Power Quality Improvement In Photovoltaic Systems

J.Devi Shree[1] and P.Anbalagan[2]

Abstract – In this paper, a maximum power point tracker and an optimum design of a pulse-width modulation (PWM) inverter for a grid connected photovoltaic energy conversion system is proposed. The MPPT provides the improved tracking operation under different conditions such as changing insolation and temperature. First, the implemented hardware of the system is described. Next, the principle of the MPPT control and selection of input and output variables and tuning of the membership functions are discussed. Then the multi-carrier pulse-width modulation (PWM) approach is introduced as a convenient way to implement a high-frequency link inverter. The approach is a direct extension of conventional PWM, and supports square- wave cyclo conversion methods that have appeared in prior literature. Finally, the performance of the system is described. Simulation results of the experiments for inspecting the working of the system are presented.

Keywords - Phase detector (PD), phase locked loop (PLL), current source inverter (CSI), electro magnetic pollution, zero crossing detection.

I. Introduction

In recent years, the efforts to spread the use of renewable energy resources instead of pollutant fossil fuels and other forms have increased. As a result of advances in the production of photovoltaic modules and equipments like inverters and charge controllers, the use of photovoltaic on houses in urbanized areas has become more practical. A grid-connected inverter is a system, which is capable of converting the solar energy to AC electricity and supplying this electricity to the utility grid, to which the building is connected. Many methods have been proposed for maximum power point tracking (MPPT). So far, algorithms to achieve MPPT techniques are based on perturb and observe techniques [1] or incremental conductance methods and techniques employing intelligent control such as those using fuzzy logic, neural networks etc. [2-4]. In this study logic controller used for MPP tracking of a grid connected photovoltaic conversion system. The method employed is believed to give a closer tracking of available energy from the sun. High-frequency (HF) ac link inverter topologies. It is possible to obtain the basic advantages directly in a PWM inverter, but only if the transformer can handle the low modulating frequency [5]. HF link topologies have not been common for medium power (1 to 20 kW), largely because of the number of power stages and control complexity. The complexity draw back has been overcome with a multiple-carrier PWM technique, which is introduced in this paper. We extend the control concept introduced in [6-7] and demonstrate that multiple-carrier PWM methods can lead to HF link inverters that are about as simple as the conventional PW M inverters. Here we also add elements to support natural commutation, thus reproducing results in [8] directly from familiar PWM processes.

II. Multi-Carries PWM Sequence Generation Description

A block diagram for the generation process is shown in Fig. 1. A base carrier (triangle or ramp) is phase-shifted, then divided into independent time segments by means of a decommutator [12] operating in synchronism with the carrier clock. A decommutator is more common in time-division multiplexing (TDM) communication systems, but its function here is the same segment the base carrier into time slices that can be used as the basis for the multiple-carrier approach.

III. HF Link Inverter Circuit Configuration and Switching Timing

Fig.2 shows a three-phase cycloconverter-type HF link inverter, which consists of an open-loop inverter to generate a 50% square wave, the HF link transformer, the output converter stack, and passive filtering for the output. The primary-side inverter bridge uses unipolar devices (MOSFETs or IGBTs with inverse diodes), while the three-phase output bridge consists of twelve unidirectional switches organized in six pairs. With natural commutation, only the leading edge of the gate pulses is needed, and the only feedback is the sign of the output currents [5]. The single-phase version of Fig.2 is interesting because control can be applied either at the input bridge or the output bridge. The gate sequence, multiplied by the square wave, recovers a conventional PWM output. Natural commutation in the HF link circuit is not affected significantly by dead time. When a short dead time is provided for the primary-side inverter, the output voltage cannot be quite as high, but the general operation is unchanged [11].

