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Sliding Mode Controller Based Grid Coupled PV System

Mohammed Ovaiz. A[1], Pradeep Katta[2]
Archana.S[3], Nanthabala.M[4],
UmaShankari.S[5]
[1,2,3,4,5]Department of Electrical and Electronics Engineering,
[1,2,3,4,5]Vel Tech High Tech Dr.Rangarajan
Dr.Sakunthala Engineering College,
Avadi, Chennai-600062.
smcpro231@gmail.com

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Abstract

In this Paper, Sliding Mode Controller Based Grid Coupled PV System is proposed. The sliding mode controller is employed in order to obtain the exact sinusoidal wave from the inverter. To track the maximum voltage from the solar panel the Maximum power point tracking algorithm is applied. Perturb and Observe is the most commonly used technique in MPPT algorithm, which perturbs the operating point of the PV array and compares the PV power before and after the perturbation. The phase locked loop is used to synchronize the injected current and the grid current. The response for grid coupled PV system with Sliding Mode Controller is simulated using MATLAB / Simulink and the experimental results have been verified.

***Index Terms*:**Maximum power point tracking(MPPT), Sliding mode control, Phase locked loop.

1 INTRODUCTION

The non-renewable energy like fossil fuels will dwindle within some years. So, renewable energy came to trend due to its abundant availability. Solar energy is sustainable, totally inexhaustible and non-polluting. The solar powered PV system sometimes produces more electricity than actually needed or consumed, especially during the long hot summer. The surplus electricity is either stored in batteries or supplied to the grid for the grid connected PV system. The major lead of our project is to control the injected current without using any converter sections.

By implementing the PV system, the urban power utilization from the grid can be reduced and minimises the power shutdown in rural areas. In existing system, there is two stage conversion and additional filter is required. The exact sinusoidal wave is not obtained from the inverter. Another great issue in grid connection is synchronization. The proposed system is converter less, to obtain the absolute sinusoidal wave Sliding mode controller is employed in the inverter which is made of MOSFET switches. The inverter converts Direct current to alternating current, the inverter is necessary because the residential loads are AC loads.

This system is mainly designed for residential application. The technique employed are MPPT-P&O, PID controller, Sliding mode controller and Phase locked loop. These techniques are applied to make the system efficient.

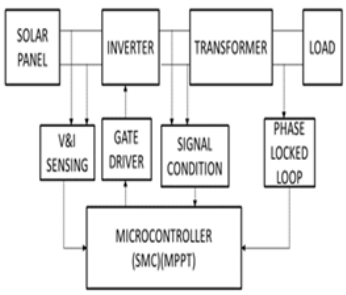

Figure: 1 Block diagram

The 12V solar panel is connected to a single-phase inverter. The output from the solar panel is DC which is converted in to AC with the help of inverter. The transformer step-ups the voltage from 6V to 230V. The load will be coupled with the grid, when the supply from the PV system is not sufficient the power is utilized from the grid.

The V&I sensing senses the voltage and current from the solar panel. The gate driver circuit provides gate signal to the switches in the inverter. The signal condition is necessary in order to eliminate the disturbance in the waveform. The component used to achieve the signal conditioning is filter. The type of filter used is inductive filter.

The Sliding mode controller will give an absolute sinusoidal wave. The phase locked loop is the technique used to achieve the synchronization with the grid. The MPPT is used to track the maximum voltage form the solar panel

2 CONTROL STRATEGY

2.1 MICROCONTROLLER:

The PIC16F887 microcontroller is used here. The entire control techniques are carried out in this microcontroller. Particularly this microcontroller is used for its attractive features like it is very easy to use, it has 256 of EEPROM data memory and high synchronous speed.

2.1.1 PIN CONFIGURATIONS:

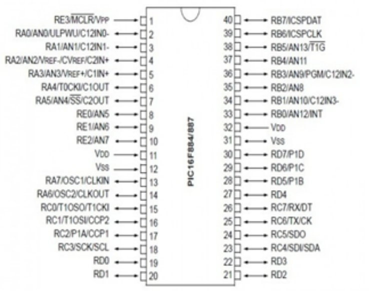

Figure 2: pin configuration of pic16f887

2.2 MAXIMUM POWER POINT TRACKING(MPPT)

MPPT is a technique that is widely used to maximize the power extraction under all environmental conditions. As it is very clear that the amount of sunlight falls on the panel varies with respect to the daily weather conditions, the load characteristic that gives the highest power transfer efficiency changes, so that the system efficiency is optimized when the load characteristic changes in order to keep the power transfer at higher efficiency. And this characteristic is known as Maximum Power Point and MPPT is the process of determining this point and placing the load characteristic there.

