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Maximum Power Point Tracking For Solar Photovoltaic System Using Synchronous Reference Frame Theory

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ABSTRACT

In recent years, solar energy has emerged as a prominent renewable energy source, resulting in the widespread deployment of photovoltaic (PV) power generation systems worldwide. Experimental validation of PV-based power systems integrated with DC–DC converters is often constrained by practical limitations such as high implementation costs, environmental variability, and hardware availability. Consequently, accurate software-based simulation models have become essential tools for performance evaluation and system optimization.

A generalized circuit-based equivalent model is particularly valuable for characterizing and validating the operating behavior of commercial PV modules under varying environmental conditions. In this study, a detailed mathematical model of a photovoltaic module is developed and implemented in a simulation environment. The model incorporates the nonlinear current–voltage (I–V) and power–voltage (P–V) characteristics of the PV module.

Furthermore, a DC–DC boost converter is designed and integrated with the PV model to enhance power extraction capability. The boost converter operates to regulate the output voltage and maximize the energy harvested from the PV array. The complete PV-powered DC–DC converter system is simulated, and the performance characteristics are analyzed to evaluate system efficiency and power optimization capability.

1. INTRODUCTION

Renewable energy resources are being utilized to fulfill the energy requirements of the world by replacing conventional fossil fuel energy resources due to lower hazardous carbon emissions and environmental protection such as global warming and greenhouse effects. These resources do not deplete and are, therefore, called renewable energy resources being replenish able. Since conventional fossil fuels are decreasing at a very high rate, a lot of research is being carried out in improving the energy efficiency of renewable energy resources. The most popular energy resources are solar, wind, hydro, tidal, geothermal, and bio mass-energy.

The design of a grid-connected solar PV system is presented in Figure 1.1 the PV panel is connected with a dc-DC converter to boost the incoming DC voltage from the panels which are then supplied to a DC bus. An inverter is connected to produce AC from this DC and this AC is supplied to the grid through a filter to remove the harmonics produced by the inverter. The injected power is controlled by the DC bus voltage controller which is of high voltage gain and continuous input current type

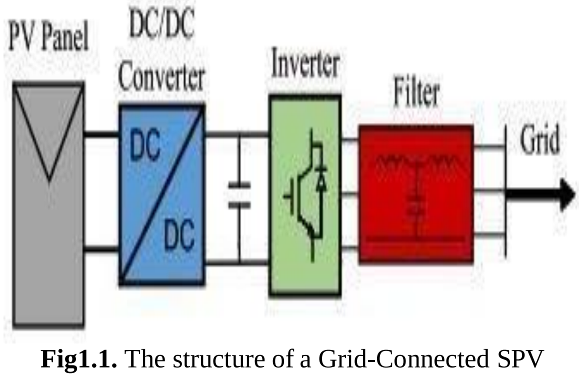


Fig1.1. The structure of a Grid-Connected SPV

The power obtained from the SPV system needs to be boosted to provide to inverter circuit which will then convert it to AC without need of transformer. Maximum Power Point Tracking (MPPT) is a scheme to obtain maximum power from the Solar Photovoltaic (SPV) system under changing conditions of ambiance and load. The power from the panels keeps changing due to the changing conditions of the environment and load nature. Therefore, power fluctuations occur reducing the overall efficiency of the system which is the main drawback of solar generation. The possible solution to this problem is to design an algorithm that can fetch maximum power from the panel in any condition. The MPPT algorithm ensures maximum power is obtained from the cells by deploying various advanced algorithms such as constant voltage, Perturb And Observe (P&O), fuzzy logic, Hill Climbing (HC), Incremental Conductance (IC), etc.

This proposes the novel technique to implement an MPPT system from PVA systems using a Synchronous Reference Frame (SFR) based approach.

The power curve for the MPPT algorithm is shown in Figure 1.2 which shows that power increases with the increase in voltage until a point comes where the rate of change of power concerning voltage $\frac{\Delta P}{\Delta V}$ becomes zero and starts becoming negative with a further increase in voltage. The point where the rate of change of power becomes zero is called a Maximum Power Point (MPP). The purpose of this algorithm is to achieve this point in variable environmental and loading conditions of the solar system

