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The Effect of Temperature and Iradiation Changes on Output Power of Grid Connected Solar Power Plant

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Abstract: The application of non-renewable energy sources of excessive fossil fuel would increase carbon emissions that cause global warming. So, to reduce the risk of global warming, can use renewable energy more environmentally friendly. Solar Power Plant is one of the renewable technology that are environmentally friendly and non-polluting for the environment that can be applied in the country of Indonesia in response to the current energy crisis. In this study, using the data of temperature and radiation in 2017 derived from software RETScreen integrated with NASA. In designing the PV system to generate a maximum power output needed boost converter connected to the grid-connected inverter. Inverter control of irradiation and temperature influence on the delivery of grid connected photovoltaic power using natural reference frame. With the effects of temperature rise of grid connected PV systems on irradiation of 1,000 W / m^2 at the lowest cell temperature in 2017 is 48,859 °C to produce power 13.638,473 W, while at the highest cell temperature in 2017 is 56,321 °C to produce power 13.226,898 W. the effect of irradiation of PV systems connected to the grid at a temperature of 25 °C when the irradiation 157,755 W / m^2 power generated 2.423,147 W, whereas at the time of irradiation 242,473 W / m^2 produce 3.786,165 W power can be concluded that the higher temperature of the power PV output decreased and the higher value of irradiation, will incrase the power generated PV.

Keywords: solar panels, grid, temperature, irradiation

1. Introduction

The construction of a power plant in Indonesia is still focused on the use of fossil fuels such as coal for PLTU and diesel for PLTD. In the use of excessive non-renewable energy sources, fossil fuels will increase carbon gas emissions, causing global warming. Based on the Indonesian National Energy Policy [1] it is targeted that by 2025 the role of new and renewable energy will be at least 23% of the total national energy use. Therefore, many people glance at renewable and environmentally friendly energy sources. One power plant that uses new renewable energy derived from solar energy is photovoltaic (PV). Energy derived from solar energy does not cause carbon emissions because it includes environmentally friendly energy that is free of pollution and can be obtained free of charge. This solar power plant works by changing solar radiation directly into electricity. The condition of the country with the location of the equator with 2 seasons brings benefits and losses, the benefits obtained are that the sun's energy shines throughout the year, so that a large amount of energy is obtained, but the average environmental temperature value will be higher compared to 4 seasons [2], which can have an effect of increasing the temperature of photovoltaic cells when not paying attention to the placement of photovoltaics and the surrounding temperature conditions. This photovoltaic can produce power that can vary according to irradiation and the temperature received from PV. This photovoltaic system has the efficiency of converting radiation into small electrical energy [4]. To increase the efficiency of conversion of electrical energy to photovoltaic, maximum power point tracking (MPPT) can be used so that PV can maintain power at its maximum point [5]. This PV solar power plant produces direct current power so that to convert direct current (DC) power into alternating current (AC) an inverter is needed. In solar power plants connected on grid, Grid-connected inverters result in output voltage and frequency of the inverter must be equal to the voltage and frequency in the Grid [6].

2. Research Methods

2.1 System Design

The design of a power delivery system to a 20 kV grid with a load consists of several blocks shown in Figure 1

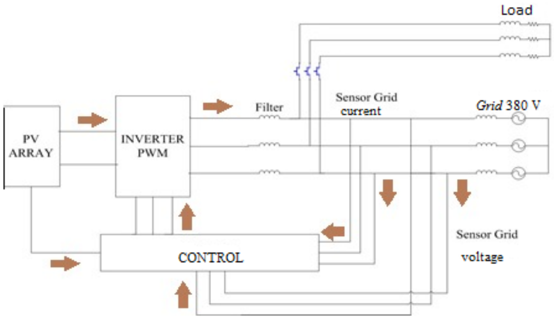

Figure 1 System design.

2.2 Photovoltaic Circuits Connected to 380 V Grid

The photovoltaic circuit connected to a 20 kV grid consists of a PV array, DC-DC booster, Maximum Power Point Tracker (MPPT), three phase IGBT inverter, Pulse Width Modulation (PWM), filters, Phase Locked Loop (PLL), grid control and grid .

