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MODELING AND DESIGNING OF HIGH EFFICIENCY AND LOW THD PV SYSTEM

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***Abstract*— The proposed system develops a high efficiency and low THD of PV generation system. The high step-up converter and PWM inverters have been introduced to make the PV generation more flexible. To improve the efficiency in converter the parallel operation of low voltage PV arrays and to decouple and simplify the control design of PWM inverter, the high step-up converter is introduced. In order to maintain the sinusoidal output voltage with low THD and less variation under various output loads, an adaptive total sliding mode control system is used. For capturing the max irradiation and increasing the generation efficiency, an active sun tracking scheme without light sensors is also introduced**

***Index Terms*—High step up DC-DC converter with coupled inductor, Single phase PWM inverter , Variable Structure mode control, DSP controller, Power Driver circuit.**

I. INTRODUCTION

Most people, who are environmentally aware and are familiar with energy technology, agree that energy from the sun has extraordinary advantages when compared with other sources. Basically, solar energy has zero emission and if manufacturing and recycling can be properly performed an extremely clean and abundant supply of energy will be attained for centuries. Besides hydrogen power and wind power, which also originate from the sun, the utilizing of solar energy can be divided into two separate branches. These two branches are thermal solar energy and photovoltaic solar energy. The former is the most mature technology and in many cases the least expensive but has a disadvantage: the energy output is heat and the efficiency is only high if heat is required. Often heat is not needed during the sunny season. This work deals with energy production using photovoltaics. The advantage of this technique compared with thermal heat is that the solar energy is converted to a very versatile form, electricity.

Paper describes a method for simulating the expected energy production of a solar power plant and compares the expected production with the actual energy yield.A PV-module inverter has been designed and constructed. The current controller has been implemented in an inexpensive 8-bit micro controller .The emphasis is on high energy-efficiency and high power quality

The conventional boost converters cannot provide such a high dc voltage gain, even for an extreme duty cycle. It also may result in serious reverse recovery problem and increase the rating of all devices. As a result, the conversion efficiency is degraded and the electromagnetic interference problem is severe under this situation. To increase the conversion efficiency and voltage gain, many

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modified step-up converter topologies have been investigated in the past decades. Although voltage clamped techniques are manipulated in the converter design to overcome the severe reverse-recovery problem of the output diode in high-level voltage applications, there still exist overlarge switch voltage stresses and the voltage gain is limited by the turn-on time of the auxiliary switch.

A novel coupled-inductor converter strategy to increase the voltage gain of a conventional boost converter with a single inductor, and deal with the problem of the leakage inductor and demagnetization of the transformer in a conventional coupled-inductor-based converter. In this paper, the high step-up converter topology is introduced to boost and stabilize the output dc voltage of PV modules for the utilization of a dc–ac inverter.

Developments in microelectronics and power devices have caused the widespread application of pulse width-modulation (PWM) inverters in industries. The basic mechanism of a PWM inverter is to convert the dc voltage to a sinusoidal ac output through the inverter-*LC* filter blocks. The performance is evaluated by the total harmonic distortion (THD), the transient response, and the efficiency. Thus, much attention has been paid to the closed-loop regulation of PWM inverters to achieve good dynamic response under different types of loads in the past decade, e.g., sliding-mode control (SMC), etc. Variable structure control with sliding mode, or SMC, is one of the effective nonlinear robust control approaches since it provides system dynamics with an invariance property to uncertainties once the system dynamics are controlled in the sliding mode. The insensitivity of the controlled system to uncertainties exists in the sliding mode, but not during the reaching phase, i.e., the system dynamic in the reaching phase is still influenced by uncertainties.

This paper focuses on the development of a high efficiency and low THD PV generation system. It contains three main contents including a high step-up converter, a PWM inverter with ATSMC, and an active sun tracking scheme. First, the active sun-tracking scheme is designed to capture maximum irradiation and powers. Then, the high step-up converter is implemented for converting the captured power from the active sun-tracking scheme to form a stable dc voltage source. In addition, the PWM inverter with ATSMC transfers this dc voltage source from the high step-up converter into ac voltage source for stand-alone utilization.

Photovoltaic (PV) offers an environmentally friendly source of electricity. With development and breakthrough in new cell materials and power electronics technologies solar power can prove to be an efficient, environmental friendly and safe means of power. In this module the solar cells is a fundamental power conversion unit of a photovoltaic system.

