Control of Single Stage Grid Tied Photovoltaic Inverter Using Incremental Conductance Method

K. Rajasekhara Reddy[1], V. Nagabhaskar Reddy[2], M. Vijaya Kumar[3]
[1,3]Department of EEE, JNTUA, Ananthapuramu, A.P, India
[2]Department of EEE, RGMCET, Nandyal, A.P, India

Article Info	ABSTRACT
	In this investigation, a study on grid-connected Photovoltaic (PV) system with single stage power conversion (SSPC) is proposed. Double Stage Power Conversion (DSPC) topology contains two power conversion stages namely DC-DC conversion and DC-AC conversion, but the SSPC system converts DC power to high-quality AC power supply for grid connected PV system. The SSPC system has several advantages over DSPC, such as better use of the PV arrays, higher efficiency, low cost and compact size. Present work proposes a Sinusoidal Pulse Width Modulation (SPWM) along with incremental conductance Maximum Power Point Tracking (IC-MPPT) for inverter switching. The PV voltage and Grid Voltages verifies under normal and change of atmospheric conditions using MATLAB / SIMULINK.

Corresponding Author:

K. Rajasekhara Reddy,
Research Scholar, Department of EEE,
JNTUA,
Ananthapuramu, A.P.
E-mail: raju.gprec@gmail.com

1. INTRODUCTION

Nowadays power demand is increasing due to the development of the industrial sector in every country and also a rise in the population [1]. The fossil fuels have not met the demand due to the shortage, and these generate more harmful to the environment. Therefore, most of the researchers are concentrating on other resources like renewable energy sources and are having low emission, abundantly available and eco-friendly [2]. The most promising renewable energy is solar power, is converted into direct electricity using photovoltaic (PV) cell. The number of cells is connected and forms an array to produce wanted output voltage and current [3]. In the PV module, the maximum power point (MPP) is very crucial, is not constant a day because of changing environmental condition. If the MPP is not close to the operating point, there exist substantial power losses. Therefore, it's necessary to track the maximum power by selecting appropriate MPP by using maximum power point tracking system (MPPT) is presented in [4],[5].

Power Electronics converters play a vital role to process the power from a PV system to load/grid. There exist two ways of power processing, firstly two-stage conversion and secondly single stage conversion. Two-stage conversion with primarily DC-DC buck/boost conversion along with MPPT to trace the maximum power by varying the duty cycle next to an inverter to convert DC power into the required form of AC power through the DC link capacitor used to reduce the oscillations of present in DC link voltage [6]-[8].

While a two-stage conversion system suffers from significant drawbacks such as high power losses, more component count, high cost and less reliability [9]. Therefore, a researcher is turning to concentrate on reduced more power processing conversion system. A single-stage conversion [10],[11] has an advantage of more reliable with less count of components, less cost and more efficient due to incorporated of MPPT and Inverter circuit in between PV system and grid.

2.   SINGLE STAGE CONVERSION SYSTEM

PV cells describe the operation of a simple p-n junction, converts solar irradiation into electricity. A grid-connected PV system converts the sunlight directly into AC electricity through two ways of conversion processes, and the first way is a double-stage conversion with boost and Inverter converter to boost up the generated array voltage and an inverter which converters DC to AC according to grid parameters. The second way is single stage conversion process which directly converts DC to AC and feeds to grid at nearly unity power factor. Figure 1 shows a single stage grid-connected PV system with MPPT controller proposed.

