Solar Smart Inverter: A Novel Design using Multi level Topology and Pulse Width Modulation with Load Detection

Nithin Krishnan
PG Scholar,
Dept.of Electronics & Communication
MohandasCollegeofEngineering,KeralaUniversity
Trivandrum-695541,Kerala,India

Divya H.
Asst.Professor,
Dept of Electronics & Communication
MohandasCollegeofEngineering,KeralaUniversity
Trivandrum-695541,Kerala,India

***Abstract*—The term solar smart inverter has become a buzzword in the electronics industry which is a blending of multilevel inverter, solar tracking and solar charging. Inverters are predominantly classified as single level inverters and multilevel inverters. Minimum harmonic distortion, reduced EMI/RFI generation are the major advantages of multilevel inverters as compared to single level inverters. Multilevel inverters can operate on various voltage levels. Multipurpose applications, such as active power filters, machine drives for sinusoidal and trapezoidal current applications can be realized by multi-stage inverter. By incorporating pulse-width modulation (PWM) control, within the inverters we can control the gain of inverters more effectively. One of the most forthright methods of describing voltage source modulation for multilevel inverter is carrier based PWM schemes that can be conceived by the intersection of a modulating signal with triangular carrier waveforms. In this paper, we are designing a Solar Multilevel Pulse Width Modulator inverter using microcontroller and cascade H bridge topology which increases the efficiency and reliability of the system. We are also assimilating Maximum Power Point Tracking for higher efficiency. The solar panel will track the sun from dusk to dawn to get maximum power of sunlight to the solar panel.**

Keywords-Multilevel inverter; pulse-width modulation; H-brige; Stepper Motor; ATmega328 microcontroller; Pic 16f877a microcontroller

I. Introduction

The problem of greenhouse effect is due to the extensive use of the fossil fuels. Cost of fossil fuel energy is rising and increase in air pollution paves a way to the study of solar energy. In this scenario, this paper emphasis on Solar Smart Inverter (SSI) which is a blending of solar tracking, charging and multilevel inverter.

In the next years the power inverter will change more than has in the past few years. The recent technology concentrates on the improvement of smart inverters. Energy economics and utility system integration are the main technical challenges addressed by the smart inverters. Energy economics highlights improving inverter reliability, increase energy harvest and improve solar power forecasting.

Multilevel Inverter topologies include the diode clamped, the flying-capacitor and the cascade H-bridge types [9][13][14][15]. Here we are using cascade H-bridge topology where switching control is done with the help of pulse width modulation (PWM)[12][11]. Along with multilevel inverter, solar tracking and charging constitute "Solar Smart Inverter" (SSI).

II. Proposed Topology

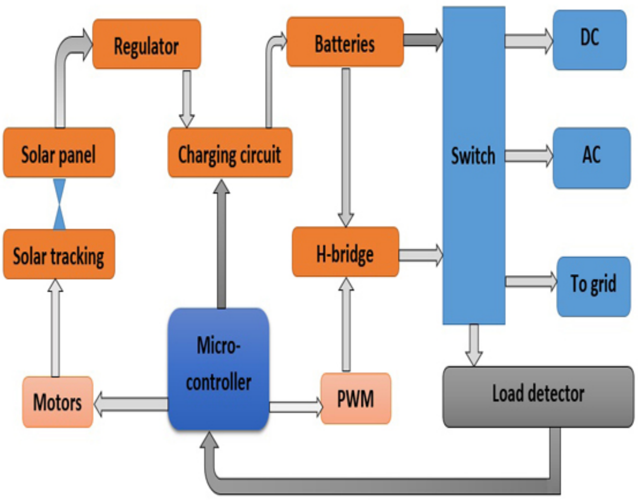

Figure 1. Proposed Solar Smart Inverter

Solar Smart Inverter can be divided into two sections. First section is solar tracking and secondly Multilevel Inverter. Solar tracking can be divided into solar panel movement and solar charging. Switching section and control section are major divisions of Multilevel Inverter.

In solar panel movement, the solar panel will track the sun from dusk to dawn. After that it return to initial position and automatically shut down the system in order to reduce the power consumption. Solar tracking will starts at forthcoming dusk with the help of delay provided by the microcontroller.

In solar charging, there may arise problem called common ground problem as we are using multiple level for switching. So we need a novel design to eliminate the common ground problem. In order to avoid this problem we are integrating relay with different switching time.

In switching section we are using cascaded H-bridge for switching the multiple levels of voltage. Here we are using cascaded five H-bridge circuit to get 11 levels of alternating current(AC) voltage.

In Control section we have to control the switching of cascaded H-bridge. There are so many switching scheme available nowadays. In this thesis we are mainly concentrated on Pulse width modulation scheme.