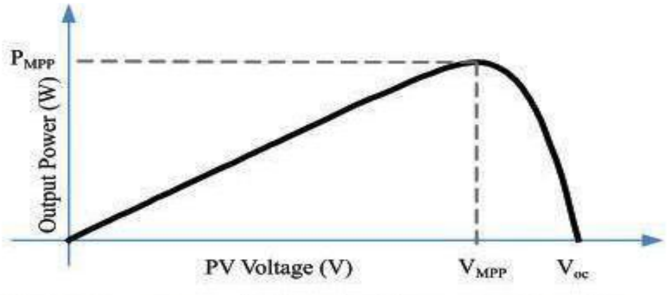


Fig.1.2. Power Curve against Voltage of SPV System

Each MPPT method has its advantages and disadvantages. Fuzzy logic and artificial neural network methods are appropriate for fast convergence applications such as solar vehicles. For better performance and reliability such as orbital and space satellites, P&O, HC, and IC methods are preferred. For domestic applications, optimation based P&O and IC methods are recommended to cover the payback time and reduce ripples around MPP.

Key applications of PV modules:

- Residential solar power: Generating electricity for homes, including powering appliances, lighting, and heating systems.
- Commercial solar power: Providing electricity for businesses, offices, and retail spaces.
- Industrial solar power: Powering large industrial facilities and processes
- Off-grid power systems: Providing electricity in remote areas without access to the grid, like cabins, rural communities,
- and disaster relief sites. Solar water heating: Using solar panels to heat water for domestic use
- Agricultural applications: Powering irrigation pumps and other farm equipment
- Street lighting: Illuminating streets and pathways using solar-powered streetlights

2. EFFECTS OF EXTERNAL CONDITION ON SOLAR PANEL

A **solar-powered boost converter** takes variable input from a PV panel and steps it up to a stable, usable DC voltage. Since PV output is highly dependent on external condition the boost converter's performance also varies. These variations directly influence **efficiency, switching behavior, duty cycle control, and Maximum Power Point Tracking (MPPT)**

2.1 Effect of Solar Irradiance on a Solar Panel

Solar irradiance plays the most critical role in determining the behavior of a **solar-powered boost converter**, because irradiance directly controls the electrical power generated by the photovoltaic (PV) array. When solar irradiance increases, more photons strike the PV cells, generating a higher photocurrent. This increase in current significantly raises the overall power available from the PV panel, shifting the **current–voltage (I–V)** and **power–voltage (P–V)** curves upward. As a result, the **maximum power point (MPP)** of the PV module moves to a higher power level, and the boost converter must adjust its duty cycle accordingly to extract this increased energy. Under high irradiance conditions (e.g., 1000 W/m²), the PV panel can deliver high current at relatively stable voltage, enabling the boost converter to operate efficiently and maintain a regulated output, making the

system highly productive.
However, when irradiance decreases—due to clouds, shading, dust accumulation, or changes in sun angle—the available current from the PV panel drops sharply. Unlike voltage, which changes only slightly with irradiance, the PV current is almost linearly dependent on the irradiance level. This reduction in current causes a large drop in the power curve, dramatically lowering the MPP. The boost converter now receives much less input power, and its output voltage regulation becomes more challenging—especially if the load demand remains constant. To track the new MPP, the Maximum Power Point Tracking (MPPT) algorithm inside the boost converter must rapidly adjust the duty cycle. During fast irradiance variations, such as passing clouds, the MPP shifts quickly, which can cause temporary mismatches between the converter duty cycle and the true MPP, leading to oscillations, reduced efficiency, or even short-term under-voltage at the load.
Low irradiance conditions also reduce the converter's dynamic response. When the available PV current becomes insufficient, the boost converter may reach its duty-cycle limit, meaning it can no longer raise the output voltage to the required value. This may trigger protection modes or force the system to disconnect non-essential loads. In extreme low-light conditions, such as early morning or late evening, the PV voltage may fall below the minimum operating threshold of the converter, preventing it from starting altogether. Thus, solar irradiance not only influences the power generation of the PV module but also directly affects the **stability, efficiency, control performance, and operating limits** of the boost converter. The system must continuously adapt to fluctuating irradiance to ensure reliable power extraction and maintain regulated output under all environmental conditions.

