PERFORMANCE EVALUATION OF MPPT BASED SOLAR PUMPING SYSTEM WITH CLIMATIC CONDITIONS, COST AND ECONOMICS

N.Karpagam [1], T.S.Ganga devi [2]
[1,2]*Department of Electrical and Electronics Engineering, Velammal College of Engineering and Technology, Madurai, Tamilnadu, India*
[1] karpagam2k@gmail.com, [2]gangadevits2892@gmail.com

***Abstract*— Solar powered pumping systems are emerging research area in sunny countries like India. Implementation of innovative techniques in solar power harvesting will lead to apply the solar power in micro power requirements. In this work, the modeling of solar power panel simulation based on five parameter model with poly crystalline panel is analyzed for different solar radiation intensity and cell temperature. A cost analysis has been carried over for the economic operation of MPPT (Perturb & Observe) based photovoltaic water pumping system with the proposed model for different head levels of water and operating time. All performance analyses have been done with PVsyst software and also a small prototype with MPPT technique using PIC microcontroller was developed to validate the simulation results.**

***Keywords*— Solar energy - Photovoltaic cell- photovoltaic module - PVsyst software - Solar pump- MPPT**

I. INTRODUCTION

Energy sources such as solar, hydro and wind are increasingly used to meet energy needs. The modelling of solar photovoltaic system is used to predict maximum power produced [1]. Hybrid PV systems offer improves proposition over PV-only systems [2]. The technical and the commercial parameters were used to carry out the performance analysis of solar photovoltaic system installed [3]. Stand alone photovoltaic system is designed to operate residential appliances such as fluorescent lamp, incandescent light and fan. Total load is estimated and the array is sized to proper values in order to operate the estimated load [4]. Set of match calculation methods are used for optimum sizing of PV-wind hybrid system. Here more accurate and practical mathematical models are used for characterizing PV module [5]. Due to the absence of reliability means for the development of the market of the hybrid systems, PV-wind hybrid system was developed [6][7]. Modular systems are suited for cathode protection applications especially in remote and hilly areas [8]. Flat roofs present a large potential of suitable areas for installation of PV plants. Flat roof PV installation has the advantage of being able to optimally positioned with support structures [9][10]. Many software used for the modeling of the solar photovoltaic system and to obtain the I-V and P-V curves and the performance of the system [11][12].To ensure the optimal utilization of PV arrays, maximum power point tracking is used . The PV characteristics depend on the level of irradiance and temperature PV array experiences different irradiance levels due to passing clouds, buildings or trees [13]. In order to get a maximum output power form the solar cells, a maximum power point tracking system is highly recommended. The output power delivered by a PV module can be maximized using MPPT control System [14]. So the use of MPPT algorithms is required in order to obtain the maximum output power from a solar array When a PV module is directly coupled to a load [15]. Parameter calculations were done by available analytical solution and numerical solution methods.Solar pumping project is an emerging technique which need control systems in surface water management. At the current prices of PV modules, the cost of the proposed photovoltaic powered water pumping system is found to be less than the cost of the conventional fuel system. The expected reduction in the prices of photovoltaic modules in the near future will make PV powered water pumping systems more feasible. In this paper, a five parameter model of a poly crystalline solar panel is analyzed for different irradiation and temperature. A series parallel combination of 15*4 solar panels to match with prescribed solar pump is analyzed. Also, MPPT based solar based water pumping system was developed in hardware to enumerate the solar panel characteristics for different climatic conditions.

II FIVE PARAMETER PV MODELLING

A photovoltaic system converts light energy into electrical direct current by taking advantage of the photoelectric effect. The current thus produced by this method is termed as photo current and it is denoted by I_{ph}. This current can be produced by any type of panel's namely mono crystalline solar panel, polycrystalline solar panel, hybrid solar panel or black solar panel. A five parameter polycrystalline panel is selected and the best operating conditions is found with the change in the temperature and the irradiance which is more suitable for the maximum power point tracking based solar water pumping system.