The topic of this paper focuses on the development of a high efficiency and low THD stand-alone PV system. It contains three main contents including a High step up DC-DC converter with coupled inductor, a Single phase PWM inverter by using Variable Structure mode control in MPPT, and an active sun tracking scheme. First, the active sun-tracking scheme is designed to capture maximum irradiation and powers, but in simulation DC source is installed instead of tracker. Then, the high step-up DC-DC converter with coupled inductor is implemented for converting the captured power from the active sun-tracking scheme to form a stable dc voltage source. In addition, a single phase PWM inverter with ATSMC transfers this dc voltage source from the high step-up converter into an ac voltage source for stand-alone utilization. This paper is organized into seven sections

II.SYSTEM DESCRIPTION

In this paper, the configuration of a high efficiency and low THD PV system is depicted in Fig. 1. The system is mainly composed of a PV module, a high step-up DC-DC converter, a single phase PWM inverter, DSP controller, and R load. The identified problems in conventional PV systems and the proposed solutions in this paper are expressed in detail as follows. Due to the PV effect, the voltage of a PV plate is not very high. However, the PV array with a higher output voltage is difficult to fabricate and it may fail when any single PV plate is inactive. Besides, the corresponding output voltage (*V*pv) is varied easily with respect to the variation of loads.

To satisfy the requirement of high voltage demand, a high-efficiency and a high step up dc–dc converter with high voltage gain is needed as one of the essential mechanisms in the high efficiency and low THD PV system. A high step-up DC-DC converter with coupled inductors is implemented to reduce the series-connected numbers of PV plates, to maintain a constant dc bus voltage (*V*d) for the inverter utilization, and to decouple and simplify the control design of a dc–ac inverter. A unipolar single phase PWM full-bridge inverter with four power semiconductors and a low-pass filter is regarded as the dc–ac power conversion circuit to meet the requirement of an ac power source. Since the PWM inverter dominates the performance in converting the dc voltage source to an ac voltage source, the quality of the ac output waveform of the PV system is highly dependent on the performance of the PWM inverter. Thus, an ATSMC system is introduced by way of switching four power semiconductors in this inverter to maintain a sinusoidal output voltage (*v*o) with lower THD and less variation under various output loads.

Generally speaking, the output power of a PV module is substantially changed according to different irradiations. To further enhance the performance of PV generation system, an active sun tracker actuated by a synchronous motor is investigated on the basis of the open-circuit voltage of the PV modules. And PV modules are used in the hardware circuit. But in the simulation, instead of PV modules a constant DC voltage source is applied. This keeps the PV plate facing the sun to improve the generation efficiency of the fixed-installation PV module, and to save the cost associated with the conventional sun tracker with light sensors. This way, it is not necessary to modify the original circuit framework of the PV system because of the simple requirement of the open-circuit voltage of PV modules in the active sun tracking scheme.

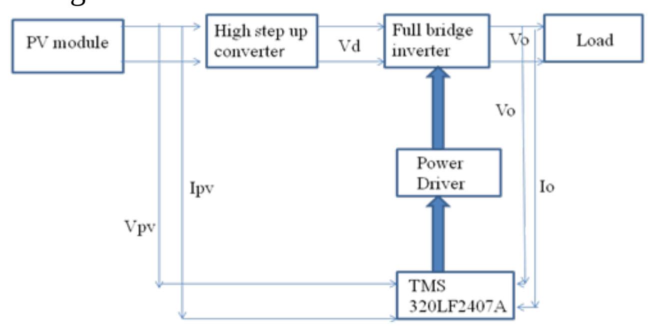

Fig. 1. Overall Block diagram of proposed system.

In this paper, the PWM inverter control and the active sun tracking scheme are carried out using C language written in a system controller, i.e., a digital signal processor (DSP) development module. This development module has a Texas Instruments TMS320LF2407A central processing unit with an evaluation module, 16-channel 10-bit analog-to-digital, 4-channel 12-bit digital-to-analog converters and programmable input–output (I/O) ports. The central processing unit has a 40MIPS 16-bit fixed point DSP core, 16 PWM channels, four general purpose timers and two encoder channels. The detailed functions of the main components in the PV system will be explained below.

III.SINGLE PHASE PWM INVERTER WITH VARIABLE STRUCTURE MODE CONTROL

3.1.PWM CONTROL:

Pulse width modulation(PWM) is a powerful technique for controlling analog circuits with a processor's digital outputs.PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion. An analog signal has a continuously

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varying value,with infinite resolution in both time and magnitude.Analog signals are distinguishable from digital signals because the latter always take values only from a finite set of predetermined possibilities.Analog voltages and currents can be used to control things directly.

