Grid Connected Solar Power System Using PWM Strategy with Single Phase Seven Level Inverter

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Abstract: In order to avoid the Thermal stresses in Semiconductor Devices in the existing methods we have to use complex control designs like Thermal Stresses Relief Carrier Based PWM (TSRPWM). In this the solar generation system with grid using multilevel inverter concept without using Thermal Stresses Relief Carrier Based PWM (TSRPWM) was proposed. To interconnect with grid or utility system with 7-level inverter and transformer. The generated voltage in the above scheme will be a sinusoidal one and will be in phase with the grid voltage and is given into the utility. The main and excellent thing proposing in this paper is that only 6-power electronic switches to generate a 7-level multi-level inverters. .

KEY TERMS: Power Converter, 7-Level Multilevel Inverter, TSRPWM, PLL, PWM Generator,MATLAB.

I INTRODUCTION

In interconnecting the solar power generation system with the grid the conversion of grid is more considered one. In solar power generation system the generated power is D.C and the grid or utility requires the A.C so while converting the DC to AC requires power conversion technique to feed the A.C utility. As the voltage generated by the solar cell is low in magnitude so we require a dc-dc voltage converter to step-up. The dc output voltage so that it can match the input voltage of the inverter.

The efficiency of the power converter is important to ensure that there is no waste of energy generated by using the solar power generator. Both the active and passive devices in the inverter will cause the more losses which includes both the switching and conducting losses i.e., conduction losses will result from the use of active device. Where switching losses will result from in proportional to the voltage and the current changes for each switching frequency.To overcome the switching harmonics we are using the inductive filter. So that power loss is proportional to the amount of switching harmonics.

In order to improve the power converter efficiency the voltage at each switching operation of the multi-level inverter is reduced. So that the switching stress on the active device gets decreased. By doing this the amount of switching harmonics will get reduced. So the power loss caused by filter inductor will also reduce.In this case from past many years most researches have been going on the multilevel inverter topology. In present project to reduce harmonic content and electromagnetic interference(EMI) and to increase the efficiency the high voltage levels are generated.

In general multilevel inverters mainly consisting of diode-clamped, flyback capacitor and the cascade H-Bridge. In the above diode-clamped and flyback capacitor multilevel inverters usage of capacitors develop several voltage levels. But it is difficult to regulate the voltage of these capacitors since it is difficult to create an asymmetric voltage technology and also the circuit designed is also complicated as we increase the voltage levels. For single phase and 7-level inverter 12-power electronics switches are needed in both the types of the devices where as in the H-Bridge inverters produces 7-level voltage by using the multiple relationships and eight power electronic devices are needed. Most recently various types of new methods have been arrived in reducing the complexity in switching devices for 7-level multilevel inverters. For Example, a single –phase seven level grid connected inverter has been developed for photovoltaic system [09]. In this grid connected inverter contains six power electronic switches but in this three capacitors are used to construct the three voltage levels, which results in that balancing the voltage levels, which results in that balancing the voltages of the capacitors is more complex. In [10], a seven-level inverter topology, configured by a level generation part and a polarity generation part is proposed. This modeled inverter is similar to H-bridge type of inverter. For this to achieve dynamic voltage balance a new modulation method is proposed. .

II PROPOSED SYSTEM

In this project a new solar generation system. This system comprising of a dc/dc power converter,and a seven-level inverter. In this 7-level inverter the output is obtained using a capacitor selection circuit and a full bridge power converter connected in series. In this proposed system we are using only 6-power electronic devices as switches to generate the 7-level output voltage. And in the power electronic switches configured in such a manner that only one power electronic switch is switched at high frequency at any time to generate the 7-level output voltage. The switching power loss is reduced and the power efficiency is improved

The below figure shows the proposed solar power generation system with the multilevel inverter.