III. System Design

The work flow of Solar Smart Inverter begins with the design of solar tracker followed battery charging and obtain alternating current from multilevel inverter. Furthermore DC power is extracted separately from batteries.

A. Solar Tracking

As irradiance and temperature changes the output power obtained from photo-voltaic (PV) panel varies. In order to trap the maximum energy solar tracking is implemented using stepper motor. A stepper motor is an electromechanical device that divides a full rotation into a number of equal step without any feedback. We can move and hold the motor position using microcontroller using desired control signal. The microcontroller used for this application is Atmega328p. We can divide a motor's fundamental step angle into micro steps by precisely controlling the current in each phase. The tracking is done by programmed time -delayed movement of the panel from dusk to dawn.

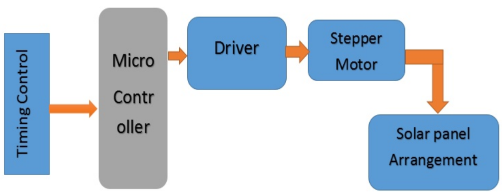

Figure 2. Solar Tracking Block diagram

B. Solar Charging

We cannot charge all batteries at a time because of common ground problem. Common ground problem arises when multilevel charging is employed. Multilevel charging needs separate ground for each battery. So we opt relay switching for charging the batteries by eliminating common ground problem.

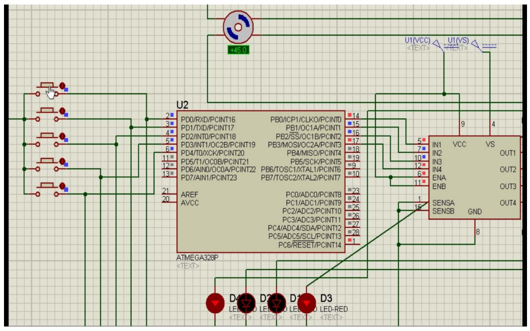

Figure 3. Solar Tracking- Simulation

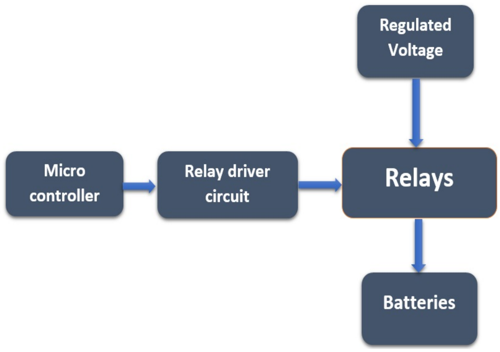

Figure 4. Solar Charging- Block diagram

C. Multilevel Inverter

Five H-bridge circuit to get eleven levels of AC voltage by PWM switching scheme powered by five separate DC source together constitute multilevel inverter.

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 6[10]. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+Vdc$, 0, and $-Vdc$ by connecting the dc source to the ac output by different combinations of the four switches, $S1$, $S2$, $S3$, and $S4$. To obtain $+Vdc$, switches S1 and S4 are turned on, whereas -Vdc can be obtained by turning on switches $S2$ and $S3$.By turning on $S1$ and $S2$ or $S3$ and $S4$, the output voltage is 0.

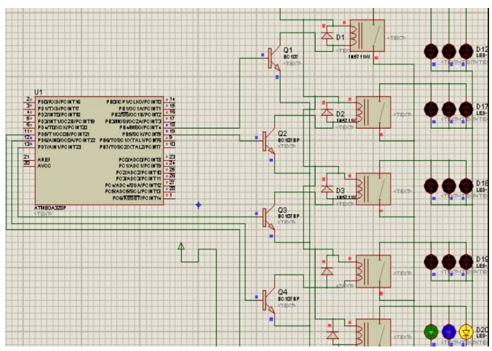

Figure 5. Solar Charging- Simulation

The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs[10]. The number of output phase voltage levels m in a cascade inverter is defined by $m = 2s + 1$, where s is the number of separate dc sources.An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 7. The phase voltage $van = va1+va2+va3+va4+va5$. For a stepped waveform such as the one depicted in Figure 7 with 5 steps, the Fourier Transform for this waveform follows:

$$V(wt) = 4V\Pi dc \sum n[cos(n\theta 1)+cos(n\theta 2)+...+cos(n\theta s)]sin(nwt) \quad (1)$$

where n = 1, 3, 5, 7

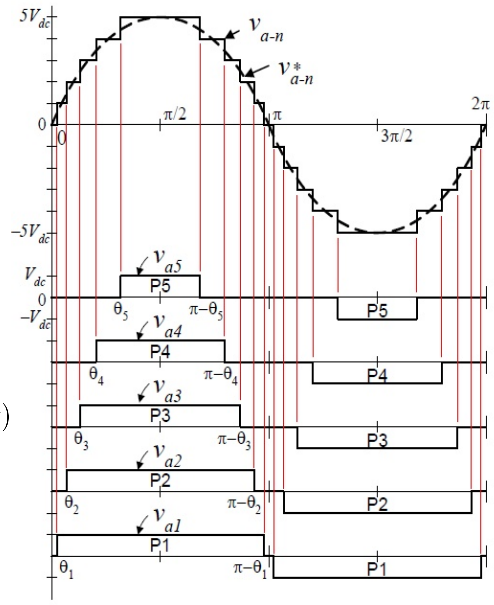

Figure 7. Output Phase Voltage Waveform.