As intutive and simple as analog control may seem,it is not always economically attractive or practical.For one thing,analog circuits tend to drift over time and can,therefore,be very difficult to tune.Precision analog circuits,which solve that problem,can be very large,heavy,and expensive. Analog circuits can also get very hot;the power dissipated is proportional to the voltage across the active elements multiplied by the current through them.

3.2. CONTROLLED PWM INVERTER:

For a fixed output power, the output voltage will drop for heavy loads and rise for light loads until clipping occurs. Depending on the application, any given load may be more requiring of a stable voltage or a stable current. An active circuit control approach can be optimized for one or the other. In the case of this project, the output voltage is to be considered more important than the output current, and therefore the control approach will attempt to keep the output voltage constant as the load varies. Its current draw is within a range that does not become too large as to overload the DC supply or destroy circuit components, nor so small that the output voltage waveform begins to clip against the DC supply rails.

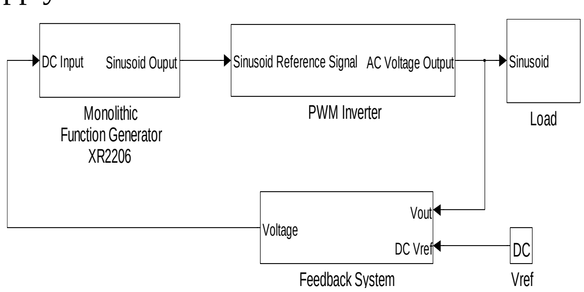

Fig.2. Controlled PWM Inverter Block Diagram

The output voltage is proportional to the control signal voltage, which is a pure sine wave. In order to have some control over the output voltage, a means for rapidly making small adjustments to the magnitude of the control signal must be provided. This is accomplished by taking the output of an error amplifier that compares fixed proportions of the peak amplitudes of the control signal and the inverter output voltage and multiplying it with the control signal as seen in Figure 2. The output of the error amplifier is normalized so that when no error in the output voltage is present, there is no change to the magnitude of the control signal. Any error, positive or negative, will induce a corresponding rise or fall in the output of the error amplifier which will be multiplied against the control signal, which will in turn then propagate through the inverter circuit and correct the final output voltage accordingly.

3.3. PWM INVERTER FRAMEWORK:

It includes four power semiconductors and a low-pass filter. In Fig3 r_{Lf} and r_{Cf} are the equivalent series resistors of the inductor (L_f) and the capacitor (C_f) in the low-pass filter; Z_L is the output load; v_{AB}, v_{Cf} , and v_o are the output voltage of the full-bridge inverter, the voltage across the filter capacitor, and the load voltage, respectively; i_{Lf} , i_{Cf} , and i_o are the filter inductor current, the filter capacitor current, and the load current, respectively; the current source i_{ld} emulates the disturbance incurred by load variations. For convenient analysis, the following assumptions are made in this PWM inverter framework.

1) The values of r_{Lf} and r_{Cf} are small enough to be ignored.

2) The conduction and switching losses are zero since all power switches are assumed to be ideal devices.

3) The delay time between the switch turn-on and turn-off states is small enough to be neglected.

4) The control signal and I/O voltages are taken as constant values because the switching frequency is much greater than the system dynamic frequency

Due to the symmetry property of the positive-half and negative-half period in the unipolar PWM

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switching, the dynamic equation during the positive-half period can be represented via the state-space average method and the linearization technique as

$$\dot{i}_{Lf} = (DiV_d - v_{Cf})/L_f$$

$$\dot{v}_{Cf} = (i_{Lf} + i_{ld} - i_o)/C_f$$

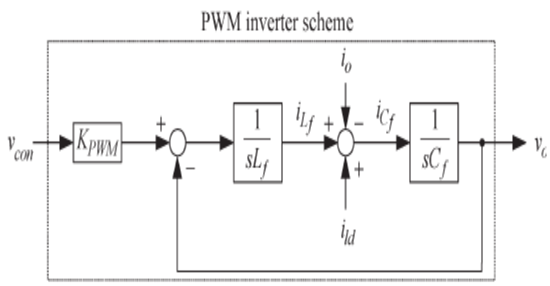

Fig.3.Equivalent dynamic model of the PWM inverter.

3.4. ATSMC SYSTEM:

The objective of the PWM inverter control is to force the system state ($x = v$o) to track a reference output voltage (xd $=v$cmd) under the possible occurrence of system uncertainties. An ATSMC system as shown in Fig is introduced for the voltage control of the PWM inverter, where the control error is chosen as $e = x - x$d $= v$o – $v$cmd.