A. SIMULATION RESULTS OF A FIVE PARAMETER MODEL POLYCRYSTALLINE STRUCTURE

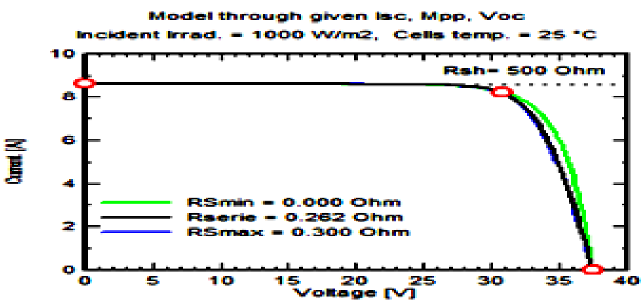


Fig.1. I-V characteristics for five parameter model with poly crystalline structure

The curve will pass through three characteristic points namely, short circuit current, open circuit voltage and maximum power point. With the help of these points diode saturation current, quality factor and voltage temperature coefficient can be found out.

B. I-V CURVE UNDER OPERATING CELL TEMPERATURE 25° C WITH 1000 IRRADIATION FOR A POLYCRYSTALLINE PANEL

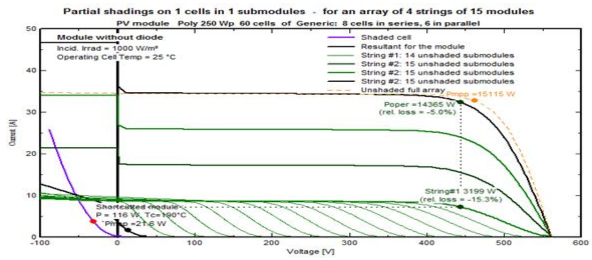


Fig.2. I-V curve under operating cell temperature 25° c with 1000 irradiation for a polycrystalline panel.

Fig 2.shows the I-V curve under different solar radiation intensity. On 1000 irradiation at 80% shading ratio and the operating temperature is 25°c the maximum peak power point occurred is 15 .11KW. Thus, highest maximum peak power point occurred during temperature at 25°C is 15.11 KW for 15 cells in series and 4 cells in parallel.

C. I-V CURVE UNDER OPERATING CELL TEMPERATURE 45° C WITH 1000 IRRADIATION FOR A POLYCRYSTALLINE PANEL

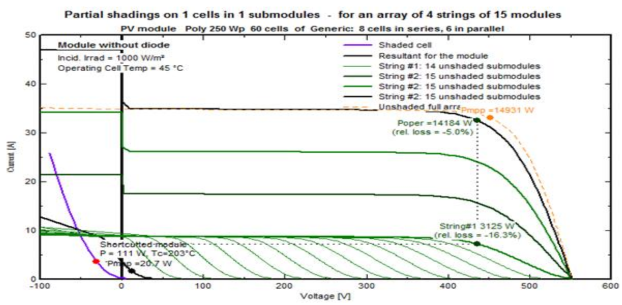


Fig. 3. I-V curve under operating cell temperature 45° c with 1000 irradiation for a polycrystalline panel

Fig 3.shows the I-V curve under different solar radiation intensity. On 1000 irradiation at 80% shading ratio and the operating temperature is 45°c the maximum peak power point occurred is 14.93KW.Thus, lowest peak power point occurred during temperature at 45°C is 14.93 KW for 15 cells in series and 4 cells in parallel.

