IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 1 Ver. III (Jan. 2014), PP 21-28
www.iosrjournals.org

Control of Hybrid System Using Multi-Input Inverter and Maximum Power Point Tracking

[1]V. Kalai Rajan, [2]A. Raymon, [3]A. Sheik Sidthik, [4]A. Senthil Kumar
[123]Assistant Professor Department of EEE Renganayagi Varatharaj College of engineering Sivakasi, Tamilnadu-India.
[4]UG Scholar Department of EEE College of engineering Tamilnadu-India.

Abstract*: The objective of this project is to control the Wind/PV hybrid system using Multi-input inverter to get constant output power for different operating conditions. The MPPT also used in this system to get the maximum peak power to the load. The perturbation observation (P&O) method is used to accomplish the maximum power point tracking algorithm for input sources. The operational principle of the open loop and closed loop circuit of multi-input inverter is explained.*
Index Terms: *Inverter, photovoltaic (PV), wind energy.*

I. Introduction

The photovoltaic (PV) energy and wind energy applications have been increased significantly due to the rapid growth of power electronics techniques [1]–[3]. Generally, PV power and wind power are complementary since sunny days are usually calm and strong winds are often occurred at cloudy days or at night time. Hence, the hybrid PV/wind power system therefore has higher reliability to deliver continuous power than either individual source [4], [5].But the size and components are made the system to complex and high cost.

Usually, two separated inverters for the PV array and the wind turbine are used for the hybrid PV/wind power system [7]. But in this project the multi-input inverter is combining with renewable energy sources in the dc end instead of the ac end. It can simplify the hybrid PV/wind power system and reduce the costs. This system used to get maximum constant power from hybrid system.

The multi-input inverter has the following advantages: 1) power from the PV array or the wind turbine can be delivered to the utility grid individually or simultaneously, 2) maximum power point tracking (MPPT) feature can be realized for both solar and wind energy, and 3) a large range of input voltage variation caused by different insolation and wind speed is acceptable.

II. Multi-Input Inverter

The schematic diagram of the proposed multi-input inverter is shown in Fig. 1. It consists of a buck/buck-boost fused multi-input dc–dc converter and a full-bridge dc/ac inverter. The input dc voltage sources, V_{pv} and V_{wind} are obtained from the PV array and the rectified wind turbine output voltage. By applying the pulse-with-modulation (PWM) control scheme with appropriate MPPT algorithm to the power switches (M_1) and (M_2) , the multi-input dc–dc converter can draw maximum power from both the PV array and the wind turbine individually or simultaneously. The dc bus voltage, V_{DC}, will be regulated by the dc/ac inverter with sinusoidal PWM (SPWM) control to achieve the input output power-flow balance. Details of the operation principle for the proposed multi-input inverter are introduced as follows.

A. Hybrid system

In this project the wind/PV hybrid system is used to deliver continuous power to the load. The control of this hybrid system is obtained by Multi-input inverter and control circuits. MPPT algorithm (P&O method) also used to get maximum peak power to the load. The operations of PV only connected with multi-input inverter and Wind side only connected with multi-input inverter are used to get the power characteristics analysis of hybrid system.

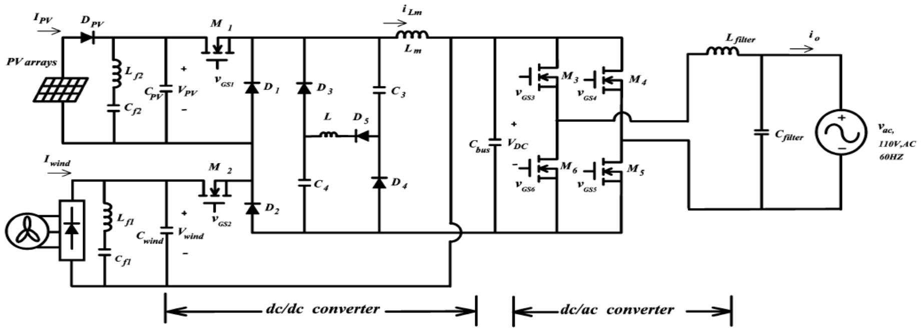


Fig 1 :Schematic diagram of Multi-input inverter.

A (1). PV Array

The PV array is constructed by many series or parallel connected solar cells [8]. Each solar cell is form by a – junction semiconductor, which can produce currents by the photovoltaic effect. Typical output power characteristic curves for the PV array under different insolation are shown in Fig. 2. It can be seen that a maximum power point exists on each output power characteristic curve. Therefore, to utilize the maximum output power from the PV array, an appropriate control algorithm must be adopted.