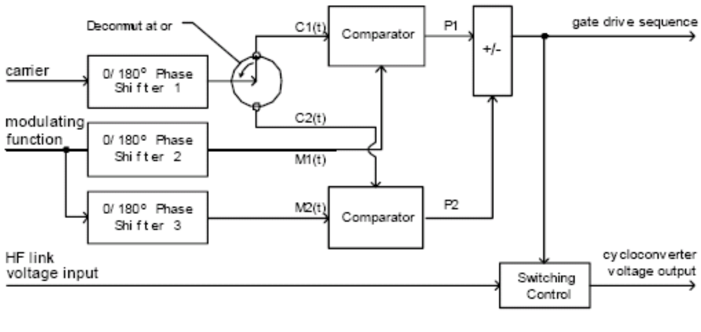

Fig.1: The general two-carrier PWM sequence generation process

Digital ref: A070101133
[1]Faculty EEE Department, Coimbatore Institute of Technology, Coimbatore
[2]Head of the Department, EEE, Coimbatore Institute of Technology, Coimbatore.
[1]e-mail id – devi_567@yahoo.com
The paper first received 31 March 2006 and in revised form 31 March 2007.

IV. Discussion and Experimental Work

Fig.3 shows a test circuit for a naturally-commutated square wave cycloconverter (similar to the power circuit in [10]), that uses the two-carrier process in Fig. 1 for control. Since the devices are SCRs, only the leading edge of the PWM pulse is needed. The decommutator is not necessary because only pulse transformers are needed to transmit the signal leading edge. Therefore, both comparators in Fig. 1 can be used directly with the original ramp. Two multivibrators use the rising edge to produce a 15 µs gate pulse train. The upper multivibrator creates a phase-delayed gate pulse train to be used when current is positive, while the lower multivibrator creates a phase-advanced gate pulse train. Simple logic is used with a current comparator to separate the positive and negative current conditions. Notice that in contrast with [9], the gate pulses have been generated directly with conventional sine-ramp PWM comparisons, with the ramp doing double-duty for both carriers.

