ISSN 2321-807X
Volume 12 Number16
Journal of Advances in chemistry

THD ANALYSIS IN THREE PHASE-THREE LEVEL VSI WITH MPPT TRACKER AND SEPIC CONVERTER FOR SOLAR PV ARRAY

S.K.Saranya,T.Gowtham Raj,P.Ranjani
M.Kumarasamy College of Engineering, Karur, Tamilnadu
Saranyask.eee@mkce.ac.in
M.Kumarasamy College of Engineering, Karur, Tamilnadu
gowthamrajt.eee@mkce.ac.in
M.Kumarasamy College of Engineering, Karur, Tamilnadu
Ranjanip.eee@mkce.ac.in

ABSTRACT

This paper deals with the analysis of total harmonic distortion in three phase three level voltage source inverter (VSI) for the solar photovoltaic array. The Voltage source inverter as used in high power applications here we are using for the Renewable Energy as Application. The result for the Voltage Source Inverter will be quasi square wave or square wave. The Harmonics will be high if we are using the low level inverter. The 120^0 or 180^0 are the two modes of operation for voltage source inverter and its choose based upon its application. The MPPT technique is used to get the maximum power from the Solar PV. The SEPIC converter is DC-DC converter in which it can operates either buck or boost modes and it eliminates the ripples by using the filter. In order to improve the efficiency the SEPIC and Perturb and Observe Technique is used. The focus of the paper is to analyze and reduce the Total Harmonic Distortion with the MPPT Technique and DC-DC converter and its connected to the Grid. The simulation results for the paper and the THD values are calculated for voltage source inverter (VSI) are given below [13], [14].

Indexing terms/Keywords

Maximum Power Point Tracking (MPPT), Perturb and Observe Algorithm (P & O), Single Ended Primary Inductance Converter (SEPIC), Voltage Source Inverter (VSI), Total Harmonic Distortion (THD).

I.INTRODUCTION

Since the use of energy has turn into an integral part of our life, its supply should be secure and sustainable [1],[2]. At the same time, it should be inexpensive, environmentally friendly and socially acceptable. The current trends in energy consumption are either neither secure nor sustainable. The raising consumption of fossil fuels and associated prices, together with increase in green house gas emission, threatens our secure energy supply[1]. Therefore, development of clean, make safe, sustainable and affordable energy sources should be our priority in this century.

Renewable energy (RE) or Non-Conventional energy sources(NCES) enables you to reduce the carbon dioxide (CO_2) that goes into the atmosphere because of the energy we use like fossil fuel, which is known as our carbon footprint. Consuming renewable sources like solar energy and wind energy, we also reduce our necessity on fossil fuel gas and oil reserves**,** which are becoming expensive and hard to find [5]. It also reduces our dependence on imported fossil fuels, improving our energy security. Tracing the maximum power point (MPP) of a photovoltaic (PV) array is a vital part of a PV system. As such, many MPP trackers (MPPT) have been developed and implemented. The methods vary in complexity, sensors required, cost, convergence speed, popularity, range of effectiveness, hardware implementation and in other respects. They range from the almost evident (but not necessarily ineffective) to the most resourceful (not necessarily most effective). Many methods have been established that it has become difficult to amply determine which method, newly proposed or existing, is most suitable for a given PV system. The number of papers per year on solar PV cell with maximum power point tracker has grown significantly of the last decades and remains strong.

II. MAXIMUM POWER POINT TRACKING

When a solar PV module is used in a system, its operating point is decided by the load to which it is connected. Since, the solar radiation falling on a PV module varies throughout the day, the operating point of module also changes throughout the day. In order to ensure the operation of PV modules for maximum power transfer, a special method called maximum power point tracking(MPPT) is employed in PV systems[1],[3]. The electronic circuitry is used in MPPT to transfer maximum power.