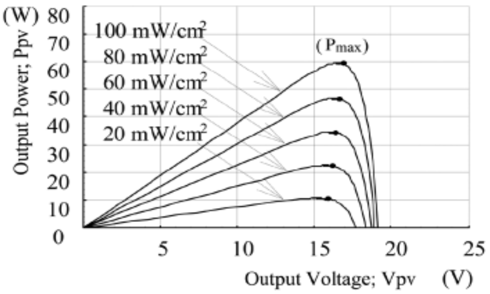


Fig. 2. Typical output power characteristic curves of the PV array.

Fig. 3 shows the measured waveforms of gate driving signals, (Vgs1) of (M1) and (Vgs2) of (M2) , and inductor current . Because switches M1and M2 have different duty ratios, the inductor current has two different charging slopes. The multi-input dc–dc converter can deliver power from both of the two energy sources to the dc bus simultaneously. The measured waveforms of voltage, current, and power for the PV array and the wind turbine are shown in Fig. 4.

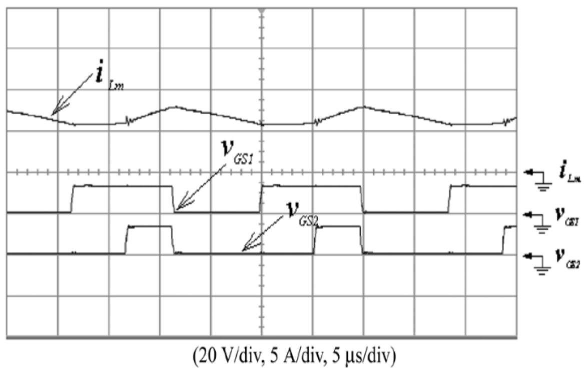
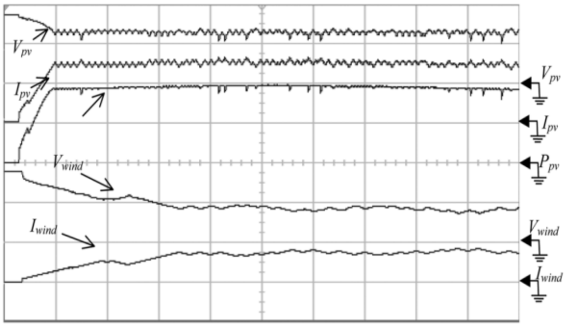


Fig 3: Gate signals Vgs1 & Vgs2 for M1 & M2 switches.

(2).Parameters of PV system

DC bus voltage (Vdc) = 230 V DC.
Switching Frequency (fs) = 50kHz , Switch (M1).
Power Factor = 0.99.
Total Hormonic distortion is less than 3%.

Only the PV array is connected to the proposed multi-input inverter. At the beginning, the controller will send out the PWM gate signal with MPPT feature to switch when the utility line voltage is detected. Once the dc bus voltage reaches its pre-set range, the dc/ac inverter will begin to inject ac output current into the utility line.



(V_{pv}: 250 V/div; I_{PV}: 2 A/div; P_{pv}: 500 W/div; V_{wind}: 120V/div.; I_{wind}: 5 A/div; 10 sec./div)

Fig 4. Measured waveforms of voltage, current, and power for the PV array and the wind turbine.

B(1). Wind Turbine

Among various types of wind turbines, the permanent magnet synchronous wind turbine, which has higher reliability and efficiency, is preferred [13]–[16]. The power (Pwind) of the wind can be derived as

$$P_{\text{wind}} = \frac{1}{2}\rho A V_{\text{wind}}^3 \quad \ldots (1)$$

Where p is the air density (kg/m), A is the area (m) swept by wind blades, and Vwind is the wind speed (m/s). It had been proven that the energy conversion efficiency, Cp, of the wind turbine is a function of the tip speed ratio is defined as,

$$\lambda_{\text{tip}} = \frac{wr}{V_{\text{wind}}} \quad \ldots (2)$$

where w is the rotational speed (rad/sec) of wind turbine blades, r is the radius of the area swept by wind turbine blades.