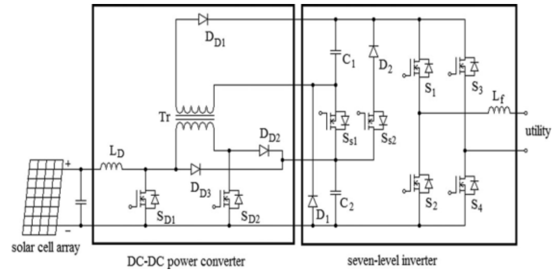

Fig (1): Proposed Grid interconnected Solar Power Generation System

In this proposed system a solar cell array, a dc-dc power converter, and a new 7-level inverter. The solar cell array is connected to dc-dc power converter consisting of a step up converter connected with a transformer having a turns ratio of 2:1. This dc-dc power converter converts the output power of solar power array into two independent voltage sources with multiple relationships, giving to the 7-level inverter. The new 7-level inverter is configured with capacitor selection and a full-bridge power converter are connected in series. Due to the multiple relationship in capacitors voltage can discharge individually or in series consisting of 3-level D.C output voltage. The 3-level D.C voltage will be given to the multilevel inverter and this inverter will generate the output as the a.c 7-level inverter which can synchronize with the utility voltage. In the above Explained process will generate the A.C voltage from a solar power array to synchronize with grid. In this proposed circuit the power circuit used in this can get simplified with the usage of 6-powe

III DC-DC POWER CONVERTER

The dc-dc power4 converter consisting of boost converter and a current-fed forward converter charging bot the capacitors c1 and c2. Capacitor c1 is charged by using the current-fed forward converter. The current fed forward converter consist of inductor LD, SD1,SD2, Diode DD1, DD2 and a Transformer. Capacitor c2 is charged by using the boost converter comprising of inductor LD, Power electronic switch SD, and Diode DD3.

OPERATION OF DC-DC CONVETER When power electronic switch SD1 is turned ON the capacitor c2 will charge by using the DC-DC power converter which is shown in figure 2(a).

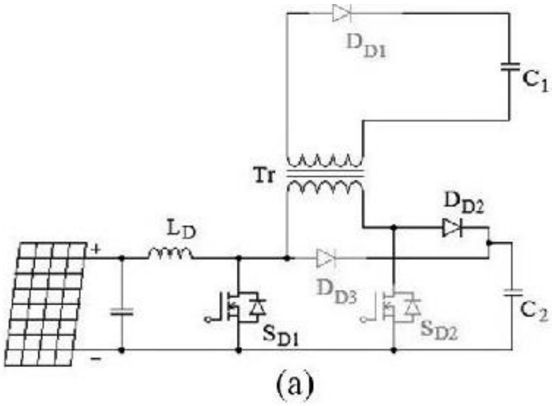

FIG2(a):Operation of power converter when switch SD2 is OFF

If the power electronic switch SD2 is turned on the capacitor c1 will get charged by using the solar power generation system energy to the inductor LD, switch SD1

Seven level multilevel inverter's PWM modulation contain three reference signal named *Vref1*, *Vref2*, and *Vref3*. These three reference signals had same frequency, amplitude and phase. The difference is that they had different offset values. The reference signals are positive sine waveform. To produce the signals for the switches, the reference signals need to be compared to a carrier signal (*Vc*);a triangular wave signal, using a comparator.

The reference signals were each compared with the carrier signal. If *Vref1* had exceeded the peak amplitude of *Vcarrier*, *Vref2* was then compared with *Vcarrier* until it had exceeded the peak amplitude of *Vcarrier*. Then, *Vref3* would be compared with *Vcarrier* until it reached zero. Once *Vref3* had reached zero, *Vref2* would be compared until it reached zero. Then, onward, *Vref1* would be compared with *Vcarrier* [8] and the process continues. Figure 4 shows the signal generation.