2.2 Temperature effects

Temperature has a significant and often adverse effect on the operation of a **solar-powered boost converter** because it directly changes the electrical characteristics of the photovoltaic (PV) module supplying the converter. As the temperature of the solar cells increases—due to strong sunlight, ambient heat, or poor ventilation—the **open-circuit voltage (Voc)** of the PV panel decreases substantially. This is because the semiconductor material in the PV cell experiences increased carrier recombination at higher temperatures, which reduces the cell's voltage. Although temperature causes a slight increase in the short-circuit current (Isc), this rise is very small compared to the large drop in voltage. Consequently, the overall **maximum power point (MPP)** shifts downward and toward a lower voltage region on the PV curve. When this reduced PV voltage is fed to the boost converter, the converter must increase its duty cycle to maintain the required output voltage, putting more stress on the switching devices and reducing energy conversion efficiency.
From the boost converter's perspective, higher temperatures not only reduce the available power from the PV source but also degrade the converter's own components. When the PV voltage decreases due to heat, the converter operates closer to its maximum duty-cycle limit, which increases conduction and switching losses. The switching MOSFET or IGBT may heat up further, causing increased on-state resistance, higher thermal losses, and decreased efficiency. The inductor and capacitor inside the boost converter also exhibit higher internal losses at elevated temperatures, and their values may drift, affecting the converter's dynamic response and stability. During extreme heat, the converter may even reach thermal protection thresholds and shut down temporarily to avoid damage. This means that high-temperature environments not only limit the input power but also reduce the converter's ability to regulate the output effectively.
When temperatures drop—such as during early morning, winter seasons, or cool windy conditions—the situation reverses. The PV module produces a **higher open-circuit voltage** and operates more efficiently, giving the boost converter a stronger and more stable input. Low temperatures reduce internal resistance and improve semiconductor performance, allowing the converter to operate with lower duty cycles and reduced losses. However, extremely low temperatures can also introduce problems such as increased inductor core losses during cold starts or poor capacitor performance, although these effects are generally less severe compared to high-temperature issues.
Overall, temperature variation significantly influences the **power availability, efficiency, switching behavior, and reliability** of a solar-powered boost converter. High temperatures reduce PV power, force the converter to work harder, and accelerate component aging, while lower temperatures enhance performance but may require careful control during startup. Thus, understanding temperature effects is essential for designing robust PV-boost converter systems and ensuring stable operation under diverse environmental conditions.

2.3. Effect of Partial Shading

Partial shading occurs when certain sections of a photovoltaic (PV) module or array are blocked from sunlight due to obstacles like trees, buildings, dust accumulation, or passing clouds. This condition causes non-uniform irradiance across the cells, resulting in multiple local maxima in the PV power–voltage (P–V) characteristic curve instead of a single global maximum power point (GMPP). For a solar-powered boost converter, partial shading introduces significant challenges in maintaining optimal power extraction. The Maximum Power Point Tracking (MPPT) algorithm may incorrectly lock onto a local maximum rather than the global one, leading to suboptimal energy harvesting. Additionally, partial shading reduces the overall output voltage and current of the PV array, forcing the boost converter to operate at a higher duty cycle to maintain the desired output voltage. This increase in duty cycle can raise conduction and switching losses, generate higher current and voltage ripples, and place additional thermal stress on power electronic components such as the inductor, capacitor, and switching devices.

In severe cases, shaded cells may enter reverse-bias mode, triggering bypass diodes that protect the module but create abrupt voltage drops. These sudden changes can cause transient instability in the boost converter, potentially leading to oscillations, reduced efficiency, and stress on control circuitry. Furthermore, repeated or prolonged partial shading can degrade the long-term reliability of both the PV array and the converter due to thermal hotspots and fluctuating electrical stresses. Therefore, partial shading is a critical external factor that must be addressed through advanced MPPT strategies, adaptive duty cycle control, and robust converter design to ensure stable, efficient, and safe operation of solar-powered systems.

2.4. Effect of Dust, Humidity, and Air Quality

Dust accumulation on PV panels reduces the amount of radiation reaching the cells, effectively decreasing power generation. The boost converter must operate at higher duty cycles to compensate for lower input voltage, but this increases switching losses and thermal stress. Humidity can also reduce PV performance and cause deterioration of panel surfaces, indirectly affecting the converter's operating range. Poor air quality, such as heavy pollution, has similar effects as dust by reducing effective irradiance and forcing the converter toward lower efficiency operating points.