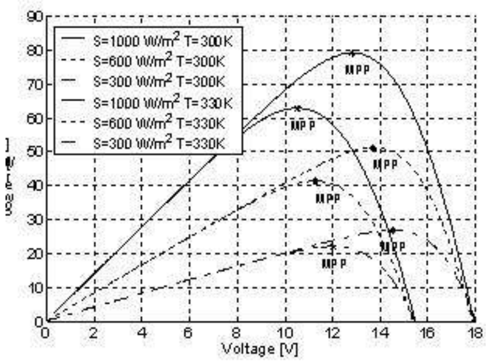

Fig. 1 PV Array Characteristics

The function of a MPPT is similar to the movement of a car. When the movement is in the wrong gear, the wheels do not receive maximum power. This is because, the engine is running either slower or faster than its approximate speed range. The purpose of movement is to couple the wheels to the engine, in a way that let the engine run in an appropriate speed, despite varying acceleration. Let's relate a PV module to a car engine. Its voltage is similar to engine speed. Its epitome voltage is that at which it can put out maximum power. This is called its maximum power point. It is also called as peak power voltage (V_{PP})[3]. V_{PP} varies with intensity of sunlight and with temperature of the solar PV cell.

III. PERTURB AND OBSERVE ALGORITHM

The most popular algorithm is hill climbing (HL) or perturb and observe algorithm[6]. The P&O algorithm involves a perturbation in the duty ratio of the power converter at regular intervals and by recording the resulting array current and voltage values, thereby gaining the power. Once the power is known, a check for the slope of the the PV curve or the operating region is carried out and the change in D is affected in the direction so that the operating point approaches MPP on power voltage characteristics.

In the voltage source region,

$\frac{\partial p}{\partial v} > 0$ which implies D= D+ΔD (i.e increment D) In the current source region,

$\frac{\partial p}{\partial v} < 0$ which implies D= D-ΔD (i.e decrement D) At MPP, $\frac{\partial p}{\partial v} = 0$ which implies D= D or ΔD=0 (i.e retain D).

In case of a PV array linked to a power converter, perturbing the duty ratio of power converter perturbs the PV array current and accordingly perturbs the PV array voltage[6]. From Fig. 2, it can be seen that decrementing (incrementing) the voltage decreases (increases) the power when operating on the left of the MPP and increases (decreases) the power when on the right of the MPP. Consequently, if there is an increase in power, the succeeding perturbation should be kept the same to attain the MPP and if there is a decrease in power, the succeeding perturbation should be reversed [6],[10]. This algorithm is summarized in Table 1. The process is repeated periodically until the MPP is reached.

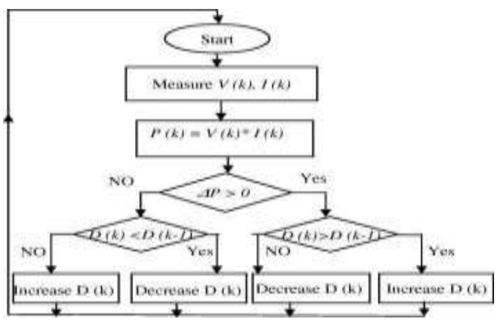

Fig. 2 Flowchart For P&O Algorithm

The system then oscillates about the MPP voltage. The oscillation can be minimized by decreasing the perturbation step size. Though, a smaller perturbation size slows down the process of MPPT, by using modified P&O algorithm will reduce the drift size compared to the normal P&O algorithm because it will sense the power , voltage, current on every duty cycle.

Table 1.Working Of P&O Algorithm

Perturbation	Change in Power	Next Perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

IV. SEPIC DC /DC CONVERTER

The DC-DC converters are used for converting one level of DC voltage or unregulated voltage to another level of dc voltage or regulated voltage. This transformation is realized with the help of network consisting of storage elements like inductor and capacitor and power devices like transistors and diodes. These converters play a vital role in the PV systems where they are used as charge controllers, MPPT and for blundering the PV source with different types of loads[6],[10]. The DC-DC converters are also used for noise isolation, power bus regulation and current boosting. The single-ended primary inductor converter (SEPIC) is a type of DC to DC converter or chopper allowing the electric potential at its output to be less than, greater than, or equal to the input. The output of the SEPIC is controlled by the duty cycle of the control transistor. A SEPIC is fundamentally a boost converter tailed by a buck-boost converter, therefore it is analogous to a traditional buck-boost converter, but it has the advantages of having non-inverted output, with a series capacitor to combine energy from the input to the output and being capable of true blackout. when the switch is turned off, its output dives to 0 V, following a reasonably awkward transient dump of charge. The SEPIC converter can be operated either in continuous conduction mode (CCM) [10]. Here, the SEPIC converter is operated in continuous conduction mode.