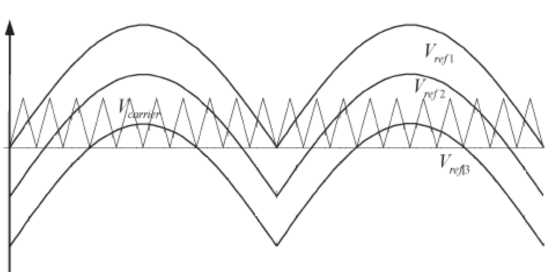

Figure3. PWM switching signal for 7-level multilevel inverter.

If the power electronic switches are operated as per pulse with modulation strategy.These manner the operation takes place.The operation of the power converter is shown above. seven level multilevel inverter pwm modulation contain reference signal and which are compared and which can been show in operation of the configuration of circuit and this operation include reduction of losses and improve of the performance of proposed system. These was method to voltage and current shape and is shown in configuration.pwm stategy is most prevalent method is used here.

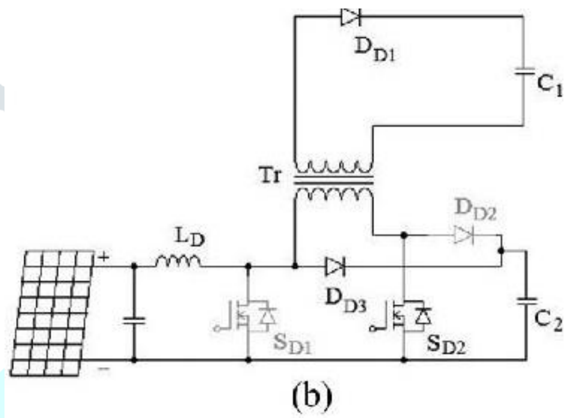

FIG 2(b): Operation power converter when switch SD1 is OFF

Capacitor c1 and capacitor c2 are connected in parallel through the transformer. In such a way that the energy of inductor LD and the solar cell array charges capacitor c2 through diode DD3 and charges capacitor c1 through the transformer and diodeDD1 during the Off state.

By using the transformer we can charge the capacitor c1 and c2 in parallel, the voltage ratio of capacitor charging is same as the transformer ratio of 2:1.

The boost converter is operated in continuous conduction mode (CCM) charging the capacitor c2 which is given by

$V_{C2}= (1/(1-D))\ V_s$

V_s= output voltage of solar cell array

D= duty ratio of SD1

The capacitor c2 voltage is given by

$V_{C1}=(1/2(1-D))\ V_s$

When the switch SD2 is in ON state then the magnetizing inductance of the transformer increases .in normal case to reduce these magnetizing inductances are sent back to the source by using the third demagnetizing winding. However in proposed system the magnetizing inductance is delivered to the capacitance c2 through the DD2 and SD1 when SD2 is turned OFF. Since the energy stored in the magnetizing inductance is transformed forward to the output capacitance c2 and not back to the dc source by doing this power efficiency also increases.

III CONTROLLING OF 7-LEVEL INVERTER

In this controlling will be done by the current mode of control and PWM is used to generate the controlling signals for the power electronic switches

In order to satisfy the synchronizing of grid with Solar Power generation system we have to control the output of the inverter within 2-levels that is in one level the output of the inverter must be higher than the utility voltage to increase the filter inductor and in another level the voltage must be more less than the utility voltage in order to reduce the filter inductor current.

The output voltage of the inverter must be changed with respect to the utility voltage by considering the referance current from the controlling

During +Ve half cycle conduction the utility voltage is smaller than Vdc/3. The multilevel inverter must be switched between modes 1 and 4 to an output voltage of Vdc/3 or 0.

