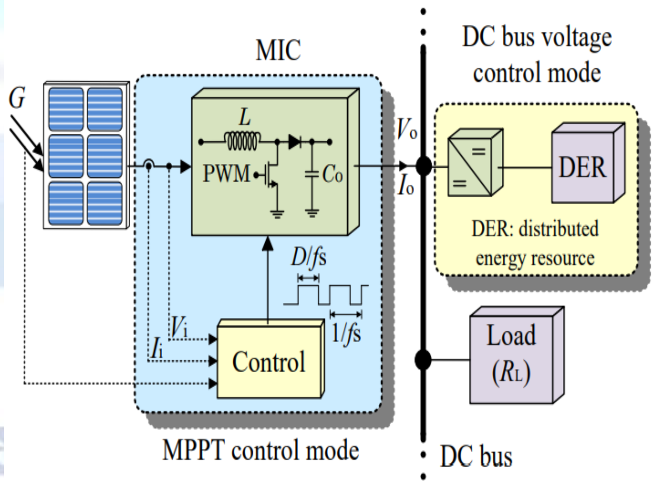


Figure 4.1: PV module integrated converter in DC microgrid application.

SFM (switching frequency modulation) is a type of pulse width modulation (PWM) in which several switching frequencies is used to operate DC-DC converters

[15]–[17]. The SFM has been used in the following instances. By broadening the power spectrum, it has helped to reduce electromagnetic interference (EMI) emissions. SFM was used in DC Microgrids [21] for power line communication, where all power converters share a common DC bus. An SFM technique was devised to reduce output current total harmonic distortion in current source inverters.

## 5. SIMULATION RESULTS

### *A. Introduction*

A Simulink block diagram is a pictorial representation which indicates the dynamic state of the system. It is made up of symbols called blocks which are present in Simulink library linked together by lines. Each block indicates the dynamic system which generates an output either constantly (a continuous block) or at specified times in time (a discrete block) (a discrete block). Based on The lines connected between output and input blocks the system performance cab be appear. Every block in a block diagram is an indication of a certain block type. The relationship between a block's outputs and its inputs, states, and time is determined by the type of the block. Any number of examples of any sort of block required to model a system can be included in a block diagram. Simulink knows how to simulate basic dynamic systems, which are represented by blocks. One or more of the following elements make up a block:

There are three types of inputs: 1) inputs, 2) states, and 3) outputs.

Table 5.1: System Parameters

| Component | Range |
|---|---|
| PV Voc | 44.8V |
| PV Module Isc | 5.5 A |
| PV Module Impp | 5.1 A |
| PV Module Vmpp | 36.5V |
| Input Capacitor | 220 microF |
| Output Capacitor | 2200 microF |
| Inductors (L1 & L2) | 500 microH |

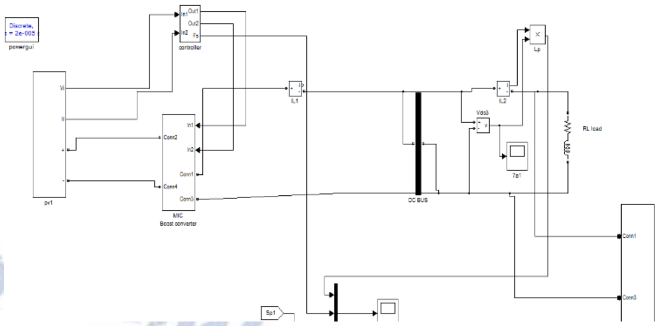

Figure 5.1: Simulation Diagram for PV system with Conventional Controller

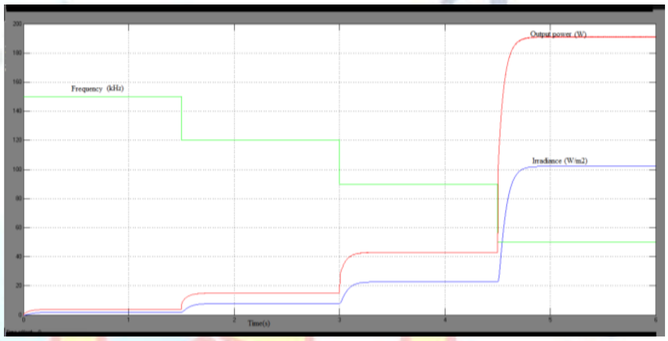

Figure 5.2: Simulation Result for irradiance, switching frequency, and power under standalone case at step changing irradiance

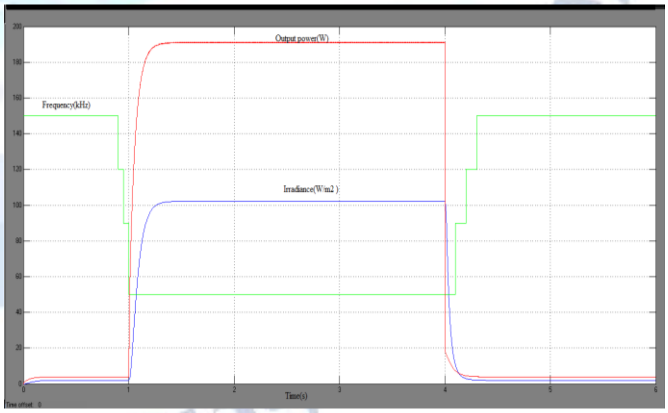

Figure 5.3: Simulation Result for irradiance, switching frequency, and power under standalone case at continuously changing irradiance

