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Impact of Photovoltaics

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ABSTRACT

Photovoltaics (PV) can convert sunlight into electricity by making use of the photovoltaic effect. Solar panels consist of photovoltaic cells made of semiconductor materials (such as silicon) to utilise the photovoltaic effect and convert sunlight into direct current (DC) electricity. Nowadays, PV has become the cheapest electrical power source with low price bids and low panel prices. The competitiveness makes it a potential path to mitigate the global warming. In this paper, we investigate the relationship of PC array output with irradiance and temperature, the performance of PV array over 24 hours period, and the simulation of PV micro grid by MATLAB simulation.

1 Introduction

Nowadays, the demand of renewable energy increases along with innovation of technology and corresponding business. In Australia, the common application of solar energy is the residential solar panels installed on the rooftops, which use photovoltaics to generate electricity in a clean and sustainable way. In this lab, we are going to investigate the effect of photovoltaics on residential micro grid.

In the first section. We use MATLAB Simulink to establish PV Array models which is composed of PV array, one phase DC/AC converter, inverter control module and LCL filter. We put real world irradiance data from the Australian PV Institute into our model and observe the output of PV array, DC/AC inverter and LCL filter which suppresses high frequency harmonics generated by PWM switching frequency.

The next section is to investigate the PV performance. We obtain data of a 24shours cycle in the summer from APVI. These irradiance and temperature information is fed into our model and calculate the output power, then compare it with the residential daily consumption.

The final section is analysing the impact of PV in residential micro grid. The task is observing the PV supply in a 24-hours period, adjusting the output power of solar module and discover the upper limit to prevent exceed power in microgrid, simulation of power grid with curtailment and explore the effect of battery in micro grid[1-3].

2. The photovoltaic Array Model

2.1. Design of PV Model

The photovoltaic array model has four components: The PV array which has fourteen 250 W solar modules connected in series, DC/AC inverter with a single-phase

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full bridge IGBT module which is controlled by PWM, an inverter control module and LCL filter. The Figure 1 illustrates the design of integrated circuit.

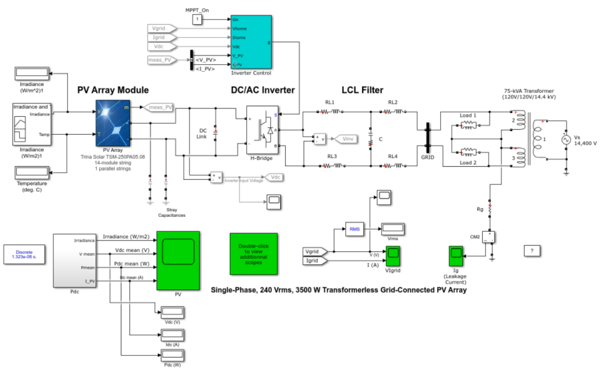

Figure 1. The topology of PV array model

2.2 PV Array Output with Varying Irradiance

This paper uses a real-world data of solar irradiance profile to explore the effect of varying irradiance. Then we plot the output voltage, output current and output power vs irradiance at 25 degrees Celsius by using Microsoft Excel.

Table 1. Voltage, Current and Output Power vs irradiance at 25 degrees

Irradiance	Vdc	Idc	Pdc
679.04	434	5.465	2375
514.81	432.4	4.147	1796
257.34	424.09	2.074	881.9
365.65	429.2	2.948	1266
878.54	434.4	7.08	3073