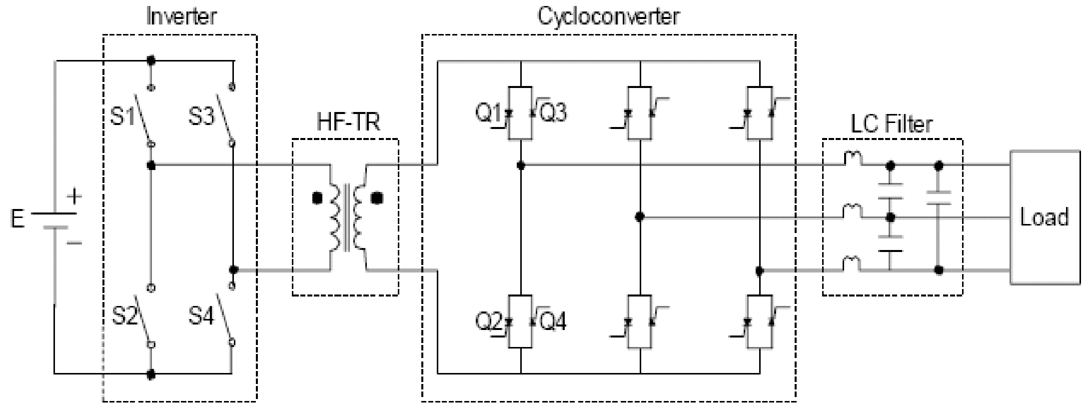

Fig. 2: Main circuit configuration of the cycloconverter type HF link inverter

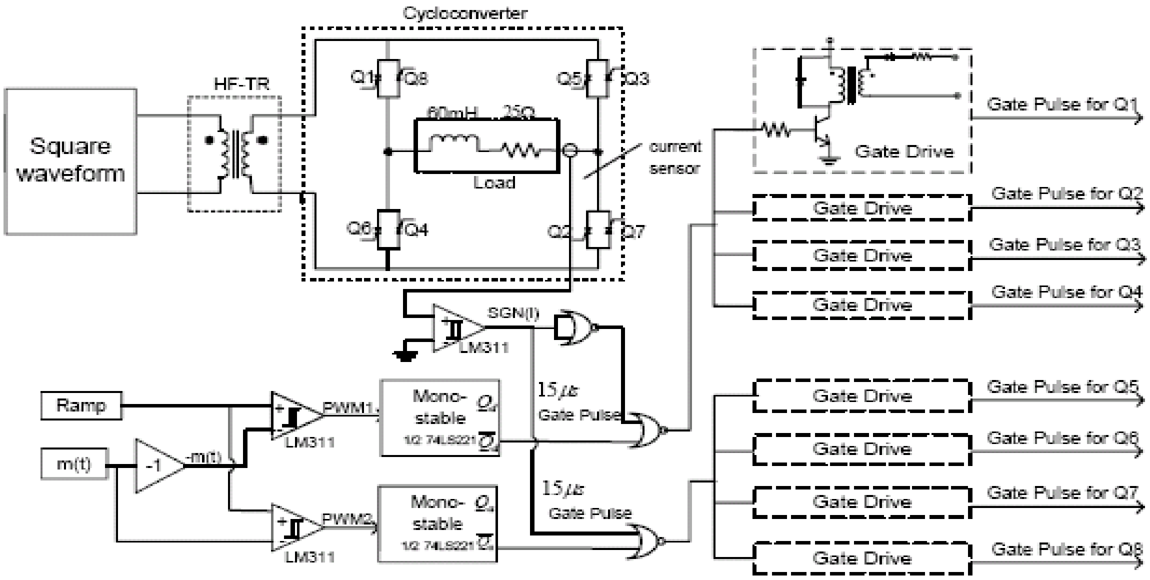

Fig. 3: Experimental circuit configuration

Fig. 4 shows experimental waveforms generated with the circuit of Fig. 3. The top trace is the ramp, at 2 kHz. The second trace is a 50Hz sinusoidal modulating function set for 70% modulation depth. Since only the leading edge is concerned, there is no need to add or subtract to produce a 50% duty ratio pulse train. We can consider signal P1(t) as phase lagging with respect to a 1 kHz square wave synchronized with the ramp, while P2(t) can be treated as phase leading. Fig. 5 shows waveforms from converter operation. The 2 kHz ramp is shown again at the top, along with a synchronized 1 kHz square wave from the H F link. The bottom two traces are the output voltage, which demonstrate the conventional two-level PWM behavior, and a signal proportional to the output current. Since the load is 60mH in series with 25 ohms, the filter allows a significant component to pass through in order to make the switch action and PWM behavior clear. Notice that this converter is using a 1 kHz link, and that the SCRs are switching at 1 kHz each. The combined behavior of devices in a pair gives rise to 2 kHz effective switching at the output. This property of the process can be used to extend the effective operating range of any given switching device [13].