2.5 Effect of Weather Conditions on Solar-Panel

Weather conditions, including cloud cover, rain, fog, and snow, significantly impact the performance of solar-powered boost converters by directly influencing the input from photovoltaic (PV) panels. Clouds and fog reduce the intensity of solar irradiance reaching the PV modules, leading to lower output voltage and current. This reduction forces the boost converter to adjust its duty cycle frequently in order to maintain a stable output voltage, which can increase switching losses and reduce overall efficiency. Rain and snowfall not only diminish irradiance but can also cause intermittent shading and accumulation of water or snow on the panel surface, further decreasing available power. Rapidly changing weather, such as passing clouds, introduces sudden fluctuations in input power, challenging the Maximum Power Point Tracking (MPPT) algorithm to track the global maximum power point effectively. If the MPPT algorithm is unable to respond quickly, the converter may operate at suboptimal points, resulting in lower energy extraction and transient oscillations in output voltage or current. Additionally, weather-induced temperature changes affect both the PV module and the boost converter components: cold conditions can increase panel voltage, while high humidity or wet conditions may lead to corrosion or insulation issues, impacting the reliability and lifespan of the system. Therefore, weather conditions create dynamic and often unpredictable variations in PV input, requiring robust converter control strategies and adaptive MPPT methods to ensure efficient, stable, and safe operation of solar energy systems.

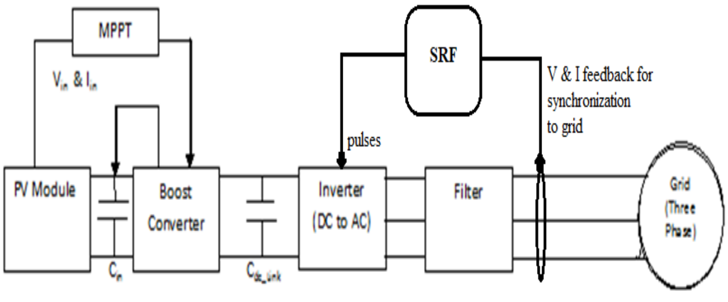


Fig 2.1 overall system of MPPT

In the above figure, a PV module is connected to a DC-DC booster converter controlled by the MPPT control algorithm with feedback from the PV module voltage and current [6] (Vin and Iin). The DC-DC booster converter constant stabilized DC voltage output is connected to a three-level voltage source inverter which converts DC to three-phase AC. The PWM three-phase AC output from the inverter passes through a LC filter to reduce the harmonics generated by the inverter converting the PWM AC voltage [9] [10] to sinusoidal AC voltage. The inverter is controlled by the SRF controller using the sinusoidal PWM technique for the power electronic devices.

The voltage generated by the inverter will be in synchronization with the grid voltage for parallel operation which is further explained in detail in section III. The operation of the PVA, MPPT technique and DC-DC booster converter is explained in section II. In section IV the modeling of all the modules in MATLAB Simulink environment [11] is done with graphical representation of the PCC voltages and power exchange between the grid and PVA module concerning time. The 5th section is a conclusion stating the solution to the problem and comparative statements followed by references taken for making the model.

The diagram represents a complete grid-connected photovoltaic (PV) energy conversion system, where each block works in sequence to extract solar energy, condition it, and deliver it to a three-phase grid. The process begins with the PV module, which converts sunlight into direct current (DC) electricity. The output of the PV module depends heavily on environmental conditions such as solar irradiation and temperature, making it variable and nonlinear. Because a PV module does not naturally operate at its maximum power point, an MPPT (Maximum Power Point Tracking) controller is included. This MPPT controller continuously measures the PV voltage and current and calculates the instantaneous power, then adjusts the operating voltage of the PV panel by controlling the duty cycle of the boost converter. By doing this, it ensures that the PV system always extracts the highest possible power under changing environmental conditions.

The boost converter acts as the power-conditioning stage that steps up the PV voltage to a level suitable for the inverter. By varying the duty cycle using the MPPT algorithm, the boost converter regulates the input current drawn from the PV array and ensures that the PV module operates precisely at the maximum power point. A capacitor at the PV side smooths the input voltage supplied to the converter, while the DC-link capacitor at the output of the boost converter stabilizes the boosted voltage and provides a steady DC supply for the inverter. This DC-link capacitor also absorbs fluctuations caused by switching and acts as an energy buffer, ensuring that the inverter receives a clean and nearly constant DC voltage.

Once the DC power is stabilized, it is fed into the inverter, whose role is to convert the DC voltage into alternating current (AC). A grid-connected inverter must not only convert DC to AC but also synchronize the output voltage with the grid in terms of phase, frequency, and magnitude. This synchronization allows seamless transfer of power from the solar system to the utility grid. However, because the inverter uses switching techniques such as PWM (Pulse Width Modulation), the output contains high-frequency harmonics that are undesirable for grid injection. Therefore, a filter—typically an L, LC, or LCL filter—is placed after the inverter to eliminate these switching harmonics and produce a clean sinusoidal AC waveform.