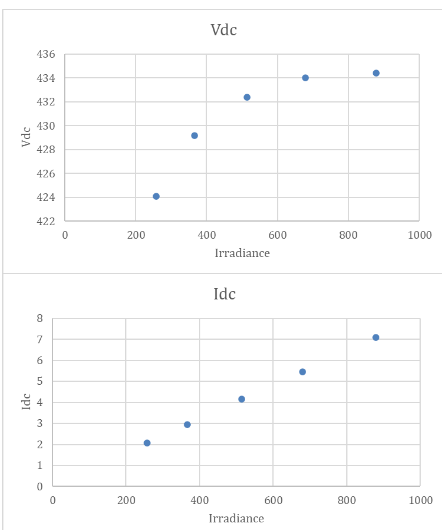

Figure 2. Output Voltage and Current at 25 degrees Celsius

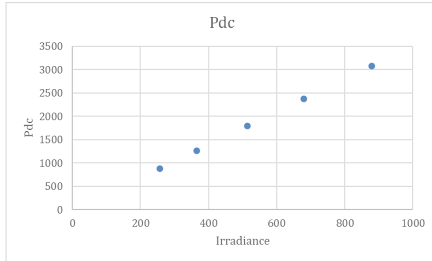

Figure 3. Output power at 25 degrees Celsius

According to the simulation results, when the temperature remains unchanged, the output voltage increases with the increase of irradiance. When irradiance is less than 800 W/m^2, the output voltage increases rapidly. When irradiance is more than 800 W/m^2, the growth increases slowly. Also, with the increase of irradiance, the output current and output power rose steadily and tended to a positive linear correlation[4-6].

2.3 PV Array Output with Varying Temperature Based on 1000 Irradiance

To explore the effects of varying temperature on a PV array. Based on the simulation model, we plot the voltage, current and output power vs temperature at 1000 W/m^2 using Microsoft Excel. We select the data in the table.

Table 2. Voltage, Current and Output Power vs irradiance at 1000 W/m^2

Temperature	Vdc	Idc	Pdc
5	450	8.232	3708
10	450	8.17	3681
15	445	8.059	3633
20	443.4	8.017	3564
25	434.2	8.024	3492
30	424.7	8.033	3420

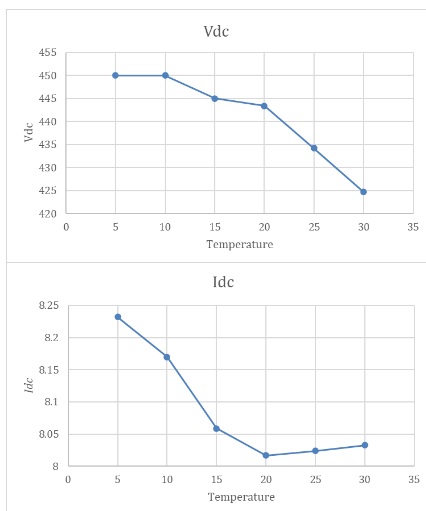

Figure 4. Output Voltage and Current at 1000 W/m^2

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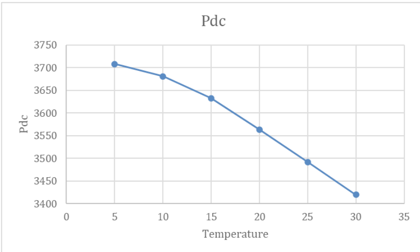

Figure 5. Output Power at 1000 W/m²

According to the simulation results, when the irradiance is fixed, the output voltage drops with the drop of temperature. When the temperature over 20C, the output voltage drops rapidly. With the increase of irradiance, the output current and output power have a negative linear correlation.

3. Investigating PV Performance over 24 Hours

The section is to simulate the single-phase PV model to view the performance of the PV model over a 24-hour cycle. Also, we only investigate day-time changes. We select the data of the table 3.

Table 3. 24h Output Power vs irradiance

Timestamp	Irradiance	BOM Temperature (C)	Pdc
2020-01-01 06:00:00 +1000	14.37	12.8	45.88
2020-01-01 07:00:00 +1000	74.59	15.9	253.6
2020-01-01 08:00:00 +1000	239.35	19.5	838.2
2020-01-01 09:00:00 +1000	460.83	20.6	1634
2020-01-01 10:00:00 +1000	673.3	22.8	2377
2020-01-01 11:00:00 +1000	826.85	22.2	2926
2020-01-01 12:00:00 +1000	925.16	22.6	3266
2020-01-01 13:00:00 +1000	959.7	24	3367
2020-01-01 14:00:00 +1000	929.01	25.2	3245
2020-01-01 15:00:00 +1000	821.47	26.6	2855
2020-01-01 16:00:00 +1000	680.19	25	2379
2020-01-01 17:00:00 +1000	508.42	24.7	1775
2020-01-01 18:00:00 +1000	287.74	23.7	995.3
2020-01-01 19:00:00 +1000	94.18	22.2	314.1
2020-01-01 20:00:00 +1000	18.97	20.8	58.95