The ATSMC system is divided into three main parts. The first part addresses the performance design. The objective is to specify the desired performance in terms of the nominal model, and it is referred to as the baseline model design (ub). Following the baseline model design, the second part is the curbing controller design (uc) to totally eliminate the unpredictable perturbation effect from the parameter variations and external disturbance so that the baseline model design performance can be assured. Finally, the third part is the adaptive observation design ($\hat{\rho}$) to estimate the upper bound of the lumped uncertainty to alleviate the chattering phenomenon caused by the inappropriate selection of a conservative constant control gain in the curbing controller.

3.5. ACTIVE SUN TRACKING SCHEME:

Because the movement of the sun is slow and monotonous, and the variation range of the climbing angle is within ±10◦, it is not necessary to adjust the inclined angle of the PV plate to simplify the mechanical framework. By way of the single-axis direction control, the PV plate can immediately achieve the goal of collecting maximum irradiation. In this paper, an active sun tracking scheme actuated by a synchronous motor is used for the sun tracking via the information of the open-circuit voltage of the PV module. The corresponding control flowchart of the active sun tracker is depicted in Fig.4.

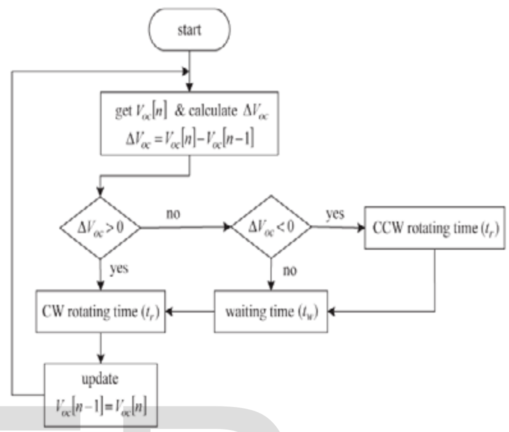

Fig.4. Control flowchart of the active sun tracker.

Voc[n] and Voc[$n - 1$] represent the present and previous open-circuit voltages; ΔVoc denote the variation of the open-circuit voltage. Because the sun only moves from East to West, the PV plate is rotated by the unit angle for time tr clockwise (CW) in the beginning of the control process to disturb the corresponding open-circuit voltage. This way, it can adjust the rotating direction by observing the variation trend of the open-circuit voltage to capture more irradiation because the open-circuit voltage of the PV module is proportional to the corresponding irradiation. If the condition of ΔVoc < 0 holds, the PV plate is rotated by the unit angle for time tr counterclockwise, i.e., it is returned to the previous location. After that, the control process will wait for time tw to further ensure whether the reason for the decrease of ΔVoc disappears or not. If the condition of ΔVoc = 0 holds, the control process also waits for time tw for the next CW rotation. Note that the function of the waiting time is helpful for alleviating

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the extra power consumption in a back-forth motion. According to the aforementioned action principle, the control target of the active sun tracking scheme can be achieved

IV. HIGH STEP UP DC-DC CONVERTER WITH COUPLED INDUCTOR

4.1. CONVERTER DESIGN AND ANALYSES:

The system configuration of the proposed converter topology is depicted in Fig. 5, where it contains seven parts including a dc input circuit, a primary side circuit, a secondary-side circuit, a passive regenerative snubber circuit, a filter circuit, a dc output circuit, and a feedback control mechanism. The major symbol representations are summarized as follows. Vin and Ii denote dc input voltage and current, and Cin is an input filter capacitor in the dc input circuit and L1, L2 represent individual inductors in the primary and secondary sides of the coupled inductor respectively, Q is a switch in the primary-side circuit and Tq is a trigger signal in the feedback control mechanism, C1, D1, and D2 and denote a clamped capacitor, a clamped diode, and a rectifier diode in the passive regenerative snubber circuit. C2 is a high-voltage capacitor in the secondary-side circuit. And Do, Co is the output diode and the filter capacitor in the filter circuit. Vo and Io describe output voltage and current. Ro is an output load.