Finally, the filtered AC power is supplied to the three-phase grid. At this stage, the inverter must maintain compliance with grid standards, ensuring that voltage levels, frequency, and harmonic distortion meet regulatory limits. The entire system—from the PV module and MPPT controller to the boost converter, inverter, and filter—works together to efficiently convert solar energy into high-quality electrical power suitable for injection into the electrical grid

2.6 P&O MPPT algorithm

The Perturb-and-Observe (P&O) technique works by perturbing the PV system by incrementing the array operating voltage and observing its impact on the array output power. Because of constant step width, the system faces high oscillation especially under unstable environmental conditions. Some techniques used waiting time to avoid high oscillation; however, it also makes the MPPT slower to respond to weather changes. Also, this technique suffers from wrong operation, especially in case of multiple local maxima when working in partial shading conditions. A lot of modifications for this technique have been presented in literature [13–21]. P&O is the most frequently used technique to track the maximum power because of its simple structure [22]. The flowchart of P&O is shown in Fig. 4.3 [23]. A common problem in this technique is that the PV module terminal voltage is perturbed every MPPT cycle. Therefore, when the MPP is reached, the output power oscillates around its MPP, resulting in power loss in the PV system. A modified P&O technique has been introduced in [24] to remedy this problem by multiplying the change in the duty ratio by dynamic constant depending on the previous change in the extracted power. Another technique [25] used artificial neural network to predict this multiplying constant. These techniques increase the complexity of the system and may cause more oscillations in stable weather conditions.

The perturb and observe (P&O) algorithm is generally the most commonly applied in the control of MPPT algorithm for the PV generator. It has simple structure, low cost, easy to implement, reduced number of parameters, the possibility to introduce improvements and may result in top-level efficiency [18,19,20]. This algorithm is depending on investigating the relation between PV module output power and its voltage. The behavior of solar panel indicating MPP and operating principle is shown in Fig. 5.4 which indicates that the resulting change of PV power is observed as follows: When the PV module operating point is on the left side of the curve ($\Delta P/\Delta V$ is positive), which means the PV module output power increases, the perturbation of the PV module voltage should be increased toward the MPP. If the operating point of the module was on the right side of the curve ($\Delta P/\Delta V$ is negative), then the perturbation of the PV module voltage should be decreased toward the MPP.

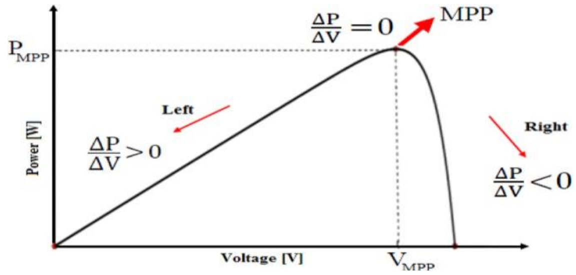


Fig. 2.2 Behavior of solar panel indicating MPP and operating principle

Behavior of solar panel indicating MPP and operating principle Figure 5.5 depicts the flowchart for implementation of the P&O algorithm; first, the practical voltage and current from PV array are measured. After that, the product of voltage and current gives the actual power of PV module. Then, it will check status what whether $\Delta P = 0$ or not. If this status is satisfied, then operating point is at the MPP. If it is not satisfying, then it will check another status that $\Delta P > 0$. If this status is satisfied, then it will check out that $\Delta V > 0$. If it is satisfied, then it indicates that operating point is at the left side of the MPP. If $\Delta V > 0$ status is not satisfied, then it indicates that operating point is at the right side of the MPP. This process is continuously repeated until it reached the MPP. So, at all times there is a compromise between the increments and the sampling rate in the P&O algorithm.