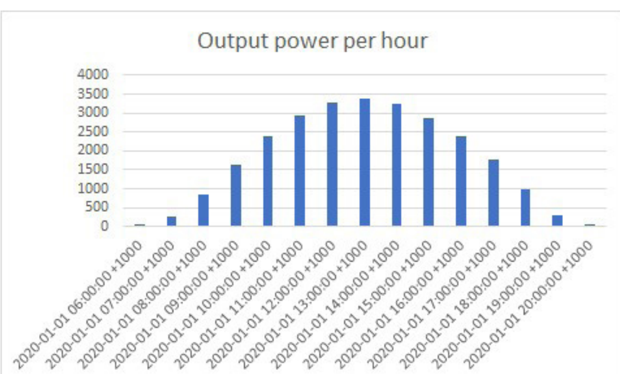

Figure 6. Output Power in one day time

From 6 a.m. to 8 p.m. PV generates power. PV generates energy, which peaks at 1 o 'clock in the afternoon. Pdc mean is 1755.335 W in PV working time. Pdc mean is 1097.085 W.

Compared with a typical household energy consumption. It can be seen from the figure that a typical family has peak electricity consumption in two time periods. The first period is about 7 am to 9 am, when electricity use is quite high, and people are just getting up to study and go to work. The second time is around 6 pm to 10 pm, when people have dinner and bedtime activities at home. Between 10 pm and 7 am, people tend to be asleep and use less electricity. People usually study and work outside from 9 am to 6 pm, so households use less electricity. As a result, less electricity is used between 10 pm and 7 am and 9 pm and 6 pm[7-8].

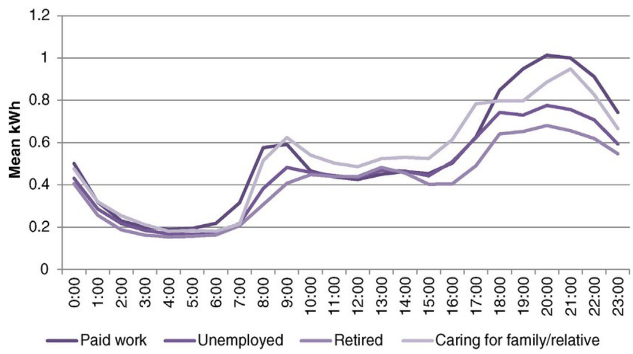

Figure 7. The energy use of a typical household

4. 24 Hour Simulation of Microgrid

In this section, this paper simulates a residential micro-grid consisting of multiple households and a PV array to observe the impact of the PV array on the residential micro-grid's performance.

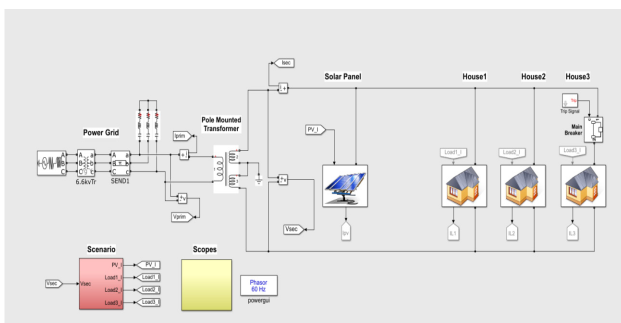

Figure 8. Simplified model of household microgrid

From the scopes, we find the relation that Power_PV = Power_Load + Power_ Secondary, which means the power of the load is equal to the PV power plus the power of the secondary side.