D. I-V CURVE UNDER OPERATING CELL TEMPERATURE 25° C WITH 800

IRRADIATION FOR A POLYCRYSTALLINE PANEL

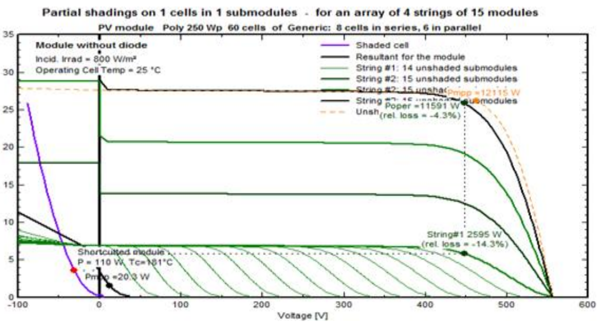
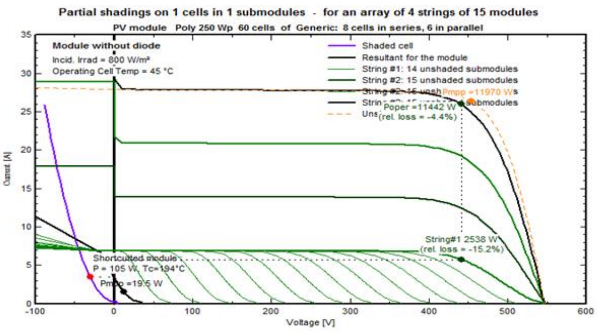


Fig. 4. I-V curve under operating cell temperature 25° c with 800 irradiation for a polycrystalline panel

Fig 4.shows the I-V curve under different solar radiation intensity. On irradiation of 800 at 80% shading ratio and the operating temperature is 25°c the maximum peak power point occurred is 12.11KW. Thus, highest peak power point occurred during temperature at 25°C is 12.11 KW for 15 cells in series and 4 cells in parallel.

E. I-V CURVE UNDER OPERATING CELL TEMPERATURE 45° C WITH 800 IRRADIATION FOR A POLYCRYSTALLINE PANEL



r

Fig.5. I-V curve under operating cell temperature 25° c with 800 irradiation for a polycrystalline panel

Fig 5.shows the I-V curve under different solar radiation intensity. On 800 irradiation at 80% shading ratio and the operating temperature is 45°c the maximum peak power point occurred is 11.97KW. Thus, lowest peak power point occurred during temperature at 45°C is 11.97KW for 15 cells in series and 4 cells in parallel. The maximum power derived, string power and string losses of the solar panel for different temperature, irradiation and shading conditions are provided in Table 1.

Table1. Evaluation of power produced

Irradiation	Shade (%)	Temp in ° C	P_{MPP} in kw	String power in w	String losses in %
1000	80	**45**	**14.93**	**3125**	**-16.3**
		40	14.98	3146	-16.0
		25	**15.11**	**3199**	**-15.3**
900	80	**45**	**13.45**	**2881**	**-14.4**
		40	13.50	2901	-14.1
		25	**13.62**	**2844**	**-16.5**
800	80	**45**	**11.97**	**2538**	**-15.2**
		40	12.01	2554	-15.0
		25	**12.11**	**2595**	**-14.3**

Here it shows about the variation of irradiation and the shading ratio. Depending about the temperature changing the power produced, string power and the string losses will be varied. For temperature 45°C the power produced is less and for the temperature 25°C the power produced will be high.

III. PERFORMANCE ANALYSIS OF SOLAR BASED WATER PUMPING SYSTEM

(i) Solar pump

A. IRRADIATION-WATER PUMPED FOR SOLAR BASED WATER PUMPING SYSTEM

Fig. 6 shows the irradiation- water pumped curve for a solar based water pumping system. It shows the variation of water production which depends upon the irradiation throughout the year. If the irradiation increases then the water pumped will also increases and if the irradiation is low then the water pumped will also low.