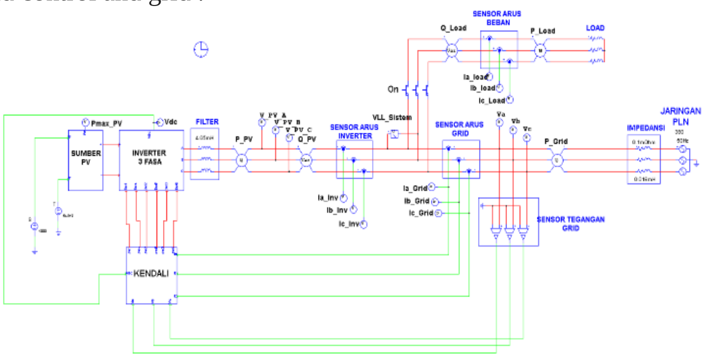

Figure 2. PV simulation circuit connected to a 20 kV network.

The grid-connected inverter system can work well if the DC input voltage is greater than [6]

$$V_{DC} = \frac{(2\sqrt{2} \times V_{LL})}{\sqrt{3}m} \qquad (1)$$

$$V_{DC} = \frac{(2\sqrt{2} \times 380)}{\sqrt{3} \times 0{,}9} = 689{,}4\ Volt$$

This study uses a DC voltage of 750 volts which is then used as an input inverter.

2.2.1 Photovoltaic design

Designed solar panels can transmit power by 50 kW by determining the desired maximum voltage (Vmpp) of 311 volts, then using equation 2 can be known the number of PV installations in series as follows. [6].

$$V_{mppM} = N_s V_{mpp} \qquad (2)$$
$$311 = N_s \times 31{,}1$$
$$N_s = 10\text{series}$$

In this study the power generated is 50 kW with VmppM 311 volts, then the maximum current value can be written with equation 3 as follows.

$$PmaxM = VmppM \times ImppM \qquad (3)$$
$$15000 = 311 \times ImppM$$
$$ImppM = 48{,}23\ Ampere$$

Then it can be seen the number of PV installations in parallel which can be calculated using equation 4 as follows.

$$I_{mppM} = N_s I_{mpp} \qquad (4)$$
$$48{,}23 = N_s \times 8{,}05$$
$$N_s = 5{,}99$$
$$N_s = 6\text{parallel circuit}$$

2.2.2 MPPT

In order for PV to transmit power to the maximum, Maximum Power Point Tracker (MPPT) is used to search and maintain the maximum power point of PV. The MPPT circuit is shown in Figure 3.

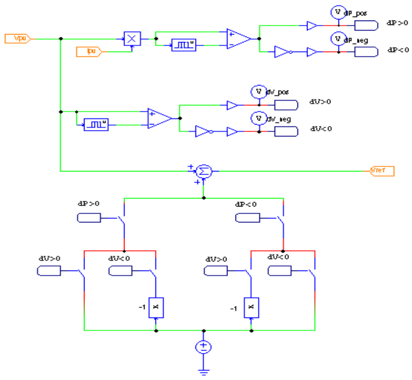

Figure 3. MPPT peturb and observe types

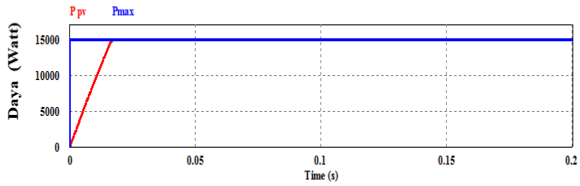

Figure 4. Graph of PV output power using MPPT

2.2.3 Boost Converter

After reaching the maximum voltage the output from the MPPT in the form of gatting activates the DC-DC booster which serves to increase the voltage as shown in Figure 5.

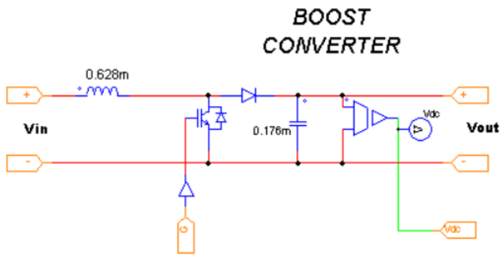

Figure 5. The DC-DC booster circuit

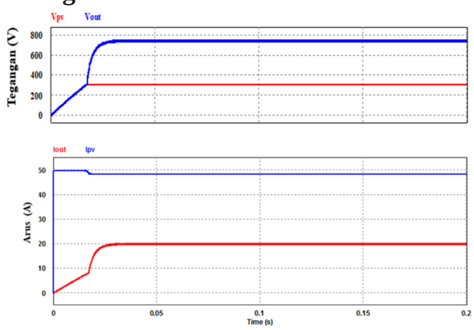

Figure 6. Boost converter output voltage and current

Then the boost converter output voltage is used as the input voltage for the inverter.