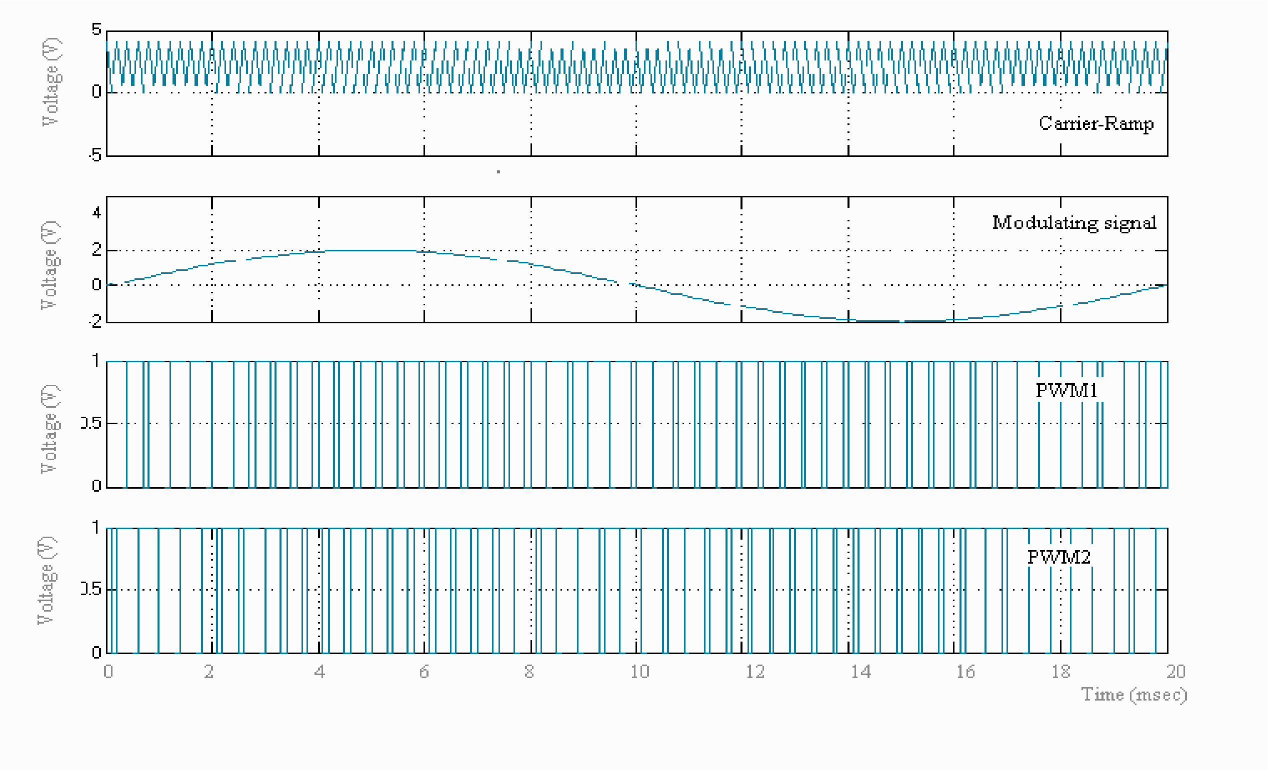

Fig: 4. PWM generation process

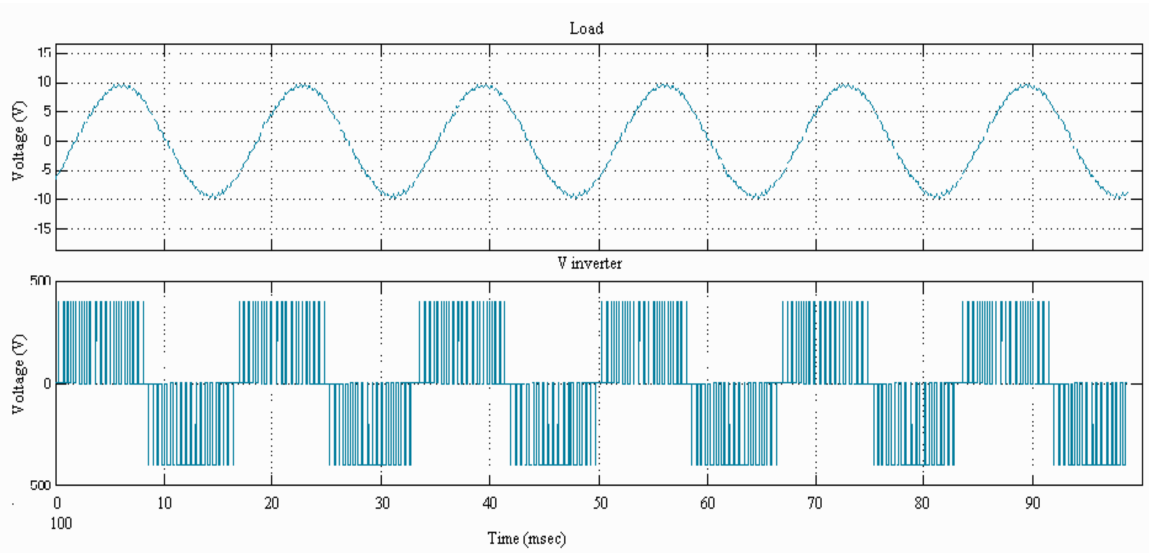

Fig: 5. Output voltage and current

In this paper, it has been shown how to generate such a switch sequence based on conventional PWM techniques. Just as important, the switch sequence can be configured to provide certain desirable properties, such as 50% duty ratio, effective frequency doubling, or natural commutation.

In our application [12], the use of two-carrier PWM leads to a more streamlined inverter topology. Total system losses can be reduced com pared to a forward-converter/PWM inverter cascade, both because one conversion stage has been eliminated and because of the frequency doubling effect possible with two-carrier PWM.

V. MPPT Tracking

A. PV Characteristics

Fig.6 shows the typical Power versus Voltage curve of the PV array [13]. In this figure, P is the power extracted from PV array and V is the voltage across the terminals of the PV array. The objective of the controller is to draw as much power as possible from the PV array. This point corresponds to the maximum power point (MPP) on the PV curve [14]. The change of PV curve and the new maximum power point is seen on the curve. It may be seen from Fig.6, that the PV curve changes when insolation changes e.g. if insolation increases the maximum power available from the PV array increases.

