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제주도 지역별 대용량 태양광발전소들의 여름 피크타임 기여도 연구

Contribution of Large-Scale PV Plants in the Respective Region of the Jeju Island to Electric Power during Summer Peak Times

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Abstract - Both the introduction of the Renewable Energy Portfolio Standard (RPS) system into the electric energy market in 2012 and a decrease in the cost of constructing photovoltaic (PV) power plants have been increasing the number of MW PV plants in South Korea. Jeju Island is located at the center of three nations, South Korea, China and Japan, and its provincial government declared in 2012 that the island will be a clean region where greenhouse gases are not emitted by 2030. The Jeju provincial government is now doing its best to install PV plants and wind farms to realize a carbon-free island.

In this study we investigated contribution of MW PV plants to the power of the electric grid during summer peak times on Jeju Island. Mt. Halla the highest mountain in South Korea, is located at the center of Jeju Island, and we divided the island into four regions and carried out analyses of a total of 24 PV plants. The average contribution of the PV plants in the respective region to electric power of Jeju Island during summer peak times was investigated and compared with those of the other regions. The best average contribution during the 12.5% maximum load period was obtained from the PV plants in the western region, and the value was 33% during 2015 and 2016.

Key Words : Photovoltaic power plants, Renewable energy, Summer peak time, Contribution to electric power, Jeju

1. Introduction

Photovoltaic generation is a promising technique for the reduction of fossil fuel consumption and carbon dioxide emissions. The Korean government introduced the Renewable Energy Portfolio Standard (RPS) system into the electric energy market in 2012 to expand the use of renewable energy [1]. The law prescribes that the major electric power plant companies must produce electric energy using renewable sources above the rate specified every year. The duty rate increases year by year. Large-scale PV plants have been increasing critically in South Korea since the RPS system was introduced.

In 2012, the Jeju Special Self-Governing Province announced, its “Carbon-Free Island, Jeju by 2030” plan which aims to make the island carbon free and a self-sustainable region by using renewable energy resources [2].

In the case of wind and solar power plants, they can’t generate at the rated capacity in peak electric power times because of their dependence on weather. Usually, summer is the peak electric power demand time in Korea. And PV generation has an advantage in that its operation rate is high in summer compared to wind generation. It is important to know how much electric energy can be generated by PV plants during electric power peak times. There have been many studies that show how PV plants contribute to alleviate the electric power peak during summer [3-6].

In this study, investigate the contribution of MW PV plants on Jeju Island during peak times in summer. Mt. Halla, the highest mountain in South Korea, is located at the center of Jeju Island, and we divided the island into four regions according to weather similarity, except for the center one in which there are no big PV plants because of the mountain. We used the data from 24 PV plants that have been operated for more than 2 years and whose capacity is larger than 0.5MW. The average contribution of the PV plants in the respective region to electric power on Jeju Island during summer peak times was analyzed and compared with those of the other regions. In order to know the contribution of PV power plants during summer peak time, we investigated the amount of electric energy generated by them and the electric power peak time during the summer season in Jeju from 2014 to 2016.

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2. Study Background and Methods

2.1. Regional Categorization of PV plants in Jeju

We chose plants that have been operated for more than 2 years and had data for summer in 2015 and 2016 at least. And only the PV plant with a capacity of more than 0.5 MW in them were chosen.

We categorized 24 PV plants into four regional groups; northern, southern, eastern and western, which are the same as the weather forecast regions[7]. The results are shown in Table 1.

Table 1 Categorization of PV plants into four regions on Jeju Island.