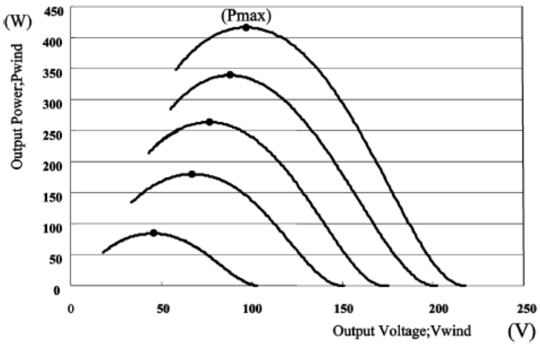


Fig5: Output power characteristic curves of the wind turbine for different wind speed.

When the output power of the wind turbine is small, the dc motor will request small power from the dc source to drive the wind turbine. When the output current of the wind turbine is increased, the output voltage and the rotational speed will be decreased. Also, the dc motor needs to provide a larger torque to the wind turbine. Since the dc motor has limited maximum input power predetermined by the control box, it can only provide limited maximum torque to the wind turbine which can only generate a limited maximum power to the load. Fig. 6 shows typical output power characteristic curves of the wind turbine under different driving power from the controllable dc motor. These curves have same characteristics with those driven by the natural air-stream. Each one of the curves represents a constant driving power from the dc motor. The output power of the wind turbine is drawn by an electronic load. The load current is gradually increased, and then the output power can be measured.

Output power characteristic curves shown in Fig.5. The P&O method is adopted as the MPPT algorithm for the wind turbine. Therefore, a power electronic converter with appropriate controller is needed. To process the wind energy which varies considerably according to the meteorological conditions such as wind speed.

(2).Wind parameters

Vwind =80 ~200 V DC.
Switching frequency =
50kHz(M2),20kHz(M3,M6).
Power factor = 0.99.
THD =below 3.5%

C .Multi-input DC-DC Converter

The proposed multi-input dc–dc converter is the fusion of the buck-boost and the buck converter [17]. Syntheses of the multi-input dc–dc converter are done by inserting the pulsating voltage source of the buck converter into the buck-boost converter. In order not to hamper the normal operation of the buck-boost converter and to utilize the inductor for the buck converter, the pulsating voltage source of the buck converter must be series-connected with the output inductor. Base on the conduction status of the switches and , the multi-input dc–dc converter has four operation modes. Fig. 8(a)–(d) show the equivalent circuits for Mode I through Mode IV, respectively. When switches or are turned off, diodes and will provide a free-wheeling path for the inductor current. If one of the voltage sources is failed, the other voltage can still provide the electric energy, normally. Therefore, it is very suitable for renewable energy applications. Details of the circuit operation principle can be found in [17].

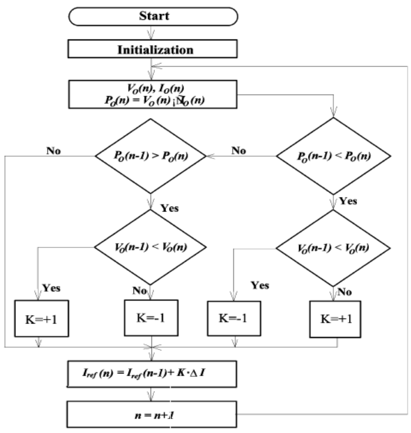


Fig 6: Flow chart of Maximum Power Point Tracking.

The input-output voltage relationship can be derived from the steady state volt-second balance analysis of the inductor. If has longer conduction time than has, then the equivalent operation circuit for one switching cycle will follow the sequence of Mode I, Mode III, and Mode IV. On the other hand,

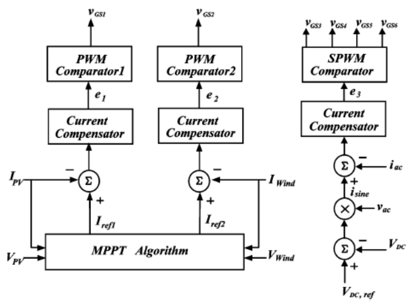


Fig.7.Control block diagram of the multi-input inverter.

if has longer conduction time than has, the sequence becomes Mode II, Mode III, and Mode IV. In either case, the output voltage can be expressed as,

$$V_{DC} = \frac{d_1}{1-d_2}V_{PV} + \frac{d_2}{1-d_2}V_{Wind} \quad \ldots(3)$$

Where d1 and are d2 the duty ratio of switches M1 and M2 , respectively. Similarly, the average input and output current can be obtained

$$I_{PV} = \frac{d_1}{1-d_2}I_o \quad \ldots(4)$$

$$I_{Wind} = \frac{d_2}{1-d_2}I_o. \quad \ldots(5)$$

From the above derived steady-state voltage and current equations, different power distribution demands of the multi-input dc–dc converter can be achieved.