In this single stage conversion scenario, the DC output voltage which is generated from PV system and processes to perform DC-AC power conversion simultaneously, the power converter are nonlinear systems, with a maximum power tracking system to tackle the nonlinearities and control strategies to inject a sinusoidal current into the grid. Single stage power conversion system is more reliable due to less number of components, operates at higher efficiency and with less cost. In this single stage conversion system, Incremental conductance MPPT method proposed.
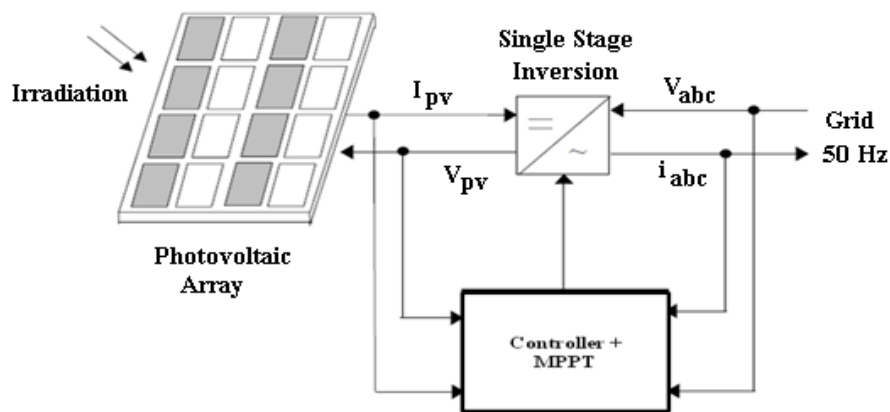

Figure 1. Single-stage grid-connected PV Generation

2.1. Incremental Conductance Tracking Method

Solar PV became commercialized due to its merits of free maintenance and friendly with the environment. To identify the MPP for tracking maximum power from the PV array, a maximum power point tracking (MPPT) used in conjunction with the power processing converters.

To tackle the nonlinear characteristics of the PV system is a significant challenge for the utilization. The i-v and p-v characteristics are nonlinear curves of PV modules and to pick a unique point in the maximum power point (PMPP), to identify this point where the optimal voltage V_{mpp} and current I_{mpp} are considered in PV system to operate at maximum efficiency at which it yields the maximum output power.

PV modules produce maximum power by operating the electronic system MPPT, it moves the modules about a point directly at the sun, but it is not a mechanical system. Maximum power point has to vary with radiation and temperature, and it is not lying on a fixed point. MPPT algorithm fundamentally division with three categories namely model-based algorithms, training based algorithms and search algorithms [12].

Based on P-V characteristics, the Incremental Conductance (IC) is designed to eliminate the drawbacks of the P&O method to get the maximum power under fast varying atmospheric conditions. The IC method works out based on the character that, the derivative of the power in the presence of the voltage at maximum power (MP) point is zero. Also, the derivative at the right of the MP point is less than zero and the left of the MP point is greater than zero. IC tries to improve the tracking time and to produce more energy on a vast irradiation changes and also which calculate that the MPPT reached the MP point and stopped the perturbing the operating point (OP). If this condition is not satisfied then, MP point to be calculated by the relations $\frac{\partial I_{pv}}{\partial V_{pv}} and - I/V$.

Figure 2 shows the algorithm of IC MPPT controller for single stage Inverter, which works with similar input data as in Perturb &Observe method. The PV module voltage and current to be calculated, later it measures the differences from the previous measurements and calculates the power, at the same time deviation between voltage and currents are calculated at every step. The output of the incremental algorithm is the duty cycle, which is incremented or decremented and is used to produce the MP in PV array, and this