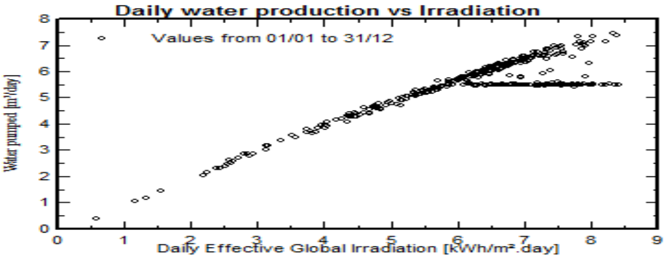


Fig.6.IRR-water pumped for solar based water pumping system

B. ARRAY POWER-WATER PUMPED FOR SOLAR BASED WATER PUMPING SYSTEM

Fig. 7 shows the array power- water pumped curve for a solar based water pumping system. It shows the effective power at the output of the array which depends upon the irradiation throughout the year. The maximum power produced by the array is 250watts.Also the power produced by the array depends upon the sun radiation on the array.

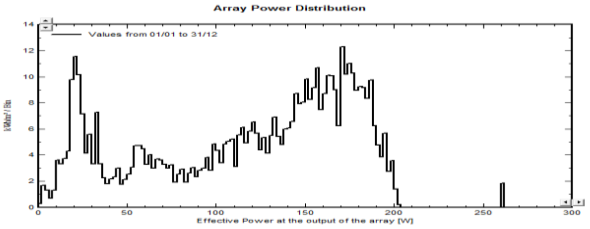


Fig.7. Array Power-Water Pumped For Solar Based Water Pumping System

Here it shows the observation of solar pump with respect to solar panel. It shows the variation of incident irradiation for a period of one year. It varies from 5.8KWh/m^2 day to 5.5KWh/m^2 day. Depending upon the irradiation the PV availability will be varied and the PV needs KWh/day will be maintained which is shown in table 2.

TABLE 2.YEARLY ANALYSIS WITH CHANGE IN INCIDENT IRRADIATION

Month	Incident Irradiation Kwh/m^{2}day	PV Available Kwh/day	PV need in Kwh/day
Jan	5.8	1.6	1.7
Feb	6.6	1.8	1.7
March	7.0	1.9	1.7
April	6.9	1.9	1.7
May	6.3	1.8	1.7
June	5.8	1.6	1.7
July	5.3	1.5	1.7
Aug	5.2	1.4	1.7
Sep	5.5	1.5	1.7
Oct	6.1	1.7	1.7
Nov	5.8	1.6	1.7
Dec	5.5	1.5	1.7
Average	5.8	1.7	1.7

C. ANALYSIS OF SOLAR BASED WATER PUMPING SYSTEM BASED ON SIMULATION RESULTS

A cost analysis of solar based water pumping system based on simulation results for both mono crystalline and poly crystalline panel considering with MPPT converter and also without MPPT converter which is provided in Table. 3**.** The specification for both MPPT and direct coupling is 5m^3 /day, H=32+6, PV=240wp, pumps 2*98w. From Table 3, it is observed that the cost for the mono crystalline panel is less when compared with the poly crystalline panel for direct coupling .Similarly the cost for poly crystalline panel is high when compared with mono crystalline panel including with MPPT converter**.**

The different observations of solar pump has been analyzed.

IV. IMPLEMENTATION OF SOLAR PUMP - PROTOTYPE

A solar powered water pumping system is made up of two basic components which are PV panels and pumps. The smallest element of a PV panel is the solar cell. Each solar cell has two or more specially prepared layers of semiconductor material that produce direct current (DC) electricity when exposed to light. This DC current is collected by the wiring in the panel. It is then supplied either to a DC pump, which in turn pumps water whenever the sun shines or stored in batteries for later use by the pump A solar-powered pump is a normal pump with an electric motor. If a pump has an alternating-current (AC) motor, an inverter would be required to convert the DC electricity produced by the solar panels to AC electricity. Due to the increased complexity and cost, and the reduced efficiency of an AC system, most solar-powered pumps have DC motors.