(2).Output Parameters

Output Voltage (Vac) = 110V,60Hz.
Output Power (Pmax) = 1kW.

(D). Control Scheme

The conceptual control block diagram of the proposed multi-input inverter is shown in Fig.7. The hardware implementation of the control circuit is realized by using a central control unit, digital signal processor (DSP) TMS320F240, and auxiliary analog circuits. The sensed voltage and current values for the PV array and the wind turbine are sent to the DSP where the MPPT algorithm will determine the reference current (Iref1) and (Iref2) for the PV array and the wind turbine. The PWM Comparator1 and Comparator2 will generate desired gate signals for power switches M1 and M2 according to the current error signals e1 and e2,respectively.

The dc/ac inverter will inject a sinusoidal current into the ac mains. The SPWM gate signals of switches M3 through M6 for producing sinusoidal ac current is generated by the DSP where the amplitude of the ac current is determined by the error signal of the measured dc bus voltage Vdc and Vdcref. If the measured dc bus voltage is less than the reference value, then the amplitude of the ac output current will be decreased in order to increase the dc bus voltage. On the contrary, if the dc bus voltage is higher than the reference one, then the amplitude of the ac output current will be decreased. On the other point of view, the dc bus voltage is regulated by the dc–ac inverter and the input-output power balance can be achieved.

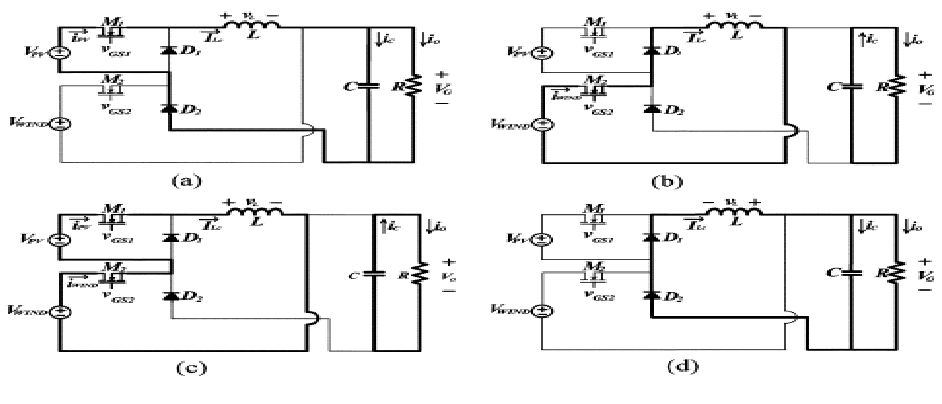


Fig. 8. Equivalent circuits for the multi-input dc–dc converter. (a) Mode I. (b) Mode II. (c) Mode III. (d) Mode IV.

III. Open loop of Multi-input inverter

The open loop control of multi input inverter is shown in fig 9. This system consist of one multi input DC-DC converter and DC-AC inverter. This converter is used to obtain maximum power from WIND/PV hybrid system. Inverter is used to regulate the dc bus voltage. This system is used to simplify the operation complexity and reduce the cost. The Output regulated voltage and current waveform of multi-input inverter is shown in fig 10.

Simulation Diagram Model

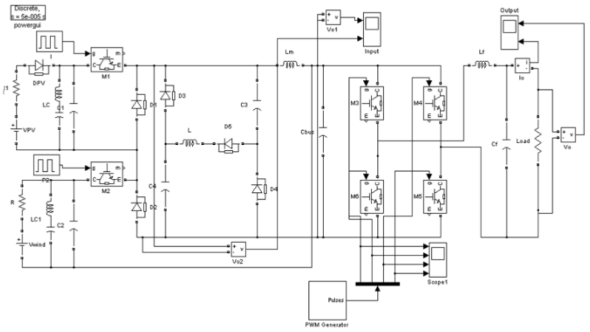


Fig 9. Open loop circuit of multi-input inverter

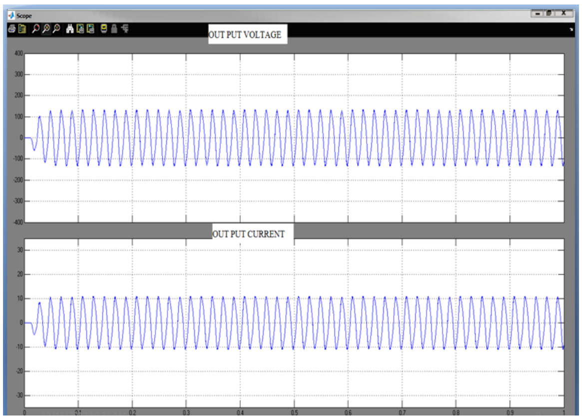


Fig10.Output voltage and current waveform of multi-input inverter.