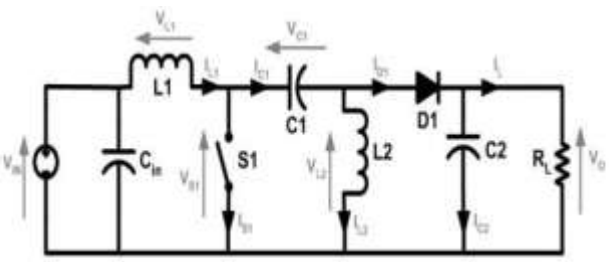

Fig.3 Circuit Diagram For SEPIC Converter

As with other switched mode power supplies (SMPS), the SEPIC exchanges the power supplies between the inductor and capacitor from one voltage to another. The energy exchanges is controlled by switch S1, which is typically a transistor such as a MOSFET. MOSFETs offer lower voltage drop and much higher input impedance than bipolar junction transistors (BJT), and do not require biasing resistors as MOSFET switching is controlled by changes in voltage rather than a current, as with BJT. A very useful application of this converters come from the fact that the variation in duty cycle can be used not only to regulate the output voltage but also to vary the input side impedance of the converter. The DC-DC converter can be controlled to present an optimum impedance across the PV array terminals which facilitates the maximum power extraction from the array. In the case of buck-boost type ,the reflected impedance at input side can be less than or higher than the load impedance. This feature can be appreciated by inspecting the input impedance (R_{in}) expression for this converter topology,

$$R_{in}=R_{L}*\frac{(1-d)\,(1-d)}{d} \qquad (1)$$

Relationship Between Input And Output Voltage

After obtaining the values of voltage across inductors in ON and OFF modes, relationship between the source and load voltages can obtained in similar as for the boost and buck-boost converters. This yields,

$$\frac{Vout}{Vin}=-\frac{d}{1-d} \qquad (2)$$

Since d is the duty cycle and it can be varied between 0 and 1 ,depending on the output of the solar PV cell. One possible drawback of this converter is that the switch cannot have terminal at ground, this complicates the driving circuitry.

V. THREE PHASE THREE LEVEL VOLAGE SOURCE INVERTER

Solar PV array generates current electricity from solar installation. However, there are several loads which will work with AC electricity. Also the grid connected applications requires that the DC is converted AC before the power the power can be fed into the grid. A DC-AC converter is also called as Inverter converts a DC quantity into an AC quantity. In the voltage source inverter by controlling the frequency of duty cycle, we can control the frequency of the output voltages and the output voltage could be fixed or variable frequency. The inverter gain is defined as the ratio of the ac output voltage to the dc input voltage.

The output voltages from an ideal inverter will be sinusoidal. However, the waveforms of practical inverter are non-sinusoidal and contain harmonics. For low and medium-power applications, square or quasi-square wave voltages may be acceptable and for high power applications low distorted sinusoidal wave forms are required[12].

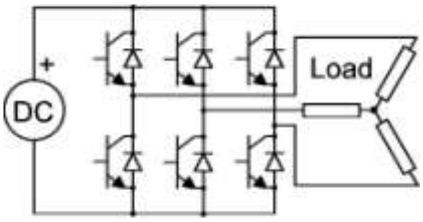

Fig.4 Three Phase-Three Level Voltage Source Inverter

With the availability of high speed power semiconductor devices, the harmonic in output voltage can be minimized or reduced significantly by switching techniques[7],[8],[9]. However Normally, for our domestic and industrial AC appliances as well as for feeding the PV power to the grid, it is desirable to get an AC voltage of 50HZ. The gating signal of three phase inverters can be either 120^0 or 180^0 mode[12],[7].

The line to neutral voltages of three phase inverter can be expressed in Fourier series as

$$\sum_{n=1,3,5...}^{\infty} \frac{2Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt + \left(\frac{\pi}{6}\right)\right) \qquad (3)$$

$$Vbn = \sum_{n=1,3,5...}^{\infty} \frac{2Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt - \left(\frac{\pi}{2}\right)\right) \qquad (4)$$

$$Vcn = \sum_{n=1,3,5...}^{\infty} \frac{2Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt - \left(\frac{7\pi}{6}\right)\right) \qquad (5)$$