TABLE.3. COST ANALYSIS OF SOLAR PANEL BASED ON SIMULATION RESULTS

SOLAR PANEL AND SOLAR PUMP			
(5m^3 /day, H=32+6,PV=240wp,pumps 2*98w direct coupling)		(5m^3 /day, H=32+6,PV=240wp,pumps 2*98w MPPT Converter - direct coupling)	
Without MPPT Converter		With MPPT Converter	
Monocrystalline (250wp, 60 cells)	Polycrystalline (250wp, 60 cells)	Monocrystalline (250wp, 60 cells)	Polycrystalline (250wp, 60 cells)
`. 2,28,000.00	`. 2,28,750.00	`. 77,850.00	`. 2,29,500.00

A PV powered water pumping system is similar to any other pumping system; only the power source is solar energy. Photovoltaic water pumping (PVWP) systems can meet a wide range of needs and are relatively simple, reliable, cost competitive, and low maintenance. The big advantages of solar pump are long term lower costs when compared with diesel or gasoline powered pumps. PV water pumps do not require an on-site operator, and have a low environmental impact (no water, air, or noise pollution).Properly designed and installed PV water pumping systems are relatively simple to operate and maintain and can exist for decades.

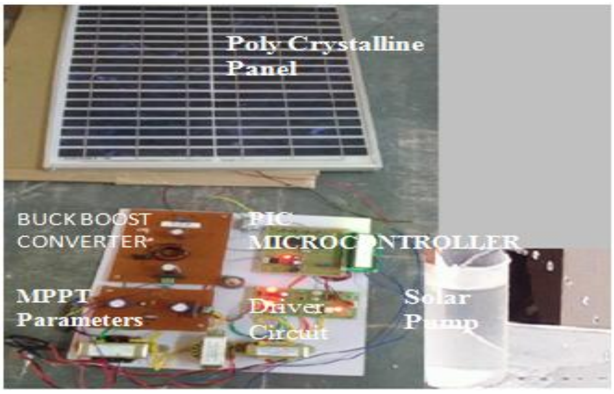


Fig-8.Prototype Model of MPPT based solar pump

- **Input supply:** Poly crystalline Solar Panel 17V
- **Filter:** Reduces the dc ripples from the solar supply and maintains constant source.
  - **Driver circuit:** -It can be used to amplify the 5V pulses to 12V for using transistor technology and provided isolations for using OPTO coupler for amplification and isolation.
- **Pulse generator (Controller) Unit:** - PIC microcontroller (PIC16F877A) to make a PWM switching signal and to adjust the duty cycle.
- **Power Supply:** Power supply unit gives the input power to micro controller and Driver circuit(+5V)
- **MPPT Control Parameters:** Here MPPT control needs reference voltage values to regulates the maximum power. This block sense the voltage values using potential divider method.
- **Buck-Boost converter:** Buck-Boost converter used to vary the voltage for regulates the MPPT Control voltage.
- **Solar pump:** DC Motor - 12Volt is used.

TABLE 4. COMPONENT DETAILS FOR PROTOTYPE

Parameters	Notation	Ratings
Maximum power	P_{max}	20Wp
Voltage at Maximum power	V_{mp}	17V
Current at Maximum Power	I_{mp}	1.18V
Open circuit voltage	Voc	20V
Short circuit current	Isc	1.42A
Tolerance	T	±5%
Normal operating temperature	T	45ºC

The main models used in the developed proto types are
1) Driver circuit module
2) Microcontroller module
3) Main circuit module

Here we are using PIC 16F877A for producing switching pulses to multilevel inverter. so as to use those vectors which do not generate any common mode voltage at the inverter poles. This eliminates common mode voltage Also it is used to eliminate capacitor voltage unbalancing. The microcontroller are driven via the driver circuit so as to boost the voltage triggering signal to 9V.To avoid any damage to micro controller due to direct passing of 230V supply to it we provide an isolator in the form of OPTO coupler in the same driver circuit. It is used to provide 5 to 12 volts to switch the MOSFET Switches of the inverter. Driver amplifies the voltage from microcontroller which is 5volts. Also it has an OPTO coupler for isolating purpose. So damage to MOSFET is prevented.