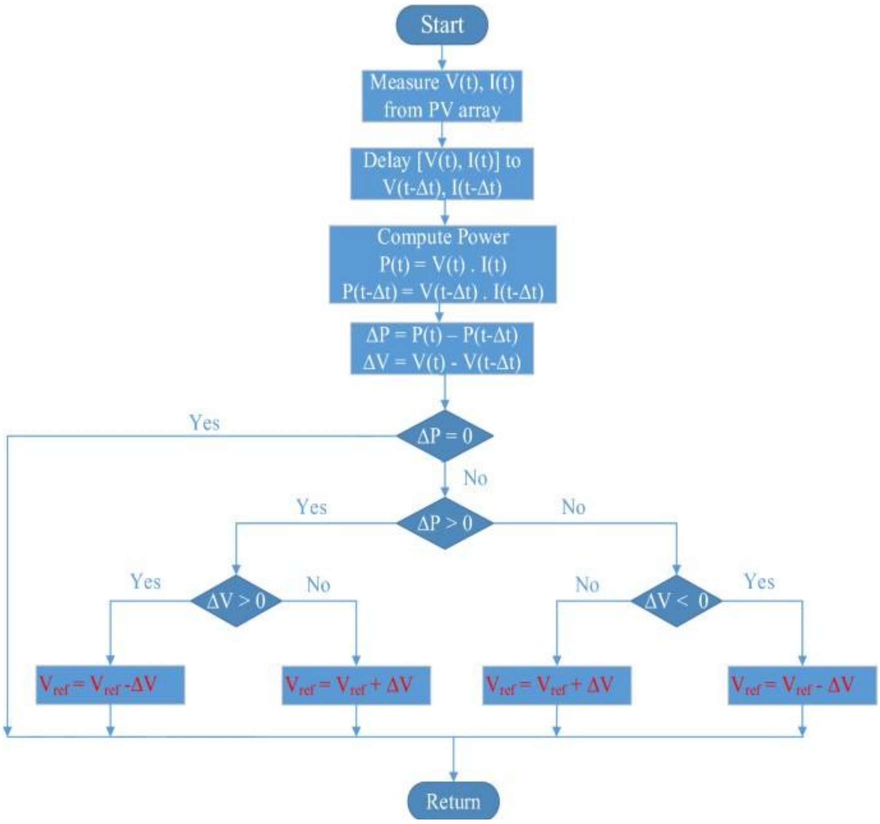
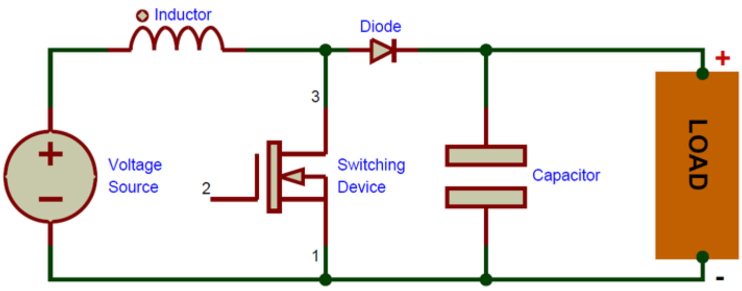


Fig. 2.3 Flowchart of the P&O algorithm



2.4 DC-DC boost converter DC-DC boost converter

The boost converter operates by periodically storing and transferring energy through controlled high-frequency switching. When the switching device (typically a MOSFET) is turned ON, the input DC source is directly connected to the inductor. During this interval, the diode becomes reverse-biased, preventing current flow to the output side. The inductor current increases linearly as energy is stored in its magnetic field. In this mode, the output capacitor supplies energy to the load to maintain a continuous output voltage.

When the switching device turns OFF, the inductor current cannot change instantaneously due to its stored magnetic energy. To maintain current flow, the inductor reverses its polarity, which forward-biases the diode. The stored energy in the inductor is then transferred to the output capacitor and the load. During this interval, the inductor voltage adds to the input voltage, resulting in an output voltage that is higher than the input voltage. The capacitor simultaneously charges and smooths the voltage, reducing ripple.

By continuously switching between these two states at high frequency and controlling the duty cycle (the ratio of ON time to total switching period), the converter regulates the output voltage. A higher duty cycle results in a higher output voltage, according to the relationship ($V_{out} = \frac{V_{in}}{1-D}$) under ideal continuous conduction conditions. Thus, the boost converter efficiently steps up the input DC voltage while maintaining controlled and stable power delivery to the load.