The duty ratio d of s1 can be represented as

$d=V_m/V_{tri}$

V_m= modulation signal

V_{tri}= amplitude of carrier signal in pwm circuit

The output voltage of 7-level inverter is given by

V_o=d *Vdc/3= K_{pwm} * V_m

K_{pwm}= gain of inverter

Closed loop transfer function show below

$$I_o = \frac{\frac{K_{pwm}\frac{G_c}{L_f}}{}}{\frac{s+K_iK_{pwm}G_cI_o}{L_f}} - \frac{\frac{1}{L_f}}{\frac{S+K_iK_{pwm}G_c}{L_f}} \qquad (1)$$

gain of the current detector

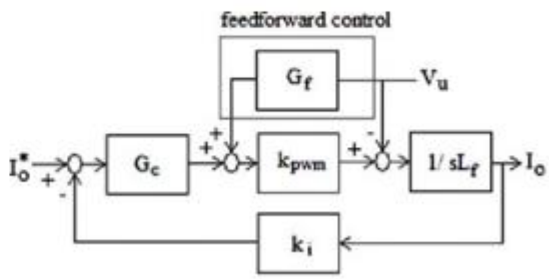

Fig.3 Model of the seven-level inverter under different range of utility voltage,in range of smaller than *V*dc/3

If the utility voltage is in the range (Vdc/3, 2Vdc/3) then the 7-level inverter is switched between modes 2 and 1. To gain the voltage range SS2 is switched in pwm so the duty ratio SS2 is same as the above switch so the output voltage is

Vo= d Vdc/3 + Vdc/3 = k_{PWM}Vm+ Vdc/3.

And the closed loop transfer function for the above range of utility voltage is shown in figure

The closed loop transfer function is derived asWhen the utility range of (2Vdc/3,Vdc) then the 7-level inverter must be switched between modes 3 and 2. To obtain this voltage range the switch SS1 is switched in PWM and SS2 remains in the ON state to avoid switching of SS2. Then the output voltage is given by.

Vo= Vdc/3+2Vdc/3 = Kpwm*Vm+ 2Vdc/3.

The closed loop controlling for this mode of operation.In the –Ve half cycle also the same feed forward controlling is used to obtain the utility range voltages. In order to have the output voltage of –Vdc/3 or 0. The switch s3 is switched in PWM and the 7-level inverter is switched in mode 6 and 5 to an output voltage of -2Vdc/3 or –Vdc/3By comparing the proposed system with the nominal or normal converters we can say that the level of complexity is reduced as we are using only 6-power electronic switches for 7-level output voltage. All the range of utility voltages for operating the 7-level inverter is placed in table which is shown below Power electronic switches conduction states

	S_{S1}	S_{S2}	S_1	S_2	S_3	S_4
positive half cycle						
$\|v_u\| < V_{dc}/3$	off	off	PWM	off	off	on
$2V_{dc}/3 > \|v_u\| > V_{dc}/3$	off	PWM	on	off	off	on
$\|v_u\| > 2V_{dc}/3$	PWM	on	on	off	off	on
negative half cycle						
$\|v_u\| < V_{dc}/3$	off	off	off	on	PWM	off
$2V_{dc}/3 > \|v_u\| > V_{dc}/3$	off	PWM	off	on	on	off
$\|v_u\| > 2V_{dc}/3$	PWM	on	off	on	on	off

In the above table we can observe that in all the cases only 3 power Electronic switches are conducting in series expect in the case V_u> 2Vdc/3. In both +Ve and –Ve cycle the 4 power electronic switches are conducting. So we can say that the switching losses will be reduced due to less number of conducting switches.

The drawback of the proposed seven level inverter is that the voltage rating of the full bridge converter is higher convention multilevel inverter.The leakage current is an important parameter in a solar power generation system for transformer less operation. The leakage current is dependent on the parasitic capacitance and the negative terminal voltage of the solar cell array respect to ground. To reduce the leakage current, the filter inductor Lf should be replaced by a symmetric topology and the solar power generation system is redrawn as shown in the below Fig

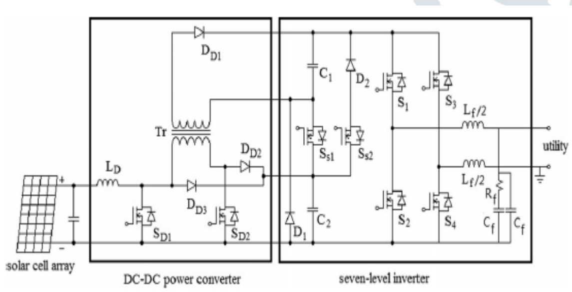

Fig. 4. Configuration of the proposed solar power generation system for suppressing the leakage current.