Binary Input	Designed Angle for Stepper Motor	Obtained Angle For Stepper Motor
1001	45^0	45^0
1000	90^0	90^0
1010	135^0	135^0
0010	180^0	180^0

Figure 8. Table 1

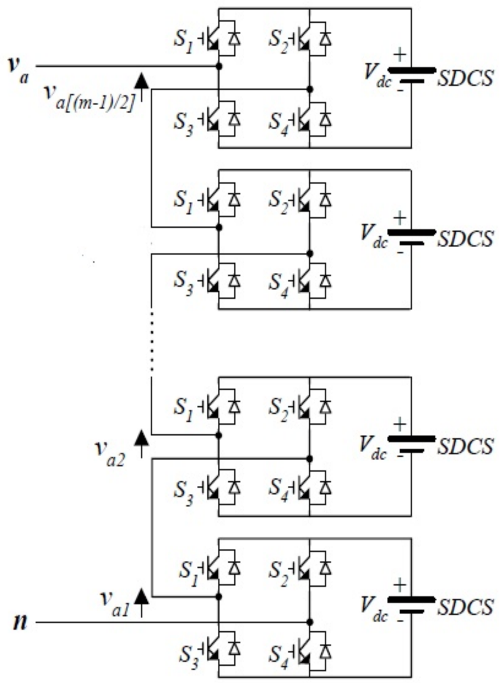

Figure 6. Cascaded Multicell Converter.

The PWM signal generated from inbuilt PWM port of PIC16f877a. Out of the five H-bridge circuit the first H-bridge is self-restrained by PWM scheme. Other H-bridge are controlled by normal control signals.

IV. Experimental Result

To verify the performance of the solar smart inverter system a prototype based on PIC and Atmega microcontroller is developed and tested. The main angles of panel rotation are listed in Table 1. For simplicity we used step angle as 90^0. Step angle is the property of stepper motor and usually it is 1.8^0.

Figure 9 shows the basic prototype test platform for solar smart inverter. A 250 watt single phase 11 level solar smart inverter is developed by using PIC and atmega microcontrollers. The photograph of the integrated system is shown in the figure 10. The output from the solar smart inverter is analyzed and shown in figure. The eleven level output obtained can be approximated to a sine wave without much distortion is shown in figure 11.

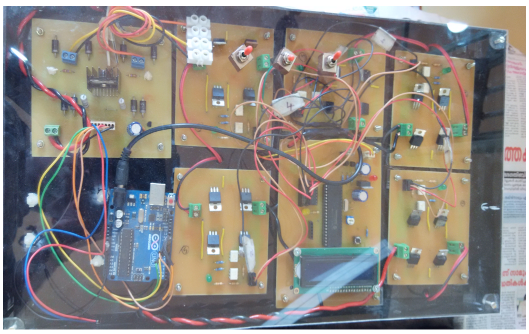

Figure 9. Prototype test platform

Figure 10. Integrated solar smart inverter system

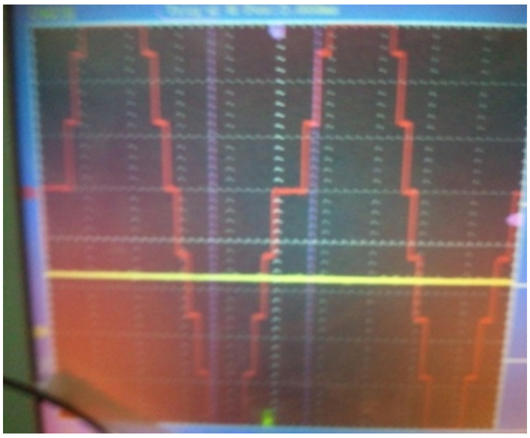

Figure 11. Output obtained

V. Conclusion

In this paper, a new solar smart inverter system is proposed for small scale application which is the latest achievement in the power electronics wing. Solar cell movement system developed will move the panel from 180 degree east to west and returned to initial position after sunset. Also solar charging is implemented by eliminating common ground problem. The main objective of this paper is to produce sinusoidal wave form with minimum distortion from separate DC source by using multilevel inverter is validated. However the focus on multilevel inverter here is not meant to downplay the importance of solar tracking and charging system. Solar Smart Inverter has a great significant to energy savings and utility system integration. The obtained simulation and hardware results met the desired output to great extent.The load detection is incorporated with the help of current transformer inorder to detect load variation. The current transformer detect load variation and feed back to microcontroller. Microcontroller is programmed in such a manner that if unendurable load variation occurs then the system will automatically shutdown.