continues until the MP point reached. Here I used to propose a single stage conversion system, in which the role of the duty cycle is to produce pulses for Inverter.
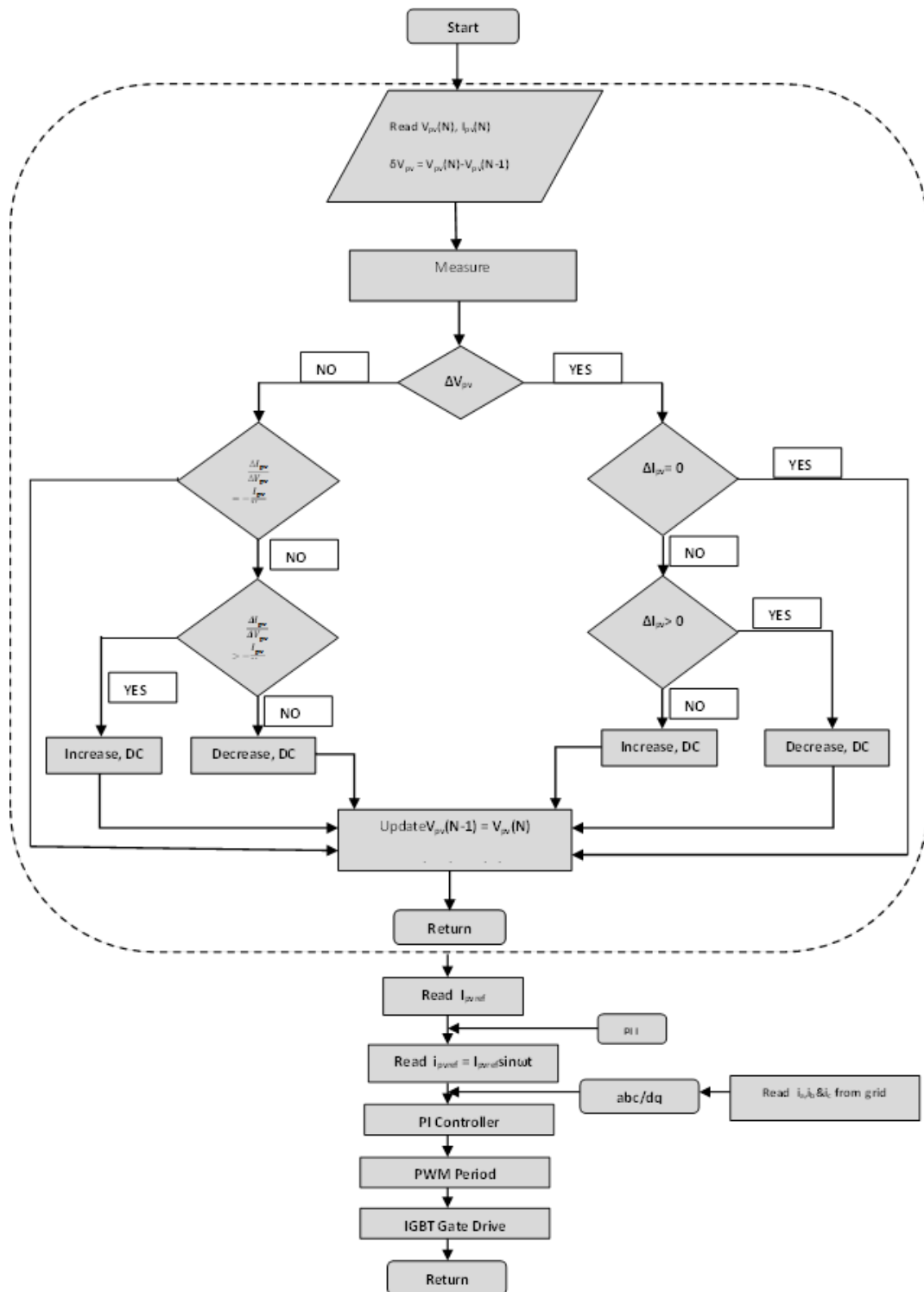

Figure 2. Flow Chart of the MPPT controller for single stage Inverter

Now the algorithm can be established in the following way

$$\frac{\partial P_{pv}}{\partial V_{pv}} > 0, \rightarrow G > \Delta G, then V_p < V_{mpp} \tag{1}$$

$$\frac{\partial P_{pv}}{\partial V_{pv}} = 0, \rightarrow G = \Delta G, then V_p = V_{mpp} \tag{2}$$

$$\frac{\partial P_{pv}}{\partial V_{pv}} < 0, \rightarrow G < \Delta G, then V_p > V_{mpp} \tag{3}$$

3. RESULTS AND ANALYSIS

To calculate the performance of the grid-connected single stage conversion PV system has 20 strings, each string is characterized with a current of 5.16 A and simulated by using MATLAB/SIMULINK. Here it is considered that a string is subdivided into 20 modules are connected in series by a rated voltage of 43.5V. The total output voltage of the PV array is 870V and current of 103A, and total power output is 90kW. The evaluation of PV system and MPPT controller performance is continuing for considering different operating conditions.

3.1. PV System Observations

I-V and P-V characteristics are observed at different operating conditions like changing irradiation, temperature, series resistance and shunt resistance.