Region name	Assigned name for power plants in this paper	Capacity [MW]
Northern region	Northern A	1.1
	Northern B	1.2
	Northern C	0.5
	Northern D	1.0
	Northern E	0.5
Eastern region	Eastern A	1.0
	Eastern B	1.0
	Eastern C	1.0
	Eastern D	0.6
	Eastern E	0.5
	Eastern F	0.5
Southern region	Southern A	1.0
	Southern B	1.7
	Southern C	0.5
	Southern D	0.5
Western region	Western A	1.0
	Western B	1.0
	Western C	0.5
	Western D	0.5
	Western E	0.5
	Western F	0.6
	Western G	0.5
	Western H	0.5
	Western I	0.9

2.2. Analysis of power demand during summer time on Jeju Island

The analysis results of the daily peak power from 2014 to 2016 are shown in Fig. 1. The value in the graph is the monthly average of the daily peak power. We were interested in the summer season, especially during July and August. Fig.

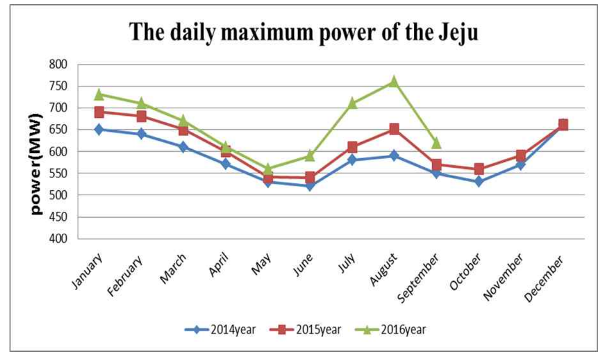

Fig. 1 Monthly average of daily maximum power use on Jeju Island

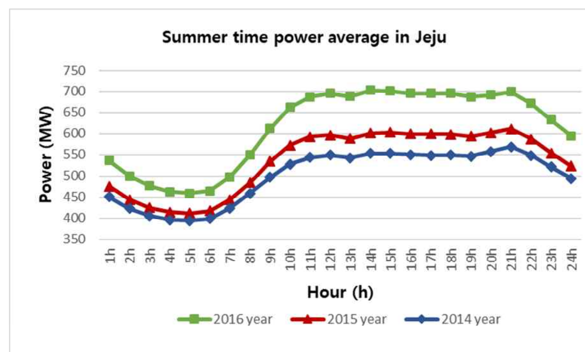

Fig. 2 Average electric power demand during July and August on Jeju Island

1 shows that the electricity demand in the summer was low in 2014 and 2015 and highest in 2016 because peak power use in summer is due to using air conditioners, and the summer weather was cool in 2014 and 2015, and very hot in 2016[8].

In order to know the power peak time, we investigated the electric energy consumed hourly on Jeju in July and August from 2014 to 2016. The amount of energy consumed hourly is the same as the magnitude of electric power in the time interval if the unit changes [kWh] into [kW] or [MWh] into [MW]. The average hourly electric power for 62 days within the two months of July and August were calculated, and the results are shown in Fig. 2.

We can see that the power demand during the summer power peak time increases year by year within these years. And the power peak, arriving near noon, was shown to be constant until 9 PM, late evening time. The power demand trend on Jeju is different from that in the other provinces of Korea, which is why Jeju is a popular tourism place and tourists spend time outside during the day, while much electric energy is consumed by hotels and restaurants during evening time.

The power peak during summer continues until late evening on Jeju. Regarding the point that we are trying to alleviate the summer power peak by using PV plants, Jeju is in a disadvantageous position because the plants can't generate electricity after sunset.

Table 2 Classification of the maximum load time bands and the time bands to be in them obtained from the average summer power during July and August in 2016 on Jeju Island.

<table>
<tr><th>Time band</th><th>Average power (MW)</th><th colspan="3">Kind of max. load</th></tr>
<tr><td>14h</td><td>703</td><td rowspan="3">Max. load 12.5%</td><td rowspan="6">Max. load 25.0%</td><td rowspan="9">Max. load 37.5%</td></tr>
<tr><td>15h</td><td>701</td></tr>
<tr><td>21h</td><td>700</td></tr>
<tr><td>12h</td><td>696</td><td></td></tr>
<tr><td>17h</td><td>696</td><td></td></tr>
<tr><td>18h</td><td>696</td><td></td></tr>
<tr><td>16h</td><td>695</td><td></td><td></td></tr>
<tr><td>20h</td><td>692</td><td></td><td></td></tr>
<tr><td>19h</td><td>687</td><td></td><td></td></tr>
</table>

※Time band example: "12h" means the time interval from 12:00 to 13:00, "14h" from 14:00 to 15:00, and so on.