2.2.4 Grid Side Controller Design

Grid side controller consists of inverter, DC link voltage controller, control circuit and pulse wit modulation. The side controller grid functions as synchronization controller on the grid side.

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A. Inverter

This study uses an inverter with voltage source inverter (VSI) which uses a Pulse Wit Modulation (PWM). The inverter in this study used IGBT, then a switching frequency of 15 kHz was used. The inverter circuit is shown in Figure 8.

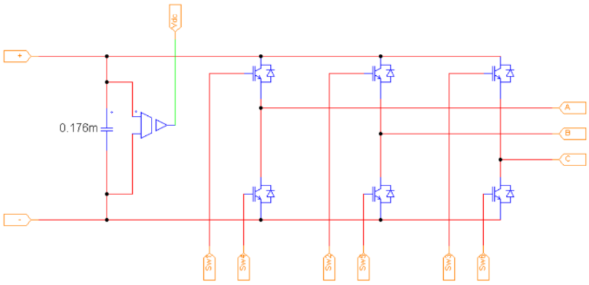

Figure 7. 3 phase inverter

The inverter output waveform is still a contact wave so a filter of 4.05mH is needed so that the output becomes a sinusoidal wave as shown in Figure 8

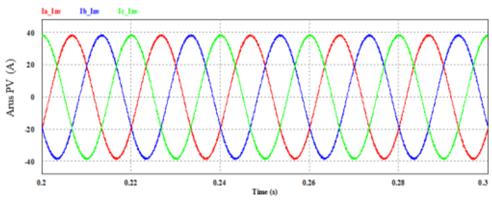

Figure 8. inverter output current wave

After a sinusoidal wave is formed then synchronization of inverter current and voltage with the grid uses a grid control circuit.

B. Control Series

This grid control circuit consists of the natural reference frame and Phase Locked Loop (PLL) current control circuit [3]. Phase Locked Loop (PLL) functions to synchronize the phase angle and frequency of the inverter with the grid. The grid control circuit is shown in Figure 9 then the PLL circuit is shown in Figure 10.

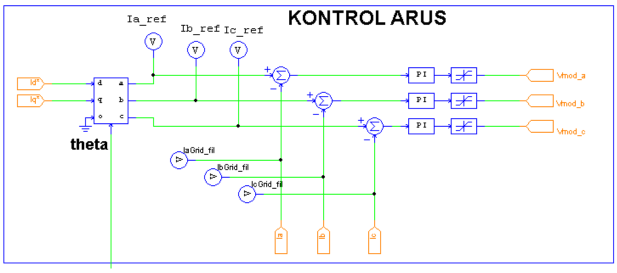

Figure 9 Grid control circuit.

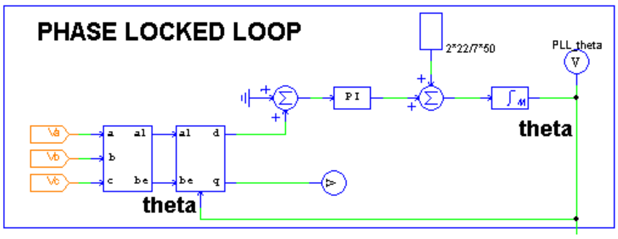

Figure 10 Phase locked loop circuit.

Controlling the natural reference frame current is successful if the grid current follows the reference current as shown in Figure 12. The reference current comes from the PV voltage which is controlled using a DC link voltage then transformed dq-abc to generate the reference current. The DC link voltage circuit is shown in Figure 11.

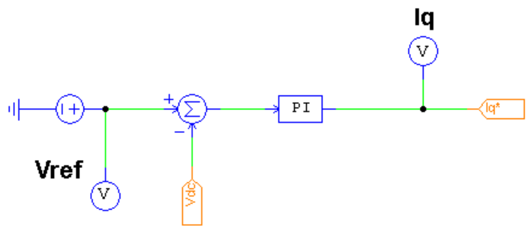

Figure 11. DC link voltage circuit.