V.PERTURB & OBSERVE METHOD (P&O)

Perturb & Observe (P&O) is the simplest and cost effective method. P&O technique is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted. In this method, two sensors voltage sensor and current sensor are used to sense the PV array voltage and current. After, that change in voltage and change in power is measured. If the change in power is equal to zero then it is incremented with previous value. If the change in power is greater than zero than the change in voltage is checked. If the change in voltage is greater than zero then value is reduced or it should be increased before the end step. The time complexity of this algorithm is very less comparing to other method but on reaching close to the MPPT it doesn't stop and keeps on perturbing on both the directions. When this happens the algorithm has reached close to the MPPT and we can set appropriate error limit or we can use a wait function which ends up increasing the time complexity of the algorithm shown in Fig.11. So, this P&O technique is implemented in the hardware.

The developed prototype model of solar pump is tested for the different temperature and irradiation conditions. The solar pump was operated for six hours with and without MPPT controller through a by pass switch in the controller section. It is observed that with P&O based MPPT converter, the voltage and the power are near to the prescribed voltage needed. The results of different operating conditions are provided in the Table 6.

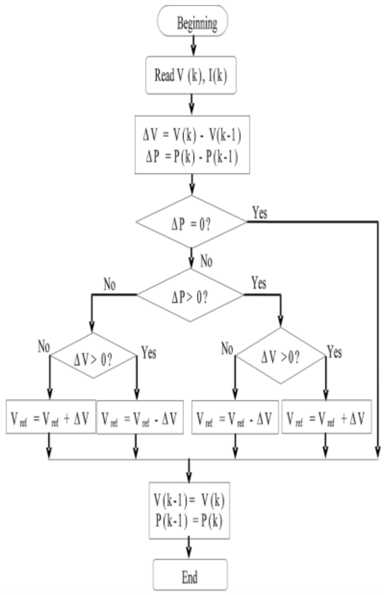


Fig.11. Flow Chart for Perturb and Observe method

Table 5 Solar panel parameters observed in the developed model

Irradiation Watts	Shade (%)	Temp In ^{0} C	P_{max} Watts	Voltage
1000	80	45	18.2	15.5
900	80	35	18.8	16.2
800	80	25	19.5	16.8

TABLE 6 SOLAR PUMP PARAMETERS OBSERVED IN THE DEVELOPED MODEL

Temp in ^{O} C	Pump Energy (KWhr)		PV Energy needed (KWhr)
	Without MPPT	With MPPT	
45	112.08	142.16	153
40	115.5	145.83	153
35	116.72	145.57	153
30	118.28	145.91	153
25	120.36	149.86	153

VI. CONCLUSION

F. This paper has presented the performance analysis of monocrystalline and polycrystalline panels for different solar radiation and cell temperature. In addition, the polycrystalline model is analyzed for high power production with series parallel combination. Solar pump characteristics matching with the suitable polycrystalline structure solar panel was also analyzed for different head levels and water requirement. Further, a comparative cost analysis for both the solar panels was presented. All the simulations were carried over through simulation in PVsyst software. Finally, prototype hardware was developed to enumerate the simulation results obtained through the software. P&O based MPPT technique was implemented through PIC controller for solar panel. The P-V parameters observed were compared with the simulation results which implies that implementation of MPPT technique will improve the performance of the whole system.

Acknowledgement

Authors thanks The Principal, Velammal College of Engineering and Technology for providing the facilities in carrying out this project.

REFERENCES

[1] S.S.Chandel, M.Nagaraju Naik, Rahul chandel " Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies''*Renewable and sustainable energy reviews*, Volume 49,April 2015,PP1084-1099.

[2] M.Sheraz Khalid, M.A.Abido "A novel and accurate photovoltaic simulator based on seven parameter model'' *Electrical power system research*, Volume 116, July 2014,PP243-251.