The purpose of the MPPT system is to sample the output of the photovoltaic (PV) cells and to apply the proper load to achieve the maximum power under any environmental conditions. The power of the MPP (Pmpp) is the product of the MPP voltage (Vmpp) and the MPP current (Impp).

$P_{mpp} = V_{mpp} * I_{mpp}$.

2.2.1 PERTURB AND OBSERVE METHOD.

The perturb and observe method for maximum power point tracking(MPPT) algorithm is mostly used because of its ability to track maximum power point (MPP) under widely varying environmental conditions.

In perturb and observe method, the maximum power point tracking(MPPT) algorithm is purely based on the power calculation of the PV array and the power is changed by sampling both the PV current and voltage.

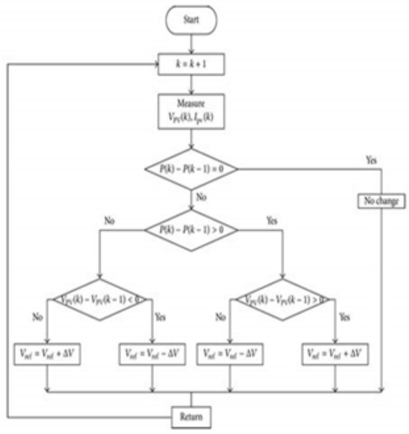

Figure 3: Flowchart of P&O

The perturb and the observe method is also called as hill climbing method, because it depends on the rise of the characteristic of power against voltage below the maximum power point and the fall above the maximum power point.

The perturb and observe method is preferred over any other method for its ability to implement easily and for its high robustness.

2.2.2 PROPORTIONAL INTEGRAL DERIVATIVE (PID) CONTROLLER.

The proportional integral derivative control is used along with the perturb and observe method in order to eliminate the oscillations that are produced by perturb and observe algorithm and also for its fast response to the system. It is used in feedback control mechanism.

A proportional integral derivative controller is a closed control loop mechanism which continuously calculates an error value as the difference between the desired set point (DS) and a measured process variable (PV). After determining the difference, it applies the correction based on the proportional, integral and derivative terms which gives the controller its name.

The basic block diagram of the proportional integral and derivative (PID) controller is given as,

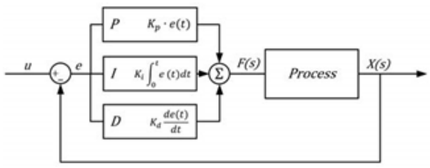

Figure 4: Block diagram of PID

The overall control function can be expressed mathematically as,

$$u(t) = k_p e(t) + k_i \int_0^t e(t^{'})dt^{'} + k_d \frac{de(t)}{dt}$$

Where k_p, k_i and $k_d$are all the non- negative coefficients of proportional integral and derivatives respectively.

2.3 V&I SENSING

2.3.1 CURRENT SENSING:

It is used to obtain DC signal from AC signal. The sensing of current is achieved with the help of current transformer. This is the accurate method to sense the current. The sensed current is rectified at first stage and amplified at second stage. The output is fed to the microcontroller, As the microcontroller works only in DC.

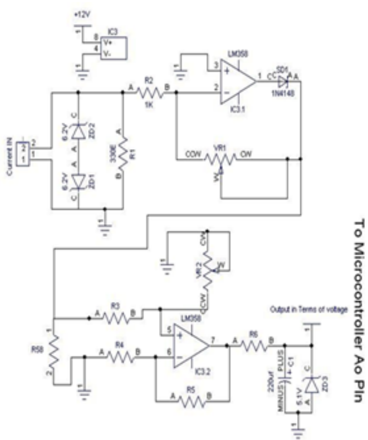

Figure 5: current sensing circuit

2.3.2 VOLTAGE SENSING:

It is used to obtain DC signal from AC signal. The sensing of voltage is achieved with the help of voltage transformer. This is the accurate method to sense the voltage. The sensed current is rectified at first op-amp stage and amplified at second op-amp stage. The output is fed to the microcontroller, As the microcontroller works only in DC.

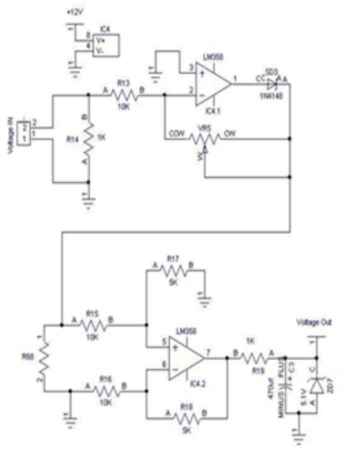

Figure 6: voltage sensing circuit.