3. SYNCHRONOUOUS REFERENCE FRAME METHOD

3.1 Synchronous Reference Frame Theory

The Synchronous Reference Frame (SRF) theory can be used to improve the power factor of the system and to achieve voltage regulation by stabilizing it firmly at point of the common coupling (PCC). This theory develops a rotating frame fo dc quantities d and q axis with the synchronous speed of the system. The three-phase system is transformed into a two-phase rotation reference that can be easily controlled. Therefore, the main purpose of the SRF theory is to derive the energy management capabilities of active and passive power with two variables. The axes d and q are perpendicular to each other, the q axis lead leading the d- axis. This frame surrounds the frequency of the system i.e. 50Hz or 314 rad/sec. Therefore, the relative speed between the d,q frame, and system vector is zero

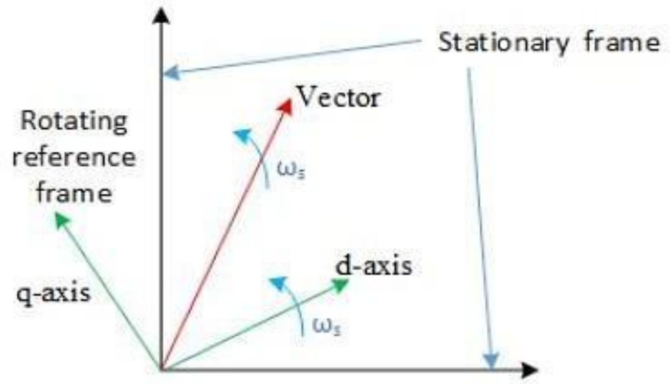


Fig 3.1 d,q-Axis proposed in Synchronous Reference Frame (SRF) Theory

The methodology of MPPT controller design with SFR theory for SPV panels been described. The design of the SPV grid-connected system consists of two important parts: the Vegetation part and the control part. The plant component incorporates the main components of power flow i.e. SPV systems, inverter, and utility grid [11]. The control component includes the design of the MPPT controller, the power controller, and the current controllers. The proposed model scheme is shown in Figure 3.1

In this suggested system, the DC voltage of the SPV and Voltage Source Converter (VSC) is set to 800 volts. A three-leg VSC was used and a PI controller was used on it for control purposes. The capacitors and filters are inserted to form a ripple filter in the next stage. The system is designed to compensate for the effective voltage regulation, boost voltage, harmonics extraction in the output, and load balancing. The overall purpose of the program is to obtain maximum power from the SPV system it produces under different environmental and loading conditions to deliver it to the grid [12]. Such kind of efficient control design has not been found in the literature so far up to our best knowledge.

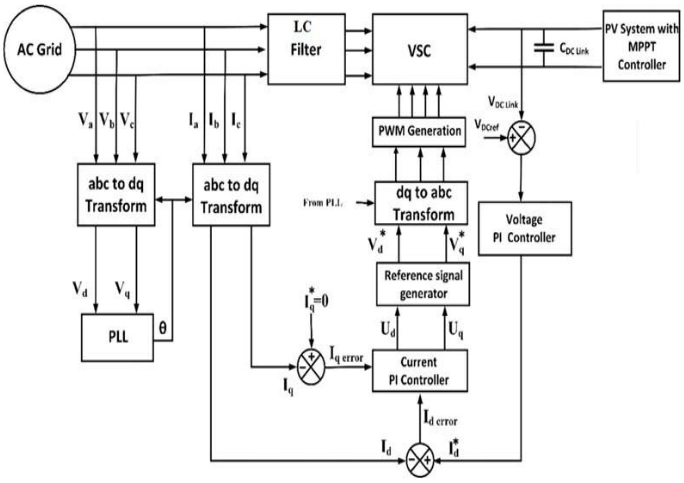


Fig. 3.2. Proposed MPPT Controller with SFR for Grid-connected SPV Systems

The Synchronous Reference Frame (SRF) uses the current indirect control method to generate control signals [13]. The three-phase elements are converted into a d-q rotating frame as described in section 2 and the control diagram is shown in Figure 3.2

The equation used for abc conversion to dq0 is:

$$\begin{bmatrix} i_{Lq} \\ i_{Ld} \\ i_{Lo} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} cos\theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ sin\theta & \sin(\theta - 2\pi/3) & \sin(\theta + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix}\begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (1)$$

where the three phase, the Locked Loop (PLL) phase is operating at the highest voltage (Vsa, Vsb, Vsc) producing cosθ and sinθ. The d, q current, and voltage components are composed of a DC component and an oscillating component.