Then synchronizing the phase angle and frequency is successful if one phase grid current with the system voltage phase. Then work on the system frequency of 50 Hz as shown in Figure 12.

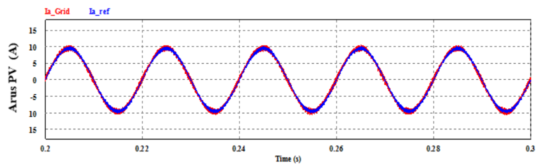

Figure 12. Grid current waves compared to reference currents

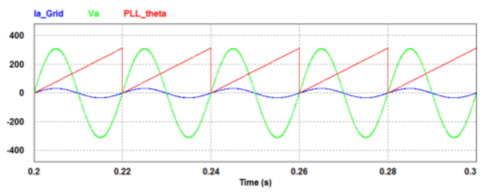

Figure 13. Wave PLL phase angle ratio with current and voltage on the network.

After grid control, the output of the dq-abc transformation takes the form of a modulation voltage which then enters the PWM as the 3 phase inverter switching work.

2.3 The Photovoltaic Circuit Connects to 380 V Grid and Load

After designing a grid-connected PV circuit that has been successfully carried out, then the grid is parallelized with a linear load by activating the push button to form the circuit shown in Figure 14.

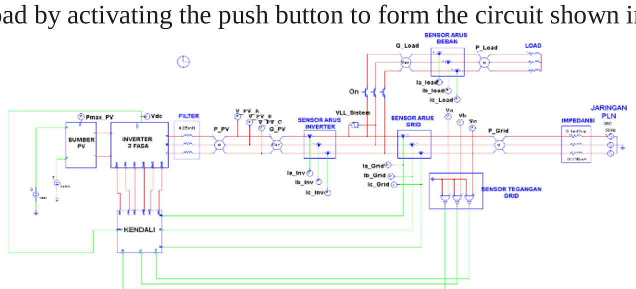

Figure 14. PV simulation circuit connected to grid and load.

3. Result and Analysis

3.1 Performance of Changing Connected Photovoltaic Source Temperature Grid 380 V

The simulation is carried out with temperature variations on the photovoltaic (PV) simulation circuit that is connected to the grid with loads as shown in Figure 14 with a power requirement of 19.4 kW at the load. In the design of solar power plants are designed to be able to produce 15 kW of power in accordance with STC conditions, namely temperatures of 25 ºC and irradiation of 1000 W / m2. Because temperature is one of the factors influencing the power, voltage, and current of photovoltaic (PV) output, after being simulated it can be seen the difference in output power, voltage and current values due to changes in temperature.

Temperature variations will use climate data from RETScreen software integrated by NASA. The data used is the change in average temperature data per month in 2017. Simulations carried out conditions of various temperature changes with constant irradiation of 1000 Watt / m2 to determine the effect of temperature on the voltage, current and output power of photovoltaic (PV) power plants. The simulation results from temperature variations with constant irradiation are shown in Table 1.

Table 1. Results of PV source simulation on temperature changes with constant irradiation of 1000 W / m2

Month	Tc (°C)	P Pv (Watt)	P Grid (Watt)	Teganga n (Volt)	Current (Ampere)
January	52,85	13418,32	5983,71	280,38	48,04
February	52,02	13464,23	5937,78	281,28	48,04
March	52,84	13418,87	5983,14	280,39	48,04
April	52,89	13415,89	5986,14	280,33	48,04
May	53,17	13400,58	6001,46	280,03	48,03
June	52,43	13441,59	5960,48	280,83	48,04
July	52,36	13445,00	5956,98	280,90	48,04
Agustt	52,35	13445,63	5956,39	280,91	48,04
September	52,76	13422,74	5979,28	280,46	48,04
October	52,37	13444,54	5957,49	280,89	48,04
November	52,51	13437,2	5964,82	280,74	48,04
December	52,02	13464,06	5938,01	281,27	48,04

In Table 1. it is found that the higher the temperature value, the power value will decrease. The highest point of power produced when the temperature is 52,017 ºC, which is 13,464.23 W at irradiation of 1000 W / m2. At a temperature of 53,171 ºC the power produced decreased, which is 13,400.58 W at irradiation of 1000 W / m2. The reduction in power can reach a point of 63.65 Watts, between the lowest temperature and the highest at maximum irradiation (1000 W / m2).