IV. Closed loop of Multi-input inverter

Fig 9 shows the maximum constant output power from the wind/PV hybrid system using Multi-input inverter and MPPT(P&O)method. This output current and voltages are for the particular predefined input values of voltages(Vin) and gate signals (Vgs).

Simulation Diagram Model

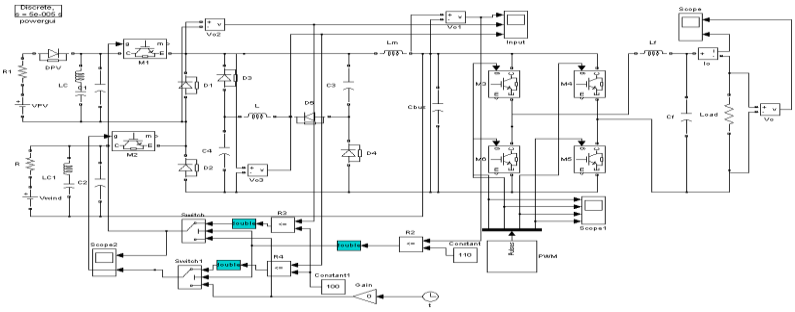


Fig.11 Closed loop operation of Multi-input inverter.

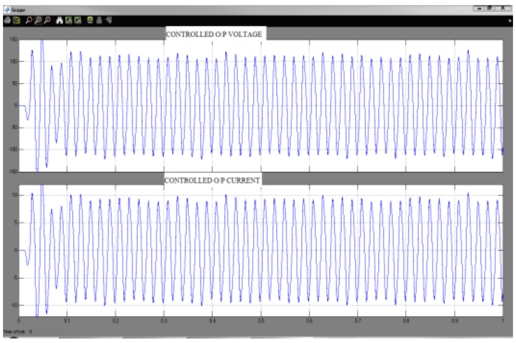


Fig.12 Output voltage and current waveform of multi-input inverter.

But in the closed loop of Multi-input inverter operation the maximum constant output power obtained for the different variable input conditions. This input and output balance controlled by using central control unit and DSP. So here no need of additional sensors.

V. Conclution

A multi-input inverter for the hybrid PV/wind power system is explained. Power from the PV array or the wind turbine can be delivered to the utility grid individually or simultaneously. MPPT feature can be realized for both PV and wind energy. A large range of input voltage variation caused by different insulation and wind speed is acceptable. The perturbation and observation method is adopted to realize the MPPT algorithm for the PV array and the wind turbine. simulation results for open loop operation shown in fig 10 to verify the performance of the multi-input inverter. The efficient control of Wind/PV system with closed loop operation of multi input inverter and simulation results for closed loop is shown in fig12 to verify the performance of the multi-input inverter and the maximum constant output power obtained for the different variable input conditions.

References

[1] T.-F. Wu, C.-H. Chang, Z.-R. Liu, and T.-H. Yu, "Single-Stage converters for photovoltaic powered lighting systems with MPPT and charging features," in *Proc. IEEE APEC*, 1998, pp. 1149–1155.

[2] M. Kolhe, J. C. Joshi, and D. P. Kothari, "Performance analysis of a directly Coupled photovoltaic water-pumping system," *IEEE Trans. Energy Conv.*, vol. 19, no. 3, pp. 613–618, Sep. 2004. [3] A. M. De Broe, S. Drouilhet, and V. Gevorgian, "A peak power tracker for small wind turbines in battery charging applications," *IEEE Trans. Energy Conv.*, vol. 14, no. 4, pp. 1630–1635, Dec. 1999.

[4] L. Solero, F. Caricchi, F. Crescimbini, O. Honorati, and F. Mezzetti, Performance of a 10 kW power electronic interface for combined wind/PV isolated generating systems," in *Proc. IEEE PESC*, 1996, pp. 1027–1032.

[5] S. Wakao, R. Ando, H. Minami, F. Shinomiya, A. Suzuki, M. Yahagi, S. Hirota, Y. Ohhashi, and A. Ishii, "Performance analysis of the PV/wind/wave hybrid power generation system," in *Proc. IEEE World Conf. Photovolt. Energy Conv.*, 2003, pp. 2337–2340.