2.4 SLIDING MODE CONTROLLER (SMC):

In pervious system the exact sinusoidal wave is not obtained in order to achieve the absolute sinusoidal wave sliding mode controller is used. The sliding mode control is recognized as one of the efficient tools to design robust controllers for complex high-order nonlinear dynamic plant. It operates efficiently even under uncertainty condition. The main advantage of sliding mode is less sensitive, In which the output is not much affected for minor variation in any parameter.

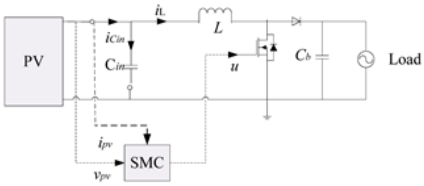

Figure 7: SMC circuit

It is a type of discontinuous control which is developed for the control of variable structure systems. In sliding mode control operating point moves through or moves within the sliding surface, which is achieved with the help of some control inputs.

The sliding mode controller works with the help of gate pulse. When the value is lower, the gate pulse is turned ON and when the value exceeds the gate pulse turns OFF. The output is fed to filter to get absolute sinusoidal wave.

2.5 SIGNAL CONDITIONING:

Signal conditioning includes amplification, filtering, converting, range matching, isolation and other processes required to make sensor output suitable for processing after conditioning.

2.5.1 FILTERING:

Filters are widely used for signal conditioning for all systems. The output from any device will have some noise, filters are employed to overcome it. In this system inductor filter is used. The filters with only an inductor called as inductive filter and it is also known as choke filter for the pulsating dc input. Due to the impedance of the filter, the output current amplitude is lower than the input.

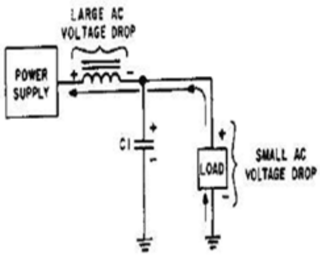

Figure 8: filter block

AMPLIFYING:

Amplification performs two important functions namely: improves the resolution of the signal and improves its signal-to-noise ratio. For example, the output of an electronic temperature sensor, which is probably in the millivolts range, is probably too low for an Analog-to-digital converter (ADC) to process directly. In this case it is necessary to bring the voltage level up to that required by the ADC. Commonly used amplifiers on signal conditioning include Sample and hold amplifiers, Peak Detectors, Log amplifiers, Antilog amplifiers, Instrumentation amplifiers or programmable gain amplifiers.

2.5.2 ISOLATIONS:

The isolation is applied to push the signal from source to measuring device without any contact. It is mainly used to isolate possible sources of signal perturbations. Also notable is that it is important to isolate the potentially expensive equipment used to process the signal after conditioning from the sensor.

Magnetic or optic isolation can be used for isolation. Magnetic isolation transforms the signal from voltage to a magnetic field, allowing the signal to be transmitted without a physical connection (for example, using a transformer). Optic isolation takes an electronic signal and modulates it to a signal coded by light transmission (optical encoding), which is then used for input for the next stage of processing.

2.6 PHASE LOCKED LOOP (PLL):

The phase locked loop is the technique implemented to achieve synchronization. When the current from the grid is surplus, the extra current is supplied to the grid. The current supplied from the PV system must add up with the grid current and if current from the panel is not sufficient, the current from the grid is utilized along with the panel current. So, synchronization plays a major lead.

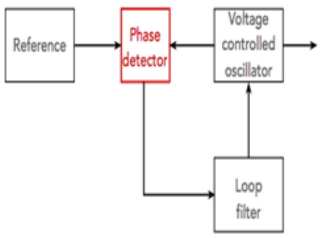

Figure 9: phase locked loop block diagram

The diagram for a basic phase locked loop shows the three-important components of the PLL: phase detector, voltage-controlled oscillator and the loop filter. In the basic PLL, reference signal of the system and the signal obtained from the voltage-controlled oscillator are applied to the two input ports present in the phase detector. The phase detector output is fed to the loop filter and the filtered signal is applied to the voltage controller oscillator. The VCO, In the PLL creates a signal that enters the phase detector. The signal from the VCO and the reference signal is compared a resultant difference or error voltage is obtained. This corresponds to the phase difference between the two signals. The error signal from the phase detector passes through a low pass filter which governs many of the properties of the loop and allows only low frequency elements on the signal. Once through the filter the error signal is applied to the control terminal of the VCO as its tuning voltage.