Figure 3 shows that the I-V and P-V characteristics of varying irradiations. The dissimilar irradiations are applied such as 1000 W/m2, 800 W/m2, 500 W/m2, and 200 W/m2 for testing of PV module, I-V & P-V characteristics are shifted down due to the distinctive of irradiation. The current and voltage become 103 A, 90 kW respectively at the standard test condition (STC) of irradiation (i.e., 1000 W/m2).
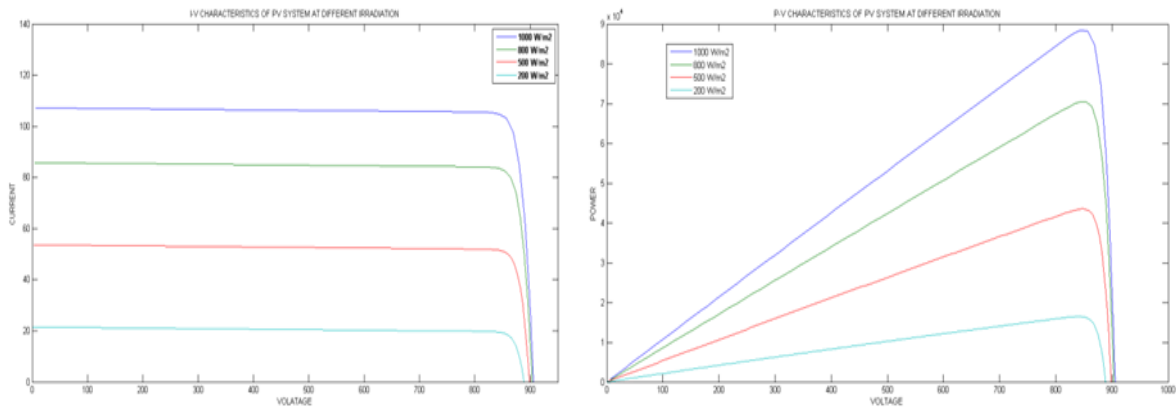

Figure 3. I-V & P-V Characteristics of PV system under the various values of Irradiation

Current increases and voltage decreases with the increase of temperature as shown in I-V curve of Figure 4. The maximum power is attaining with below STC, and it is reduced with increase STC as shown in the PV curve of Figure 4. The current and voltage become 103 A, 90 kW respectively at the standard test condition of temperature (i.e., 25^0C).
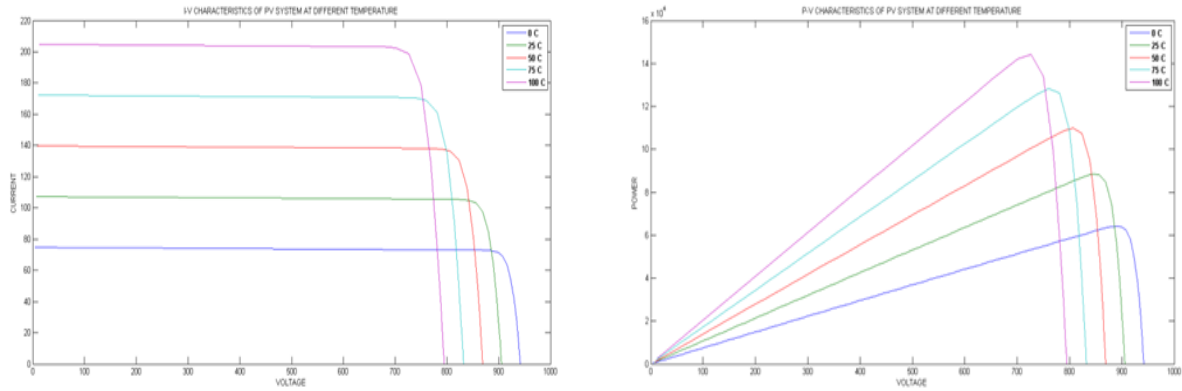
Figure 4. I-V & P-V Characteristics of PV system with the change of Temperature