The PV curve is also dependent on the temperature of PV array as shown in Fig.7. It is seen that as the temperature increases, the maximum power available from the PV array decreases. ΔP and ΔV are change in power and change in voltage respectively and calculated using P and V values as shown in Fig. 8 in successive steps. The slope of the tangent lines to the curve is different at different points. By inspecting Fig.5, it may be seen that the slope is negative and large when power extracted from the PV array is small. It is zero at maximum power point. ΔP is required to ensure movement towards the peak i.e. MPP.

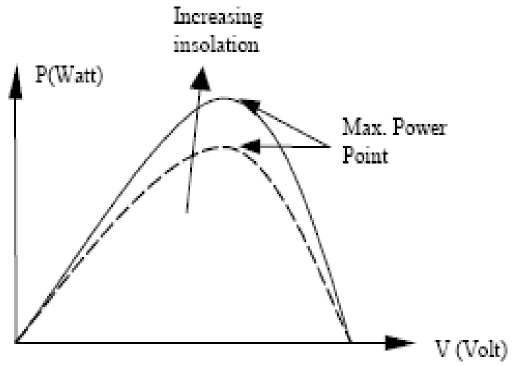

Fig: 6. Change of PV curve with increasing insolation

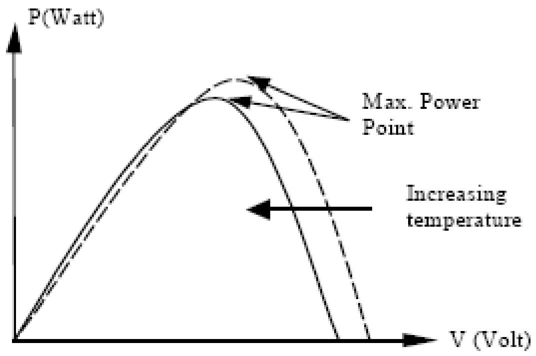

Fig: 7. Change of PV curve with increasing temperature

The technique is based on observing the calculated slope and ΔP and perturbing the system appropriately. The basic principle of the fuzzy controller can be explained with the following algorithm

1. Calculate slope (ΔP/ΔV) and ΔP.
2. If slope is negative, increase reference current so that more power is drawn from PV array.
3. Else if the slope is positive, system is operating at the left hand side of the MPP so decrease the reference current to return to MPP point.
4. Return to 1 in the next control step.