IV CONTROLLING FOR BOOST CONVERTER AND POWER INVERTER

In this proposed system we are having dc-dc power converter and a 7-level inverter. The dc-dc power converter feeds the inverter with capacitance providing two independent voltage sources with multiple relationships and performs maximu8m power point tracking (MPPT) in order to extract the maximum output power from the solar cell array. The 7-level inverter converts the capacitance voltage into a high range A.C Voltage for utility voltage system.

In order to perform the operation of the boost converter and inverter perfectly we are constructing a controlling system for both the converter and inverter.

IV SIMULATION RESULTS

The comparator circuit has three output signals, which correspond to the operation voltage ranges, (0, Vdc/3), (Vdc/3, 2Vdc/3), and (2Vdc/3,Vdc). The feed-forward control eliminates the disturbances of the utility voltage, Vdc/3 and 2Vdc/3,. The absolute value ofthe utility voltage and the outputs of the compared circuit are sent to a feed-forward controller to generate the feed-forward signal. Then, the output of the current controller and the feed-forward signal are summed and sent to a PWM circuit to produce the PWM signal. The detected utility voltage is also compared with zero, in order to obtain a square signal that is synchronized with the utility voltage. Finally, the PWM signal, the square signal, and the outputs of the compared circuit are sent to the switching signal processing circuit to generate the control signals for the power electronic switches of the seven-level inverter, according to Table I. The current controller controls the output current of the seven level inverter, which is a sinusoidal signal of 60 Hz. Since the feed-forward control is used in the control circuit, the current controller can be a simple amplifier, which gives good tracking performance. As can be seen in (6), (8), and (10), the gain of the current controller determines the bandwidth and the steady state error. The gain of the current controller must be as large as possible in order to ensure a fast response and a low steady-state error. But the gain of the current controller is limited because the bandwidth of the power converter is limited by the switching frequency.

The inner current control loop controls the inductor current so that it approaches a constant current and blocks the ripple voltages in C1 and C2.The perturbation and observation method is used to provide MPPT [24]. The output voltage of the solar cell array and the inductor current are detected and sent to a MPPT controller to determine the desired output voltage for the solar cell array. Then the detected output voltage and the desired output voltage of the solar cell array are sent to a sub tractor and the difference is sent to a PI controller.