I-V and P-V characteristics are affected due to the variation of series resistance as shown in Figure 5. From Figure 5, it is observing that the better performance obtained with a low value of series resistance.
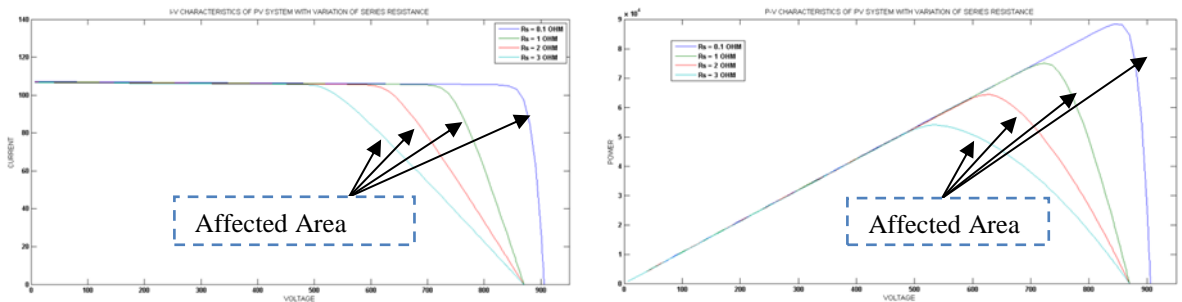

Figure 5. I-V & P-V Characteristics of PV system under the various values of series resistance

In PV system, ideally series resistance is zero and shunt resistance should be infinite, but in practically shunt resistance is not so. For testing of cell performance, shunt resistance as chosen as 1Ω, 10Ω, 50Ω and 500Ω, apart from all these resistances 500Ω gave the best performance and selected for complete operation of the solar cell, due to the variations of shunt resistance the output voltage is affected as shown in figure6. For PV conversion process is very sensitive to the small variation of series resistance but insensitive in shunt resistance.
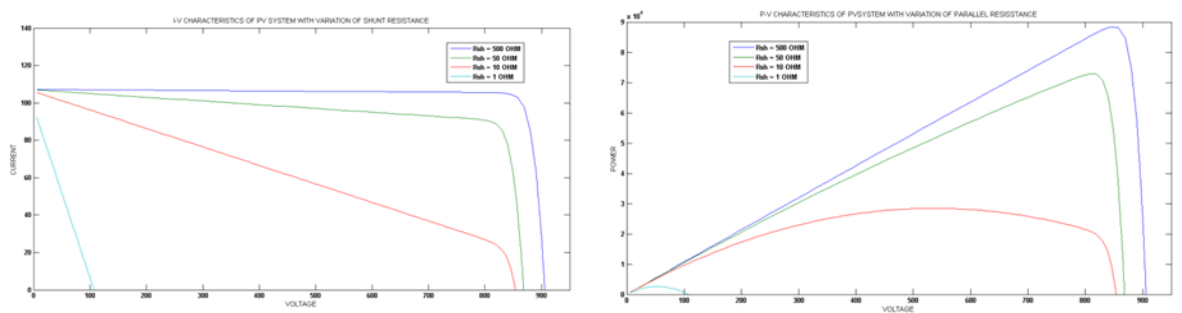

Figure 6. I-V & P-V Characteristics of PV system under the various values of the shunt resistance

3.2. MPPT Controller Performance Observations

The performance of the proposed MPPT controller is tested at the grid for the following case study:
1) Standard Atmospheric Conditions (SAC) and; 2) Changing Atmospheric Conditions (CAC). Figure 1 is
used for development of single stage grid-connected PV system with proposed MPPT controller in digital
simulation.

Case 1: The standard values of ecological aspects of 1 kWm^{-2}solar irradiation and 298 K of
atmospheric temperature were considered in this study. Figure 7 show the controller ensures the three-phase
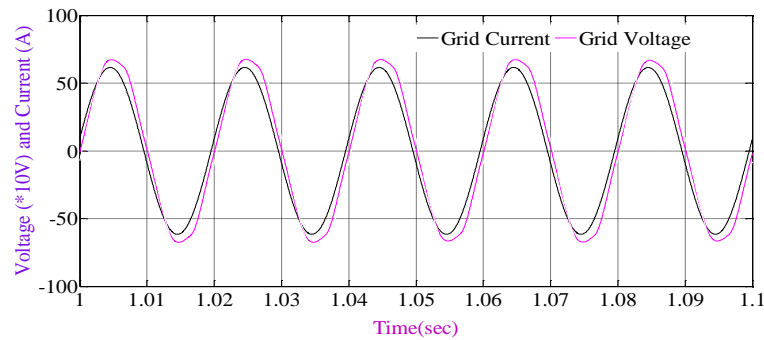single stage grid-connected PV system at unity power factor.