If some extreme cases are handled separately, much better performance can be obtained from the controller. Thus the conditions are checked to identify whether any extreme cases are present. If they do not exist then the controller is allowed

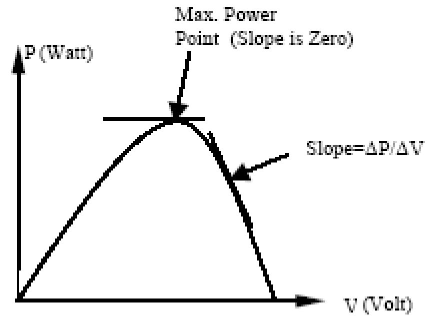

Fig: 8. The slope at different points on the PV curve.

B. Priority Rules

Rule 1:
Starting algorithm:
IF PV array voltage is not very small AND system is shutdown
THEN Start applying reference current.

Rule 2.
IF "PV Array Voltage" is very small AND "PV current" is not very small
THEN Decrease "reference current" a little.

Rule 3
IF "PV Array Voltage" is very small AND "PV current" is very small
THEN Set "Current Reference" to zero.

Rule 4
IF Change in "PV Array Voltage" is very small
THEN
Decrease "reference current" a little.

If the change in PV array voltage is very small then division by zero exception occurs in the calculation of the slope and slope is calculated as very large which is shown in Fig.9. This condition may arise when change in PV curve occurs. For instance, assume the previous command was to increase reference current to extract more power. As a result, the PV array voltage is expected to decrease due to the fact that the power drawn from PV increases. On the other hand, if insolation increases as well, the PV curve moves also upwards increasing available power. Then the slope will be calculated incorrectly. In this condition, the fuzzy controller output will not be valid and it must be by-passed.

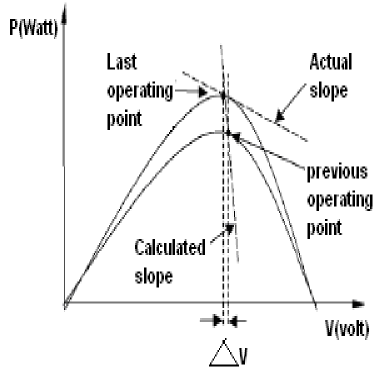

Fig: 9. Occurrence of very small change in PV array voltage due to increase in insolation

In order to calculate slope correctly in the next control step, operating point is moved towards right simply by decreasing the reference current by 0.1A.

VI. CONCLUSION

In this paper a logic based MPP Tracker for a grid connected PV system is presented. The controller performance is optimized for better performance under changing PV conditions such as insolation and temperature. In order to increase the robustness of the system under exceptional conditions, and to maximize energy efficiency, the controller supported with a set of "if-then" like priority rules. Multi-carrier PWM serves as a direct way to construct HF inverter control waveforms. The results of multi-carrier PWM provide gating singles suitable for square-wave cycloconverters, for isolated gate drives, and for other implementation aspects of HF link inverters. The output results match those of conventional two-level PWM, except that the effective switching frequency doubles. Multi-carrier PWM techniques have special promise in the implementation of low-cost inverters. They support reduction in the number of stages, reduction in switching frequency, enhancements to gate drive design. When multi-carrier PWM is used, cycloconverter-type HF link inverters can be realized without additional complexity when com pared to conventional cascaded inverters.

REFERENCES

[1] K.H. Hussein, I. Muta, T. Hohino and M. Osakada, "Maximum Photovoltaic Power Tracking: An Algorithm for Rapidly Changing Atmospheric Conditions", Proceedings IEE Generation, Transmission and distribution, Vol. 148, No. 1, Jan 1995, pp. 59-64.

[2] Leon M. Tolbert and Fang Z. Peng, "Multilevel Converter as a Utility Interface for Renewable Energy System", in proceedings of IEEE Power Energy Society Summer Meeting, Vol. 2, 16-20 July 2000, pp. 1271-1279.