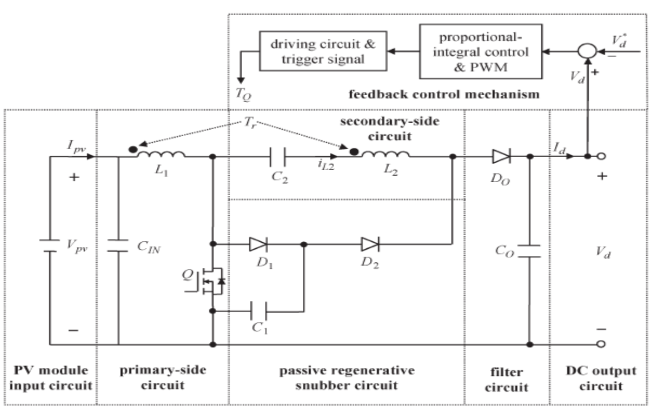


Fig.5. Architecture of high step up converter

In this strategy, a coupled inductor with a lowvoltage- rated switch is used for raising the voltage gain whether the switch is turned on or off. Moreover, a passive regenerative snubber is utilized for absorbing the energy of stray inductance so that the switch duty cycle can be operated under a wide range, and the related voltage gain is higher than other coupled-inductor-based converters. It can select low-voltage low-conduction-loss devices, and there are no reverse-recovery currents within the diodes in this circuit. Furthermore, the closed-loop control methodology is utilized to overcome the voltage drift problem of the power source under the load variations. As a result, this converter topology can increase the voltage gain of a conventional boost converter with a single inductor, and deal with the problem of the leakage inductor and demagnetization of the transformer for a coupled-inductor-based converter.

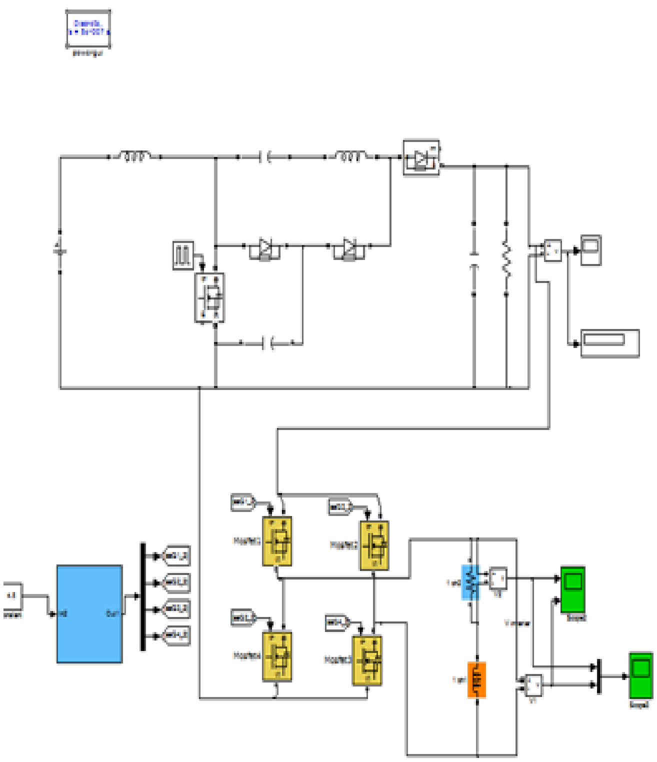
The coupled inductor could be modeled as an ideal transformer, a magnetizing inductor (*L*m), and a leakage inductor (*L*k). The turns ratio (*n*) and coupling coefficient (*k*) of this ideal transformer are defined as

$$n = N2/N1$$

$$k = Lm/(Lk + Lm)$$

where *N*1 and *N*2 are the winding turns in the primary and secondary sides, respectively. The voltages across the switch, the primary and secondary winding of the ideal transformer, and the leakage inductor are denoted as *v*DS, *v*Lm, *vL*2, and *v*Lk, respectively. Moreover, the primary current (*iL*1) of the coupled inductor is composed of the magnetizing current (*i*Lm) and the primary induced current (*i*1). The secondary current (*iL*2) is formed by the primary induced current (*i*1) through the ideal transformer, and its value is related to the turns ratio (*n*). In addition, the conductive voltage drops of the switch (*Q*) and all diodes (*D*o, *D*1, and *D*2) are neglected to simplify circuit analyses.

V. SIMULINK MODEL OF THE SYSTEM



VI.CONCLUSION

This paper has successfully developed a Simulink model of high efficiency and low THD PV generation system. The efficiency of the high step-up converter with coupled inductors, the PWM inverter control using variable structure mode control, and the active sun tracker for the PV generation system was verified by using MATLAB.According to the simulation results, the maximum conversion efficiency of the high step-up converter is over 96.5,by giving an input of 50v we are getting a output voltage of near 150v.The ac output voltage of the PWM inverter can maintain a sinusoidal waveform, and the corresponding THD values under different loads are less than 3.1% which is merely 1.9%.The implementation of the active sun tracking scheme is to improve the generation efficiency of the fixed-installation PV module,to save the cost of the conventional sun tracker with light sensors. And the hardware experimental results are on the process…..

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