The line a to b voltage is $V_{ab} = \sqrt{3} V_{an}$ phase advance of 30^0. Therefore the instantaneous line to line voltae will be

$$V_{ab} = \sum_{n=1,3,5...}^{\infty} \frac{2\sqrt{3}Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt + \left(\frac{\pi}{3}\right)\right) \qquad (6)$$

$$V_{bc} = \sum_{n=1,3,5...}^{\infty} \frac{2\sqrt{3}Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(wt - \left(\frac{\pi}{3}\right)\right) \qquad (7)$$

$$V_{ca} = \sum_{n=1,3,5...}^{\infty} \frac{2\sqrt{3}Vin}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n(wt - \pi) \qquad (8)$$

VI. TOTAL HARMONIC DISTORTION

The output of AC voltage is of square shape but not sinusoidal shape. The squared AC waveform can be considered as a distorted version of the perfect sinusoidal waveform. In principle, a square waveform can be represented by the sum of several sinusoidal waveforms of different frequency and amplitude [12].The distortion in the waveform is represented in the form of Total Hamonic Distortion (THD).

The THD is defined as the ratio of sum of the power of total harmonic components to the power of the fundamental component. In terms of voltages, the THD is defined as the ratio of square root of the sum of the squares (RMS voltages) of all harmonic component to the fundamental component as given in eqn.

$$THD = C^2_2 + C^2_3 + C^2_4 + C^2_5 / C^2_1$$

$c_1, c_2, ..., c_n$ are the RMS values of different harmonic component of the waveform.

Cn= $\sqrt{(a_n^2 + b_n^2)}$ (9)

The THD represents the losses in the inverter when used in the circuit. Therefore it's value should be as low as possible.