The PV-MIC system's performance is discussed for two solar irradiance time series with sequentially and continually changing patterns. First, the performance was evaluated under four different irradiance levels: 0.1 kW/m2, 0.175 kW/m2, 0.3 kW/m2, and 1 kW/m2. In Fig. 5.2, the solar irradiance, switching frequency, and output power are shown. According to the SFM system, the MIC control was able to adjust the switching frequency in response to solar irradiation. In the meantime, the maximum PV power was meticulously monitored. In common conduction mode, the MIC converter was used. At a switching frequency of 20 kHz, the interleaved converter cell is only engaged at the greatest irradiance level. As a result, the output voltage ripple is reduced from 1.30 percent to 0.59 percent. It falls within the same irradiation range as the other levels. Fig. 5.3 shows the effect of continually changing irradiance patterns on the switching frequency and output power. The switching frequency is dropped from 50 kHz to 40 kHz when the irradiance rises and crosses 0.17 kW/m2 after 10.8 seconds of simulation. This occurs at 0.13 kW/m2 after 49.7 s with dropping irradiance in the opposite direction from 40 kHz to 50 kHz. Transitions from 40 kHz to 30 kHz and from 30 kHz to 20 kHz produce similar results.

### 5.3 Case 2: Irradiance adaptive PV System with Hysteresis Controller:

Simulation is used to examine the Hysteresis controlling topology and the best SFM technique. In the first step, the SFM scheme's parameters are determined. Then, for standalone and DC microgrid scenarios, simulation cases with varying irradiance patterns are discussed. The Hysteresis based PV-MIC system were simulated using MATLAB/SIMULINK R.

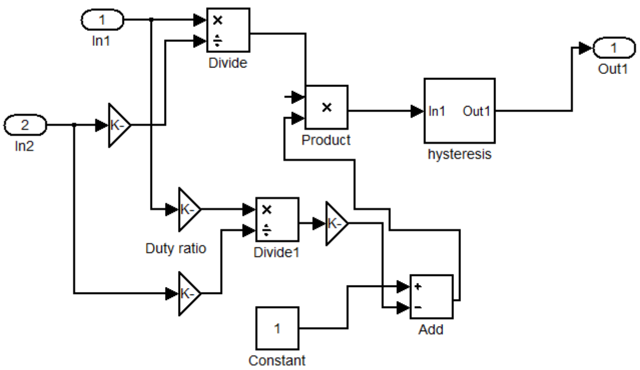


Figure 5.4: Simulation Diagram for PV system with Hysteresis Controller

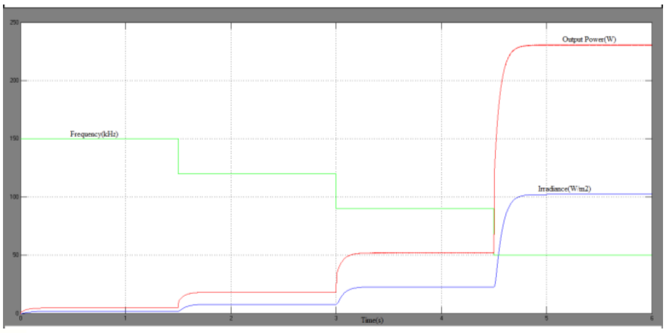

Figure 5.5: Simulation Result for irradiance, switching frequency, and power under standalone case at step changing irradiance

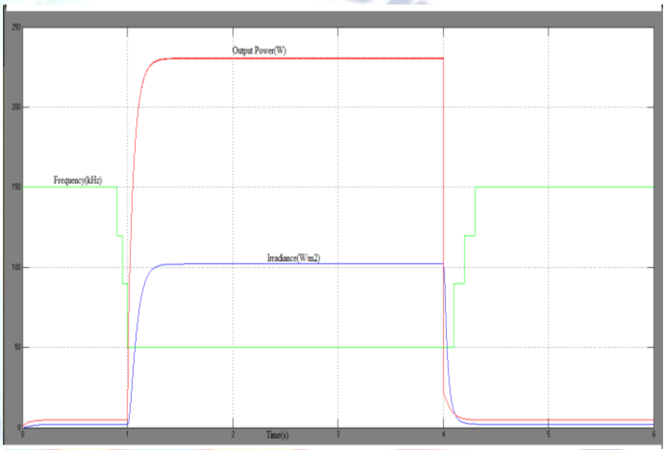


Figure 5.6: Simulation Result for irradiance, switching frequency, and power under standalone case at continuously changing irradiance

In figures 5.5 and 5.6, the solar irradiation, switching frequency, and output power are displayed. According to the SFM scheme, the Hysteresis control was able to vary the switching frequency adaptively with the solar irradiation. In the meantime, the maximum PV power was efficiently tracked, resulting in increased power handling capability.

## 6. CONCLUSION

A Hysteresis-based Irradiance adaptive PV module integrated converter was conceived, implemented, and tested for boosting voltage in DC standalone and DC microgrid applications. The switching frequency modulation chooses an irradiance-adjusted switching frequency that is always high enough to avoid discontinuous conduction mode operation. The switching frequency modulation sets a lower value for the frequency at a high irradiance, led by the goal of high efficiency through reduced switching losses. In addition, at high irradiance, a modulated integrated converter is triggered to maintain a high level of power quality. As the irradiance fluctuates and the ripple content decreases, hysteresis functions support the transitions between different discrete switching frequencies. An MPPT built for quick tracking and increased power handling capability complements the adaptive irradiance Hysteresis control system. Thus, aims of high efficiency, power handling capacity, and power quality are achieved by combining the SFM with adaptive use of the modulated integrated converter with Hysteresis logic controller and a quick MPPT.

## Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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