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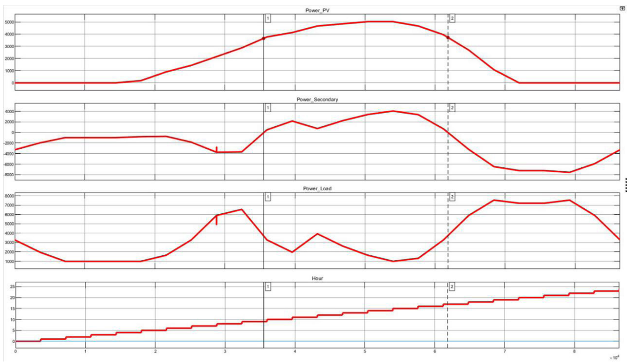

Figure 9. Secondary side, PV side and load side voltage

5. 24 Hour Simulation of Microgrid with Battery Storage

In this section, we simulate the Micro-grid with Battery Storage to observe the performance, a battery model is added at original microgrid

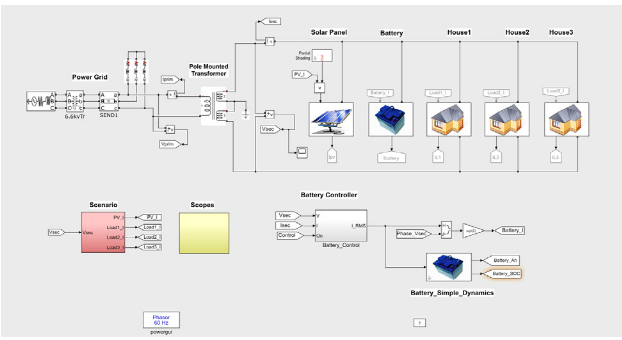

Figure 10. Simplified model of household microgrid with battery

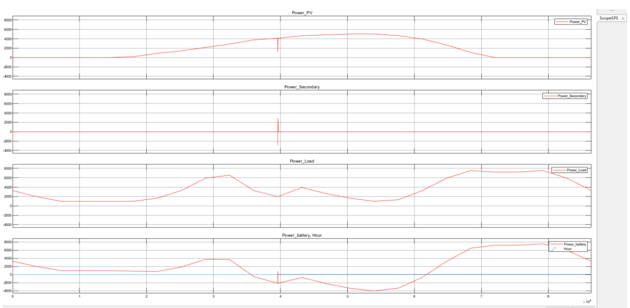

Figure 11. Secondary side, PV side and load side voltage

After the battery is added, the power of the secondary side is maintained at 0. If the battery is not added, the power of the secondary side is maintained at 0, and the upper limit of PV power is 800W. When the PV works normally, the PV power must be greater than 800W, and then the power of the secondary side cannot be guaranteed to be 0. When people's electricity consumption is less than the upper limit of PV power generation, that is, excess electricity generation, the power on the secondary side will be greater than 0. Therefore, when the battery is added, the PV generated power can be stored in the battery, thus reducing the PV power and keeping the power of the secondary side at 0. Improved energy efficiency. When people's electricity consumption is greater than the upper limit of PV power generation, that is, the excess electricity consumption, the power on the secondary side will be less than 0. After the battery increased, the amount of power generated before PV can be used, thus improving the power of the secondary side and keeping the power of the secondary side at 0, which improved the energy efficiency[9-15].

6. Conclusion

Photovoltaics effect of solar panel could generate electricity by sunlight and support residential microgrid. The output power, voltage and current in PV array is affected by irradiance and temperature. With the increase of irradiance, output power of PV module increases rapidly. However, temperature has a negative correlation with PV's performance.

The performance of PV is constrained to sunlight. From our observation, PV works in the daytime and reach its peak performance at midday. By comparison to mean household energy consumption, the output of PV may not be sufficient in high-demand period like morning and night especially at summer. After we investigate the impact of PV on residential micro grid, we found that the output power may exceed the threshold of micro grid especially in the afternoon when PV has peak performance. The feasible solution is to equip a battery storage in micro grid. It could maintain the secondary power to zero and avoid overvoltage phenomenon. Furthermore, it would provide energy when people's electricity consumption surpasses the upper limit of PV power generation.

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