From the findings we can enhance system by interfacing to power grid and with the assistance of weather forecasting we can minimize problem caused by the adverse effect of weather disasters. Furthermore efficiency of switching scheme can be improved by implementing space vector pulse width modulation.

References

[1] Ammar Masaoud, Hew Wooi Ping,Saad Mekhilef, Member, IEEE,New Three-Phase Multilevel Inverter With Reduced Number of Power Electronic Components,IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 29, NO. 11, August 2014

[2] Meghdad Fazeli,Janaka B. Ekanayake,PaulM.Holland,Petar Igic, Member, IEEE,Exploiting PV Inverters to Support Local VoltageA Small-Signal Model,IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 29, NO. 2, June 2014

[3] Marcelo A. Perez,Steffen Bernet,Jose Rodriguez,Samir Kouro,Ricardo Lizana, Member, IEEE,Circuit Topologies, Modelling, Control Schemes and Applications of Modular Multilevel Converters,IEEE Transactions on Power Electronics,June 2014

[4] Md. Rabiul Islam, Youguang Guo,Jianguo Zhu, Senior Member, IEEE,A Multilevel Medium-Voltage Inverter for Step-Up-Transformer-Less Grid Connection of Photovoltaic Power Plants,IEEE Journal Of Photovoltaics, VOL. 4, NO. 3, May 2014

[5] Nasrudin Abd. Rahim,Mohamad Fathi Mohamad Elias,Wooi Ping Hew, Member,IEEE,Transistor−Clamped H−Bridge Based Cascaded Multilevel Inverter With New Method of Capacitor Voltage Balancing,IEEE Transactions On Industrial Electronics, VOL. 60, NO. 8, August 2013

[6] Jia-Min Shen,Hurng-Liahng Jou,Jinn-Chang Wu, Member, IEEE,Five-Level Inverter for Renewable Power Generation System,IEEE Transactions On Energy Conversion, VOL. 28, NO. 2, June 2013

[7] R.Sakthivel, M.Murugesan, R.Senthilkumar,Selective Harmonics Elimination Pwm Based Multilevel Inverter With Reduced Number Of Switches, Quest International Multidisciplinary Research Journal,Volume II , Issue I June 2013

[8] Mohammad Farhadi Kangarlu, Ebrahim Babaei, Department of Electrical Engineering Tsinghua University Beijing, 100084,China,A Generalized Cascaded Multilevel Inverter Using Series Connection of Submultilevel Inverters,IEEE Transactions On Power Electronics, VOL. 28, NO. 2, February 2012

[9] Samir Kouro, Mariusz Malinowski, , K. Gopakumar,Josep Pou, Leopoldo Jose Rodriguez, Senior Members, IEEE,Recent Advances and Industrial Applications of Multilevel Converters,IEEE Transactions On Industrial Electronics, Vol. 57, No. 8, August 2010.

[10] Surin Khomfoi, Leon M,The University of Tennessee.Chapter 31 Multilevel Power Converter

[11] B.Urmila, D.Subbarayudu,Multilevel Inverters: A Comparative Study of Pulse Width Modulation Techniques,International Journal of Scientific Engineering Research, Volume 1, Issue 3, December 2010 ISSN $2229-5518$

[12] V. Naga Bhaskar Reddy,Ch.Sai Babu,S.Nagaraja Rao,Comparison of Modulation Techniques for Multilevel Inverter fed Permanent Magnet Synchronous Motor,International Journal of Engineering Science and Technology Vol. 2(10), 2010, 5206-5214

[13] G Panagiotis Panagis, Fotis Stergiopoulos, Pantelis Marabeas and Stefanos ManiasUniversity of Newcastle Upon Tyne, Department of Electrical, Electronic and Computer Engineering, Newcastle, United Kingdom ,Comparison of State of the Art Multilevel Inverters,$978-1-4244-1668-4/08/25.00$2008 IEEE

[14] Jose Rodriguez, Jih-Sheng Lai,and Fang Zheng Peng, Senior Member, IEEE,Multilevel Inverters: A Survey of Topologies, Controls, and Applications,IEEE Transactions On Industrial Electronics, Vol. 49, No. 4, August 2002

[15] Jih-Sheng Lai, Senior Member, IEEE, and Fang Zheng Peng, Member, IEEE,Multilevel Converters-A New Breed of Power Converters,IEEE Transactions On Industry Applications, Vol. 32, No. 3, May$-$june 1996