Table 2: PV simulation results on temperature changes in August 2016 with constant irradiation of 1000 W / m2

Tc Min-Max (°C)	P Pv (Watt)	P Grid (Watt)	TEGANGAN (Volt)	ARUS (Ampere)
48,86	13638,47	5763,62	284,71	48,08
50,26	13560,82	5841,14	283,19	48,06
51,65	13484,19	5917,83	281,67	48,05
53,05	13407,75	5994,22	280,15	48,03
54,44	13330,53	6071,52	278,64	48,02
55,84	13253,68	6148,33	277,13	48,01

Selected in August for example because in August has the highest difference in minimum and maximum temperature values so that it can represent other months. In Table 2. it is found that the higher the temperature value, the power value will decrease. The highest point of power produced at a temperature of 48.86 ºC is 13,638,473 W at irradiation of 1000 W / m2. At temperatures of 55.84 ºC the power produced decreased, ie 13.253,681 W at 1000 W / m2 irradiation. The difference between the minimum and maximum temperatures in August was 6.98 ºC which was obtained from a reduction in temperature of 55.84 ºC and 48.86 ºC resulting in a decrease in power reaching the point of 384,792 Watts.

Table 3: Results of simulation of irradiation variation at 25 ° C

Month	Tc (ºC)		P PV (Watt)	P Grid (Watt)	V Pv (Volt)	Current (Ampere)
Jan	MIN	49,96	13577,60	5824,39	283,50	48,06
	MAX	56,32	13226,89	6175,11	276,60	48,00
Feb	MIN	50,30	13558,59	5843,41	283,14	48,06
	MAX	55,06	13296,01	6106,01	277,96	48,01
Mar	MIN	50,85	13528,41	5873,56	282,54	48,05
	MAX	55,41	13276,99	6125,09	277,59	48,01
Apr	MIN	50,97	13521,92	5880,15	282,31	48,05
	MAX	55,54	13269,57	6132,42	277,45	48,00
Mei	MIN	50,96	13522,38	5879,66	282,42	48,05
	MAX	55,73	13259,26	6142,74	277,24	48,00
Jun	MIN	49,99	13575,90	5826,09	283,48	48,06
	MAX	55,13	13291,56	6110,45	277,89	48,01
Jul	MIN	49,89	13581,21	5820,79	283,58	48,06
	MAX	55,46	13273,84	6128,18	277,53	48,00
Aug	MIN	48,85	13638,53	5763,50	283,62	48,06
	MAX	55,83	13253,51	6148,55	277,13	48,00
Sep	MIN	49,92	13579,81	5822,21	283,56	48,06
	MAX	56,27	13229,72	6172,31	277,74	48,01
Okt	MIN	49,66	13594,29	5807,72	283,84	48,07
	MAX	55,82	13254,56	6147,41	277,14	48,00
Nov	MIN	50,26	13560,75	5841,22	283,18	48,06
	MAX	55,45	13274,55	6127,42	277,54	48,01
Des	MIN	50,11	13569,39	5832,55	283,35	48,06
	MAX	54,91	13304,64	6097,42	278,30	48,01

In Table 3. it can be seen every month that there are differences in the power output values at a minimum and maximum monthly temperature. For example, in January when the temperature (minimum) was 49,969 ºC can produce power of 13,577,603 W, while at temperature (maximum) 56,321 ºC produced power 13,226,898 W this indicates that the higher the value of temperature, the value of power will decrease. The difference between the minimum and maximum temperatures in January was 6.35 ºC which was obtained from a reduction in temperature of 56.321 ºC and 49.969 ºC resulting in a decrease in power reaching a point of 350.705 Watt, at maximum irradiation (1000 W / m2).

3.2 Performance Changes in Irradiation of Photovoltaic Sources and Effects on Grid 380 V

Simulation will be carried out by irradiation variations with a constant temperature of 25 ºC to a series of photovoltaic (PV) simulations connected to the grid. Irradiation variations will use climate data from RET Screen software integrated by NASA. The data used is the average irradiation data in 2017.