[6] B. S. Borowy and Z. M. Salameh, "Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system," *IEEE Trans. Energy Conv.*, vol. 11, no. 2, pp. 367–375, Jun. 1996.

[7] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single-phase grid-connected inverters for photovoltaic modules," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[8] S. J. Chiang, K. T. Chang, and C. Y. Yen, "Residential photovoltaic energy storage system," *IEEE Trans. Ind. Electron.*, vol. 45, no. 3, pp. 385–394, Jun. 1998.

[9] G. B. Shrestha and L. Goel, "A study on optimal sizing of stand-alone photovoltaic stations," *IEEE Trans. Energy Conv.*, vol. 13, no. 4, pp. 373–378, Dec. 1998.

[10] J. H. R. Enslin and D. B. Snyman, "Combined low-cost, high-efficient inverter, peak power tracker and regulator for PV applications," *IEEE Tran. Power Electron.*, vol. 6, no. 1, pp. 73–82, Jan. 1991.

[11] K. H. Hussein, I. Muta, T. Hoshino, and M. Osakada, "Maximum photovoltaic power tracking: An algorithon for rapidly changing atmospheric conditions," *Proc. Inst. Elect. Eng.*, vol. 142, no. 1, pp. 59–64, 1995.

[12] C. Hua, J. Lin, and C. shen, "Implementation of a DSP-controlled photovoltaic system with peak power tracking," *IEEE Trans. Ind. Electron.*, vol. 45, no. 1, pp. 99–107, Feb. 1998.

[13] O. F. Walker, *Wind Energy Technology*. New York: Wiley, 1997.

[14] P. Gipe, *Wind Energy Comes of Age*. New York: Wiley, 1995.

[15] K. Amei, Y. Takayasu, T. Ohji, and M. Sakui, "Amaximum power control of wind generator system using a permanent magnet synchronous generator and a boost chopper circuit," in *Proc. Power Conv.*, 2002, vol. 3, pp. 1447–1452.

[16] R. Cardenas, R. Pena, G. Asher, and J. Cilia, "Sensorless control of induction machines for wind energy applications," in *Proc. IEEE PESC*, 2002, pp. 265–270.

[17] Y.-M. Chen, Y.-C. Liu, and S.-H. Lin, "Double Input PWM DC/DC converter for high/low voltage sources," in *Proc. IEEE Int. Telecommun. Energy Conf.*, 2003, pp. 27–32.

AUTHORS BIOGRAPHY IN ORDER

V. Kalai Rajan was born in Sivakasi, India in 1990. He obtained his B.E (Electrical) degree from National Engineering College, Kovilpatti, Tamilnadu, India and his M.E. (Electrical Drives and Embedded Control) from Anna University Regional Centre, Coimbatore, Tamilnadu, India. He is presently working as Assistant Professor in the Department of EEE in Renganayagi Varatharaj College of Engineering, Salvarpatti, India. His area of interest includes Power Electronics, Embedded Systems, High Voltage Engineering.

A. Raymon was born in Vilathikulam, India in 1987. He obtained his B.E (Electrical) degree from P.S.R. Engineering College, Sivakasi, Tamilnadu, India, M.E. (High Voltage Engineering) from National Engineering College, Kovilpatti, Tamilnadu, India and M.B.A (Human Resources) from Manonmanium Sundaranar University, Tirunelveli, India. He is presently working as Assistant Professor in the Department of EEE in Renganayagi Varatharaj College of Engineering, Salvarpatti, India. His area of interest includes Power System, High Voltage and Insulation Engineering.

A. Sheik Sidthik was born in Tirunelveli, India in 1990. He obtained his B.E (Electrical) degree from National College of Engineering, Tirunelveli, Tamilnadu, India. He is presently working as Assistant Professor in the Department of EEE in Renganayagi Varatharaj College of Engineering, Salvarpatti, India. His area of interest includes Power System, High Voltage and Insulation Engineering.

A. Senthil Kumar was born in Sattur, India in 1987. He obtained his Diploma (Electrical) from Tamilnadu Polytechnic College, Madurai, Tamilnadu, India. He is presently pursuing his B.E (Electrical) degree from Renganayagi Varatharaj College of Engineering, Salvarpatti, Tamilnadu, India. His area of interest includes Power Electronics, High Voltage and Insulation Engineering.