To achieve the energy control of the composite material, the control algorithm assigns the d axis component of the load current and therefore controls the effective force component brought to the grid. A dedicated DC PI controller works on powering the voltage by performing voltage regulation with a reference voltage. It also makes compensation to the VSC for losses by providing effective power. The amount of the current loss compensation is provided by the following formula:

$$i_w(k) = i_w(k-1) + K_{pd}\big(v_{de}(k) - v_{de}(k-1)\big) + K_{id}(v_{de}(k)) \quad (2)$$

where $v_{de}(k) = v_{dc}^*(k) - v_{dc}(k)$.

The reference current produced for d component of grid current is given as:

$$i_d^* = i_{ddc} + i_{loss} \quad (3)$$

The voltage regulation algorithm enables the gid to assign the q axis to the current axis and the d axis element current and the voltage law is made by the PI controller in the PCC position. The installation of the controller is generated by an error signal between the reference and the measured voltage. The PCC voltage amplitude is obtained by the following formula:

$$V_s = \left(\frac{2}{3}\right)^{\frac{1}{2}} (v_{sa}^2 + v_{sb}^2 + v_{sc}^2)^{\frac{1}{2}} \quad (4)$$

The reference current generated in terms of q components is as follows:

$$i_d^* = i_{qdc} - i_{qr} \quad (5)$$

The conversion of the quadrature axis to three phase AC phases by park's transformation is given by formula:

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = \frac{2}{3}\begin{bmatrix} cos\theta & sin\theta & 1 \\ \cos(\theta - 2\pi/3) & \sin(\theta - 2\pi/3) & 1 \\ \cos(\theta + 2\pi/3) & \sin(\theta + 2\pi/3) & 1 \end{bmatrix}\begin{bmatrix} i_d^* \\ i_q^* \\ i_0^* \end{bmatrix} \quad (6)$$

4. DESIGN OF SOLAR PHOTOVOLTAIC SYSTEM:

The SPV system has been designed in which different panels are connected in series for the addition of open-circuit voltages that are normally in the range of 0.5-0.7 volts. SPV panels are installed in series to escalate the overall voltage and are installed in parallel to escalate the current rating being delivered to load [14]. The power equations for the panels is as follows:

$$PmaxM = VmppM * ImppM \quad (7)$$

Thus the overall power is determined by the product of the measured voltage and current at the MPP. The power rating can be adjusted by integrating the suitable quantity of panel sheets in series and panel [15] [16].

The following formulas have been used to calculate the values of inductance and capacitance:

$$L = \frac{V_{pv}D}{2\Delta i_1 f_{sh}} \quad (8)$$

$$C = \frac{I_d D}{\Delta V f_{sh}} \quad (9)$$

I_d = Output load current
Δi_1 = Input current ripple
D = Duty cycle
V_{pv} = PV Output Voltage
f_{sh} = Switching frequency
ΔV = Output voltage ripples

The duty cycle (D) of the dc-dc boost converter can be represented as follows:

$$D = 1 - \frac{V_{in}}{V_b} \quad (10)$$

V_{in} is input voltage from the PV to the converter and V_b is the output voltage of the converter. Δi_1 taken to be 10 percent of the input current and ΔV is taken to be 5 percent of the output voltage level.

The following formula has been used to calculate the DC link capacitor of VSC:

$$V_{dc} = \frac{2\sqrt{2}V_{LL}}{\sqrt{3}m} \quad (11)$$

where
V_{dc} = DC-Link voltage
V_{LL} = RMS value of line voltage
m = modulation index

The capacitance value can be calculated bu the following formula:

$$C_d = \frac{I_d}{2 * \omega * V_{dc-ripple}} \quad (12)$$

where
C_d = Capacitance
ω = angular frequency
I_d = dc link current
$V_{dc-ripple}$ = ripple voltage

The value of dc link current is selected to be 2/3 or 33% of load current i.e. if one phase of the load is to removed. The value of the dc-link capacitor is thus calculated as 1200 μF.

The inductance value of the filter is calculated by the following formula:

$$L = \frac{\sqrt{3}mV_{dc}}{12hf_s\Delta i_1} \quad (13)$$

5.CONCLUSIONS

In this paper, a novel SRF based on the MPPT controller was developed for the SPV system connected to the grid using indirect current control mode of operation. The entire system consisted of an SPV system, a DC-dc boost converter, an MPPT controller, a VSC, a ripple filter, and a grid. MATLAB / Simulink was used to develop the proposed fraud scheme. Simulation results showed that the system provides high grid power under varying load conditions, maintains electrical power to unity, and perform stabilizing of system voltage at the

PCC. The presented research is very important in solar energy production because of the many different benefits offered by the proposed design.

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