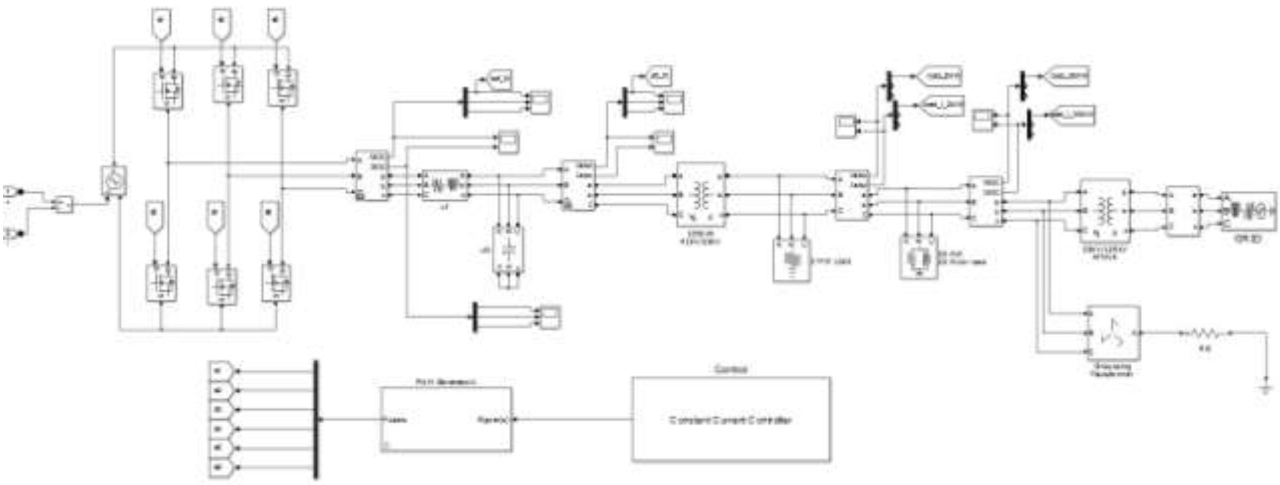

Fig. 5 Grid Connected Inverter

VII. MEASUREMENTS

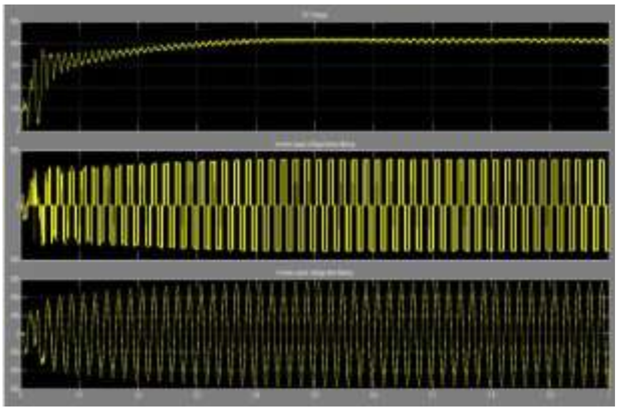

Fig.6 Output Of SEPIC Converter, VSI

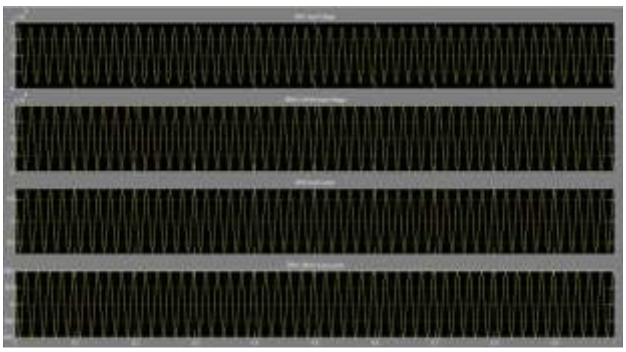

Fig 7 Output Of VSI After Filtering With Load

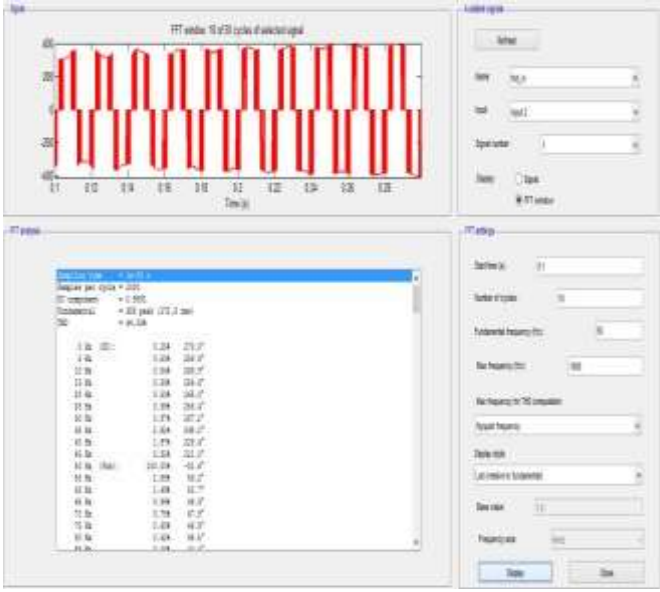

Fig.8 Output Of Inverter Before Filter

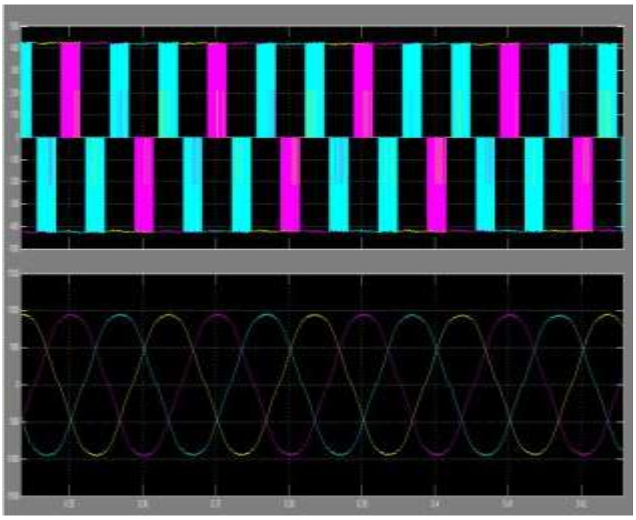

Fig.9 Total Harmonic Distortion From Inverter

VIII. CONCLUSION

By using MPPT tracker, the output of solar PV cell is 650 watts. With the help of SEPIC converter and PI controller the voltage is regulated to 415V and given as input to the VSI. As the output of VSI is three level, the THD of inverter is very high. This THD can be reduced by using Multi-level inverter (MLI) or by calculating the optimal switching angles for the MOSFET switch.