Figure 7. The performance plot of MPPT Controller

Case 2: Under various atmospheric conditions: It is observed from the Figure 8, the PV unit
operates under normal atmospheric conditions until Time of 1.1 sec. When time reaches to 1.1 sec, the
environmental conditions changes in such a way that the solar radiation of the PV unit reduces to 70% from
the normal value. Under these circumstances, there are no phase differences between grid voltages and
current, therefore the MPPT controller works well under varying atmospheric conditions as shown in
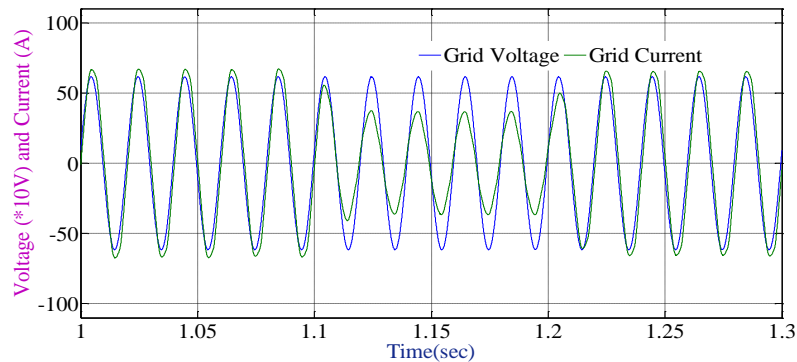Figure 8.

Figure 8. The performance of MPPT Controller

4.   CONCLUSION

A single stage conversion system with Incremental conductance MPPT controller has implemented
for three-phase grid-connected PV system under normal and varying atmospheric conditions are verified. In
my research single stage conversion system had low cost with less space as compared with double stage
conversion system and one more important fact which identified is the single stage conversion system with
MPPT which works with the steadiness of the system and also there are no phase differences between grid
voltage and current.

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BIOGRAPHIES OF AUTHORS

Mr. K.Rajasekhara Reddy was born in Nandyal, India. He received the B.Tech (Electrical and Electronics Engineering) degree from Sri Krishna Devaraya University, Ananthapuramu, A.P, India and M.Tech (Power Electronics) from Jawaharlal Nehru Technological University Hyderabad, India in 2005 and 2007 respectively. Presently, he is working as Assistant Professcor in Department of Electrical and Electroniocs Engineering in Santhiram Engineering college, Nandyal, A.P, India.Also he is working toward the Ph.D. degree in Electrical Engineering at Jawaharlal Nehru Technological University, Ananthapuramu, A.P, India. His field of interest includes, Multilevel Inverters, Renewable Energy Sources, and Power Electronics and Drives.

Dr. V. Naga Bhaskar Reddy was born in Kurnool, India. He received the B.Tech (Electrical and Electronic Engineering) degree from the Bangalore University, Bangalore in 2000, M.Tech (Power Electronics and Drives) from the Bharath Institute of Higher Education Research [BIHER], Chennai in 2005. He attained his Doctoral degree from Jawaharlal Nehru Technological University; Kakinada in 2012. He is currently a professor & HOD of the Dept. of Electrical and Electronic Engineering, R.G.M College of Engineering and Technology, Nandyal. His area of interest is Power Electronics, Microcontrollers, Power Electronic converters.

Dr.M.Vijaya Kumar graduated from S.V.University, Tirupathi, A.P. India in 1988, the M.Tech degree from Regional Engineering College, Warangal, A.P, India in 1990 and the Ph.D. degree from Jawaharlal Nehru Technological University, Hyderabad, A.P, India in 2000. He is currently working as professor in Electrical Engineerting Department and Director of admissions, JNTU College of Engineering, Ananthapuramu, A.P, India. He has published 93 research papers in national and international conferencesand journals. He received two research awards from the Institution of Engineers (India). He served as Director, AICTE, New Delhi for a short period. His research interest includes Electrical Machines, Electrical Drives, Microprocessors and Power Electronics.