If there is any change in voltage, there will be reduction in the phase difference and frequency between two signals. Firstly, the loop is out of lock, and the error voltage will lower the frequency of the VCO towards that of the reference, until it cannot reduce the error any further and the loop is locked. When the PLL, is locked a steady state error in voltage is produced. By application of an amplifier between the phase detector and the VCO, the actual error between the signals can be reduced to very small levels. There must be some voltage presence at the control terminal of the VCO as this is what puts onto the correct frequency. The fact that the steady state error voltage is present means of the phase difference between the reference signal and the VCO is non-changeable. As the phase between these two signals is non-changeable as two signals are in same frequency. The PLL is widely used in radio frequency applications.

The phase sensitive detectors are used in many areas. Whenever there is a need to find phase difference the phase sensitive detectors are used. It is mainly used in phase locked loops to detect the phase difference and the error voltage produced.

3 SIMULATION:

In this paper, Absolute sinusoidal is obtained without any converter. The synchronization problem is rectified with the help of Phase Locked Loop.

Simulated power circuit of sliding mode controller-based grid coupled PV system

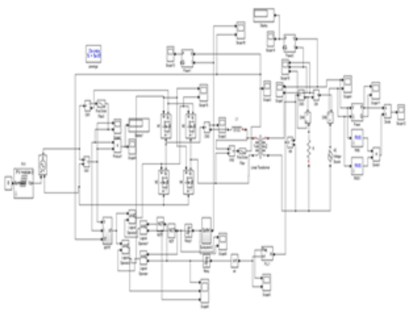

Figure 10: Simulated power circuit of the system

Current from the inverter to primary of transformer

The Fig .11 shows the absolute sinusoidal wave after implementing sliding mode controller to the inverter.

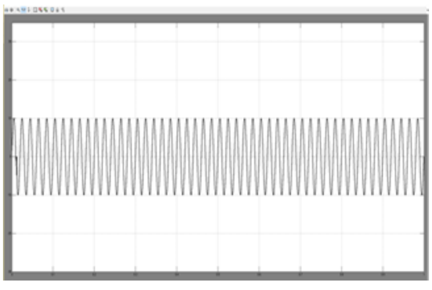

Figure 11: Transformer primary current

Current across the load

The Fig .12 shows current across the load. If the current from the PV system is not sufficient, the remaining current is utilized from the grid. If current is surplus, it will be injected to the grid.

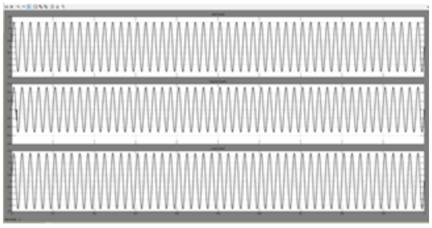

Figure 12: Current across the load

Power factor of the system

The Fig .13 Shows the Power factor of this system. It is nearly unity.

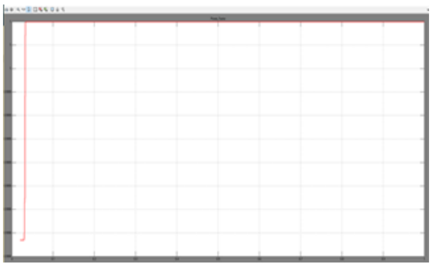

Figure 13: Power factor of the system

Total harmonic distortion of the system

The Fig.14. shows the total harmonic distortion in this system

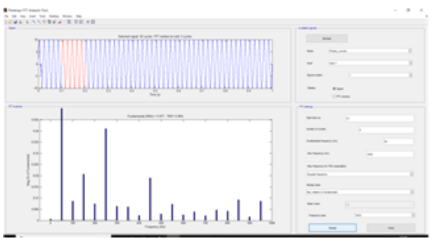

Figure 14: THD

4 TABULATION:

The values in the tabulation is obtained from the simulation.

Parameter Name	Parameter Values	Units
Panel voltage	12	V
Panel power	10	W
Panel current	1	A
Primary Current of the transformer	10	A
Primary voltage of the transformer	6	V
Secondary current of the transformer	0.25	A
Secondary voltage of the transformer	230	V
Frequency	50	Hz
Resistance of the load	100	ohms
Load current	2.25	A
Voltage across the load	230	V
Current form the grid	2	A
Power	529	W
Power factor	0.99	

Figure 9: phase locked loop block diagram

5 CONCLUSION

This paper is the key to achieve the absolute sinusoidal wave. It not only reduces the number of filters but also it overcomes the synchronization problem for grid connected PV system. This system is mainly designed to make the residential application of PV system effective.

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