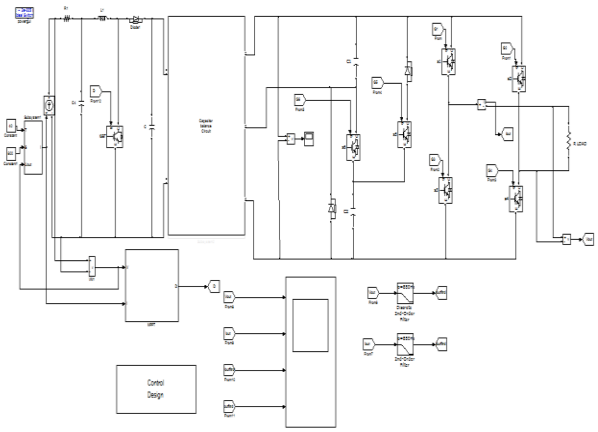

Fig 5 Simulink Model of the Proposed Seven Level PV System with TSRPWM

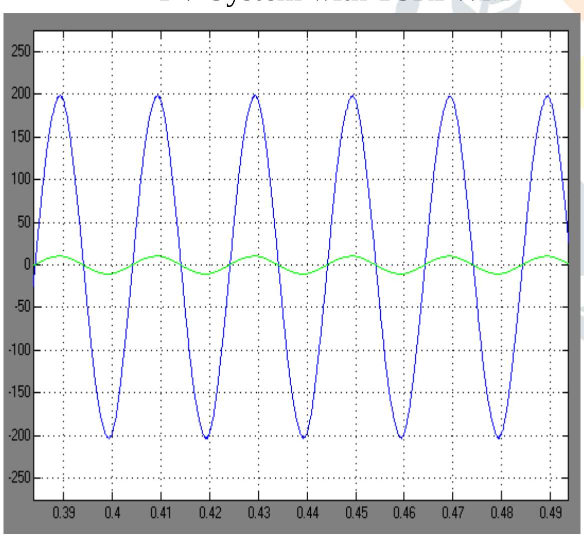

Fig 6 Simulation Waveforms of the grid Voltage & Current.

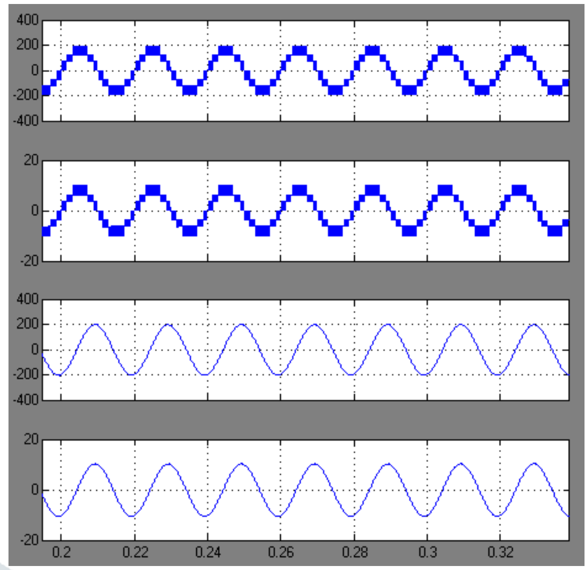

Fig 7 Simulation Waveforms of the Output Voltage (V), Current (A), Filtered Voltage (V) & Filtered Current (A).

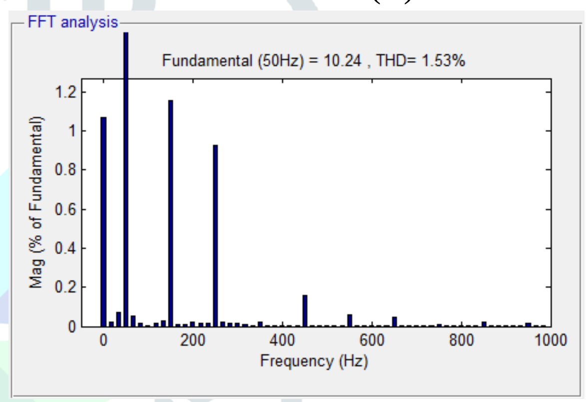

Fig 8 Total Harmonic Distortion (THD in %)

The output of the PI controller is the reference signal of the inner current control loop. The reference signal and the detected inductor current are sent to a subtractor and the difference is sent to an amplifier to complete the inner current control loop. The output of the amplifier is sent to the PWM circuit. The PWM circuit generates a set of complementary signals that control the power electronic switches of the power converter.

CONCLUSION

. The proposed solar power generation system with is composed of a dc–dc power converter and a seven level inverter. The seven-level inverter contains only six power electronic switches, which simplifies the circuit configuration. Furthermore, only one power electronic switch is switched at high frequency at any time to generate the seven-level output voltage. This reduces the switching power loss and improves the power efficiency.In order to avoid the Thermal stresses in Semiconductor Devices in the existing methods we have to use complex control designs like Thermal Stresses Relief Carrier Based PWM (TSRPWM). In this the solar generation system with grid using multilevel inverter concept without using Thermal Stresses Relief Carrier Based PWM (TSRPWM) was proposed. To interconnect with grid or utility system with 7-level inverter and transformer.

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