[3] P.M. Espelage and B.K. Bose, "High-Frequency Link Power Conversion", IEEE Trans. Indus. Appl., Vol. IA-1, No. 5, 1977, pp. 387-394.

[4] J.Y. Liu, Y.H. Song, P.A. Metha, "Strategies for Handling UPFC Constraints in Steady State Power Flow and Voltage Control", IEEE Transactions on Power Systems, Vol. 15, May 2000, pp. 566-571.

[5] C.J. Hatziadoniu, V.K. Feiste, "Power Conditioner for a Grid-Connected Photovoltaic Generator Based on the 3-Level Inverter", IEEE Transactions on Energy Conversion, Vol. 14, No. 4, 1999, pp. 1605-1610.

[6] J. Rodriguez, J.S. Lai and F.Z. Peng, "Multilevel Inverters: A Survey of Topologies Controls and Applications", IEEE Transactions on Industry electronics, Vol. 49, August 2002, pp. 724-738.

[7] M. Matsui and T. Fukao, "Study on d-q Equivalent Circuit Topologies of HF Base Converters with Circulating Current", in Proc. IPEC-Tokyo, Vol. 1, 1990, pp. 212-219.

[8] I. Yamato, N. Tokunaga, Y. Matsuda, Y. Suzuki, H. Amaro, "High Frequency Link DC/AC Converter for UPS with a New Voltage Clamper", in Rec. IEEE Power Electronics Spec. Conf., 1990, pp. 749-756.

[9] T. Kawabata, K. Honjo, N. Sashida, K. Sanada, M. Koyama, "High Frequency Link DC/AC Converter with PWM Cycloconverter", in Proc. IEEE Industry Appl. Annual Meeting, Vol. 2, 1990, pp. 1119-1124.

[10] M. Matsui, M. Nagai, M. Mochizuki, A. Nabae, "High Frequency Link DC/AC Converter with Suppressed Voltage Clamp Circuits Naturally Commutated Phase Angle Control with Self Turn-off Devices", IEEE Indus. Appl., Vol. 32, No. 2, March-April 1996, pp. 293-300.

[11] K. Inagaki and S. Okuma, "High Frequency Link DC/AC Converters Using Three Phase Output PWM Cycloconverters for Uninterruptible Power Supplies", 1991, pp. 580-586.

[12] S. Haykin, Communication Systems, 4th Edition, New York Wiley, 2001, pp. 211.

[13] J. Kassakian, M. Schlecht, G. Verghese, Principles of Power Electronics, Addison-Wesley, 1991, pp. 186-187.

[14] M. Zhang, J. Wu and H. Zhao, "The Application of Slide Technology in PV Maximum Power Point Tracking System", in Fifth World Congress on Intelligent Control And Automation, 2004, pp. 5591-5594.

BIOGRAPHIES

J.Devi Shree, received B.E Degree in Electrical and Electronics Engineering from Coimbatore Institute of Technology the year 1996 and M.E (Applied Electronics) from Bharathiar University in 1997. Currently she is pursuing Ph.D research work in the area of Non Conventional Energy under the guidance of Dr.P.Anbalagan. She is a lecturer of EEE department in Coimbatore Institute of Technology. She is having a 10 years in teaching experience. She has published six technical papers in national /international conferences. She is a member of IEEE. Her special fields of interest are Power electronics and Power Systems.

Dr.P.Anbalagan received B.E. Degree in Electrical and Electronics Engineering from Government College of Technology in the year 1973 and M.Sc(Engg.) from Madras University in 1977. He obtained Ph.D from Bharathiar University in the area of Digital Protection of Power Systems in the year 1994. He is having a teaching experience of 30 years. He is currently Professor and Head of EEE department in Coimbatore Institute of Technology. He has published 85 technical papers in national /international conferences and journals . He is a fellow member IE(India) and senior member of IEEE. His special fields of interest are Digital protection of power systems and Embedded Systems.