[3] S.S.Chandel, M.NagarajuNaik, Vikrantsharma, Rahul Chandel "Degradation analysis of 28 year field exposed mono-c-Si photovoltaic modules of a direct coupled solar water pumping system in western himalayan region of India'' *Renewable energy*, Volume 78,January 2015,PP193-202.

[4] Packiam Periasamy, N.K.Jain, I.P.Singh "A review on development of photovoltaic water pumping system" *Renewable and sustainable energy reviews*, Volume 43,December 2014, PP918-925.

[5] Jose Pablo Parades-Sanchez, Eunice Villicane Ortiz, Jorge Xiberta-Bernat "Solar water pumping system for water mining environmental control in a state mine of spain''*Journal of cleaner production*, Volume 87,October 2014,PP501-504.

[6] Amit Sahay, V.K.Sethi, A.C.Tiwari, Mukesh Pandey "A review of solar photovoltaic panel cooling systems with special reference to ground coupled central panel cooling system (GC-CPCS)''*Renewable and sustainable energy reviews*, Volume 42,October 2014, PP306-312.

[7] Juan Jose Sarralde, David James Quinn, Danel wiesmann, Koen Steemers "Solar energy and urban morphology: Scenarios for increasing the renewable energy potential of neighbourhoods in london''*Renewable energy*, Volume 73, July 2014, PP10-17.

[8] Tao Ma, Hongxing Yang, Lin Lu "Solar Photovoltaic System Modelling and Performance Prediction" *Renewable and sustainable energy Reviews*, Volume 36, May 2014, PP 304-315.

[9] K.Padmavathi, S.Arul Daniel " Studies on installing solar water pumps in domestic urban sector''*Sustainable cities and society*, Volume 1,June 2011,PP135-141.

[10] Bhubaneswari Parida, S.Iniyan,Ranko Goic 'A review of solar photovoltaic technologies', *Renewable and sustainable energy views*,Volume15,January2011.

[11] Mohamed Rebhi A, Ali Benatillah a, Mabrouk Sellam b, Boufeldja Kadri "Comparative Study of MPPT Controllers for PV System Implemented in the South-west of Algeria'', *Advancements in Renewable Energy and Clean Environment*, Volume 36, May 2013,PP 142-153.

[12] Ravindra M.Moharil, Prakash S.Kulkarni "A case study of solar photovoltaic power system at sagardeep Island, India''Renewable and sustainable energy reviews, Volume 13, November 2007.

[13] M.M.H.Bhuiyan, M.Ali Asagar "Sizing of a standalone photovoltaic power system *at dhaka*''Renewable energy, Volume 28, July2002, PP 929-938.

[14] B.Eker "*Solar powered water pumping systems'' Journal of science*, 2005, Vol. 3 , No 7, PP7-11

[15] Mohammed A.S.Masoum, Hoomam Dehbonei, Ewald F.Fuchs *"Theoretical and experimental analyses of photovoltaic systems with voltage and current based maximum power –point tracking*'' Energy conversion, Volume 17, December 2002, PP 514-522.

Karpagam N received the B.E in Electrical and Electronics Engineering and M.E Power System Engineering from Thiagarajar College of Engineering, Madurai Kamaraj University in 1994 and 2000. She received the Ph.D. degree in electrical engineering from Anna University, Chennai, Tamilnadu, India in 2010. She worked as a teaching faculty at Kalasalingam University, Tamilnadu. At present she is a Professor in EEE department at Velammal College of Engineering & Technology, Madurai. Her area of specialization are power system, FACTS devices and fuzzy logic and genetic algorithm applications to engineering problems.

Ganga Devi T S graduated in Electrical and Electronics Engineering in 2014 from SACS MAVMM Engineering College Madurai, India, and post graduated in Power Systems from Velammal College of Engineering & Technology, Madurai, India in 2016.