IX. REFERENCE

1. K. Irisawa, T. Saito, I. Takano, and Y. Sawada,“Maximum power point tracking control of photovoltaic generation system under non-uniform insolation by means of monitoring cells,” in *Proc. 28th IEEE Photovoltaic Specialists Conf.*, Sep. 2000, pp. 1707–1710

2. K. H. Hussein, I. Muta, T. Hshino, and M. Osakada,“Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions,” *Proc. Inst. Elect. Eng.*, vol. 142, no. 1, pp. 59–64, Jan. 1995.

3.O. Wasynczuk, “Dynamic behavior of a class of photovoltaic power systems,” *IEEE Trans. Power App. Syst.*, vol. 102, no. 9, pp. 3031–3037,Sep. 1983.

4.M. A. Slonim and L. M. Rahovich, “Maximum power point regulator for 4 kWsolar cell array connected through inverter to the AC grid,” in *Proc. 31st Intersociety Energy Conver. Eng. Conf.*, 1996, pp. 1669–1672.

5.D. P. Hohm and M. E. Ropp, "Comparative study of maximum power point tracking algorithms," in *Proc. 28th IEEE Photovoltaic Specialists Conf.*, Sep. 2000, pp. 1699–1702.

6.X. Yuan, W. Merk, H. Stemmler, and J. Allmeling, "Stationary-frame generalized integrators for current control of active power filters with zero steady-state error for current harmonics of concern under unbalanced and distorted operating conditions," *IEEE Trans. Ind. Appl.*, vol. 38, no. 2, pp. 523–532, Mar./Apr. 2002.

7.M. Liserre, F. Blaabjerg, and S. Hansen, "Design and control of an LCL-filter based active rectifier," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1281–1291, Sep./Oct. 2005.

8.M. Liserre, R. Teodorescu, and F. Blaabjerg, "Multiple harmonics control for three-phase grid converter systems with the use of PI-RES current controller in a rotating frame," *IEEE Trans. Power Electron.*, vol. 21, no. 3, pp. 836–841, May 2006

9.T. Tafticht and K. Agbossou, "Development of a MPPT method for photovoltaic systems," in *Canadian Conf. Elect. Comput. Eng.*, 2004, pp. 1123– 1126.

10. T. Tafticht and K. Agbossou, "Development of a MPPT method for photovoltaic systems," in *Canadian Conf. Elect. Comput. Eng.*, 2004, pp. 1123– 1126.

11. N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," *IEEE Trans.Power Electron.*, vol. 20, no. 4, pp. 963–973, Jul. 2005.

12. S. Fukuda and T. Yoda, "A novel current-tracking method for active filters based on a sinusoidal internal model," *IEEE Trans. Ind. Appl.*, vol. 37, no. 3, pp. 888– 895, May/Jun. 2001.

13. S.K.Saranya and Dr.R.Karthikeyan "Security for Smart distribution grid by using wireless communication", ICGICT'14 pp.791-1040 , July 2014.

14. Dr.R.Udhaya Shankar,Dr.Rani Thottungal, T.Gowtham Raj, "comparative analysis of cuk and luo converter fed bldc motor" International journl of applied engineering research,vol.10,no.88,pp.68-72.

Ms S.K.Saranya received her B.E Degree in Electrical and Electronics Engineering from Mookambigai College of Engineering, Trichy, India in 2012 and M.E Degree in Power System Engineering from M.Kumarasamy College of Engineering, Karur, India in 2014. She is currently working as Assistant Professor in M.Kumarasamy College of Engineeriing, Karur. Her main research are DC-DC converters,protection system and digital circuits.

Mr.T.Gowtham Raj has completed his B.E degree in Electrical and Electronics Engineering from RVS College of Engineering and Technology, Coimbatore India in 2014 and Post Graduate career in Power Electronics and Drives from Kumaraguru College of Technology, Coimbatore, India in 2016.He is currently working as Assistant Professor in M.Kumarasamy College of Engineeing, Karur. His main area of interests are Solar Energy conversion,DC-DC converters and DC machines.

Ms.P.Ranjani obtained her B.E Degree in Electrical and Electronics Engineeriing from Kalasilingam University,Thirunelveli, India in 2011 and M.E Degree in VLSI Design from M.Kumarasamy College of Engineering,Karur, India in 2015. She has five years of experience in Teaching field and she is currently working as Assistant Professor in M.Kumarasamy College of Engineering.Karur. Her main area of Interest are Digital Electronics and circuit design.