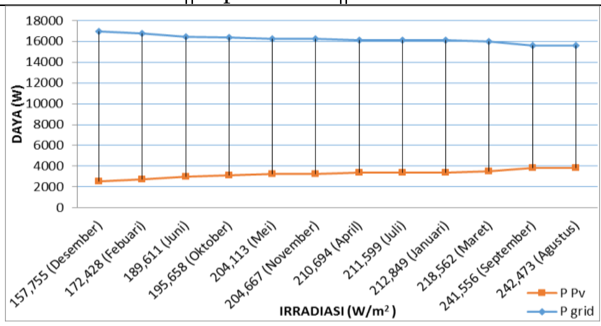

Figure 15. Graph of the Relationship of Monthly Temperature and PV Output in 2017

Table 4. The results of PV performance are connected to the grid with a load of variation of irradiation at 25°C.

Bulan	Iradiasi (W/m^2)	P pv Max (W)	P pv (W)	P Grid (W)
Januari	212,85	3392,46	3306,96	16094,54
Februari	172,43	2747,84	2655,47	16745,95
March	218,56	3483,29	3400,20	16001,37
April	210,69	3358,16	3275,95	16125,59
Mey	204,11	3253,41	3166,34	16235,11
June	189,61	3022,25	2932,92	16468,53
July	211,60	3372,56	3289,88	16111,63
August	242,47	3862,68	3786,16	15615,42
September	241,56	3848,15	3770,57	15630,99
October	195,66	3118,71	3032,23	16369,2
November	204,67	3262,23	3175,51	16225,93
December	157,76	2513,12	2423,14	16978,29

In Figure 15. it is found that the change in power output of the photovoltaic source also changes the power supply from the grid. For example, when irradiation 242,473 W / m2 produces 3786.165 W of power to meet a load of 19.4 kW supply from the grid is 15615.42W, while at irradiation 157.755 W / m2 produces 2423,147 W power needs from grid power of 16978 , 29 W to meet load requirements.

4. Conclusion

The results of research are the effect of temperature rise from grid-connected PV systems, at 1,000 W / m2 irradiation when the lowest cell temperature in 2017 is 48,859 ℃ produces power 13,638,473 W, while when the highest cell temperature in 2017 is 56,321 ℃ produces power 13,226,898 W. The effect of irradiation from grid-connected PV systems at 25 ℃ at irradiation 157.755 W / m2 produces 2,423,147 W, while at irradiation 242,473 W / m2 produces 3,786,165 W power, it can be concluded that the higher temperature makes the PV output power decreasingand the higher irradiation makes the greater the value of the power.

Reference

[1]. P. R. Indonesia, Republic of Indonesia Government Regulation Number 79 concerning National Energy Policy, Jakarta, 2014
[2]. S, Kurtz., D, Miller., Evaluation of the High-Temperature Exposure of Photovoltaic Modules, NREL (National Renewable Energy Laboratory), Philadelphia, 2009
[3]. Frede Blaabjberg, Remus Teodorescu, Marco Liserre, Adrian V. Timbus. "Overview of Control and Grid Synchronization for Distributed Power Generation Systems". IEEE Transactions on Industrial Electronics, October 2006. pp. VOL.53, NO.5
[4]. Susatyo Handoko, Tejo Sukmadi. "Maximum Power Point Tracking Simulation for a Photovoltaic System". Int. Conference on Information Technology, Computer and Electrical Engineering (ICITACEE). 2015
[5]. Tito, Beng. "New MPPT Method for Solar Cells Based on PI Controllers". University of Indonesia Electrical Engineering. 2012.

[6]. Bhim Singh, D. T. Shahani, Arun Kumar Verma. "Power Theory Based Control of Interfaced Grid Solar Photovoltaic Power Generating System with Improved Power Quality". IEEE International Conference on Power Electronics, Drives and Energy Systems. 2012
[7]. RG, Ross., Flat-Plate Photovoltaic Array Design Optimization, 14th IEEE Photovoltaic Specialists Conference, 1980
[8]. K. Vinil, "Improvement of Solar Cell Efficiency", International Journal of Engineering Trends and Technology (IJETT), India, 2013, Vol 4
[9]. Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy, B. Moselle, J. Padilla, and R. Schmalensee, Eds. Washington, DC: RFF Press, Aug. 2010.