We defined the max. load as three types: 12.5%, 25% and 37.5%, which reflected that the time interval of the data we obtained was 1 hour. The power use during the summer period was highest in 2016, and we found the time bands of the respective max. loads from the 2016 average power demand during July and August. The results are shown in the Table 2.

2.3 Calculation of average peak power contribution and average utilization rate for PV plants in each region

The performance of a PV power plant is evaluated by the utilization factor. This is the ratio of the actual output of the PV plant over one year to the maximum possible output from it for a year in ideal conditions. The contribution of a PV plant to the grid power during the specified time interval is the utilization of the plant only during that time. So, the peak power contribution of a plant, the contribution of a PV plant to the grid power during the peak time interval, is the utilization of the plant only during the peak time interval.

Because PV generation depends on weather conditions, the PV plants in a region with the same climate are likely to have the same utilization rate and the same peak power contribution. It is important to calculate the average values in the case where there are many PV plants with different capacities in the region considered. In order to obtain the average values that reflect the weather conditions in various locations in the region, we calculated the average utilization factor of the PV plants in the specified region by averaging arithmetically the utilization factors of all the PV plants within the region. The average peak power contribution was also calculated by averaging arithmetically the peak power contributions of all the PV plants with in the region.

3. Results

3.1 Peak power contribution of PV plants in the northern region

The average utilization rate of PV plants in the northern region is shown in Fig. 3. The results were obtained by analyzing the generation data of the five PV plants in the northern region of Jeju during the period from 2014. 10. 01 to 2016. 09. 30.

Table 3 shows the average contribution of five PV plants in the northern region of Jeju to the top 12.5%, 25.0%, and 37.5% of peak power in the Jeju region during July and August in 2015 to 2016.

The summer peak power contribution in table 3 is the value which is the contribution of electric power generated by the self-generation capacity of the PV plants. In 2015, they contributed 27% to the top 12.5%, 26% to the top

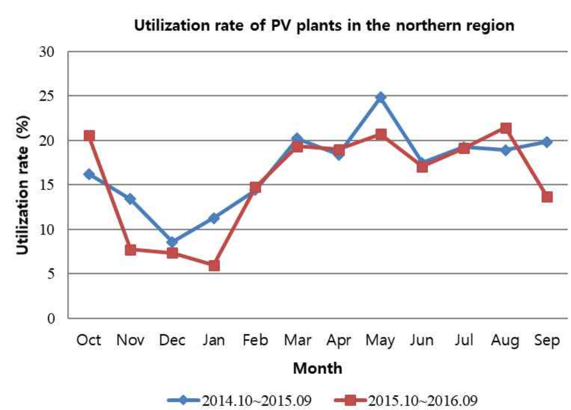

Fig. 3 Average utilization rate of PV plants in the northern region of Jeju Island

Table 3 Average peak power contribution of PV plants in the northern region of Jeju Island

Division of max. load time band	Summer peak power contribution rate (%)		
	2015	2016	Average
12.5%	27	28	28
25.0%	26	27	27
37.5%	12	12	12

25.0% and 12% to the top 37.5%. In 2016, they contributed 28% to the top 12.5%, 27% to the top 25.0% and 12% to the top 37.5%.

Table 4 Average peak power contribution of PV plants in the eastern region of Jeju Island

Division of max. load time band	Summer peak power contribution rate (%)		
	2015	2016	Average
12.5%	27	28	28
25.0%	27	28	28
37.5%	12	12	12

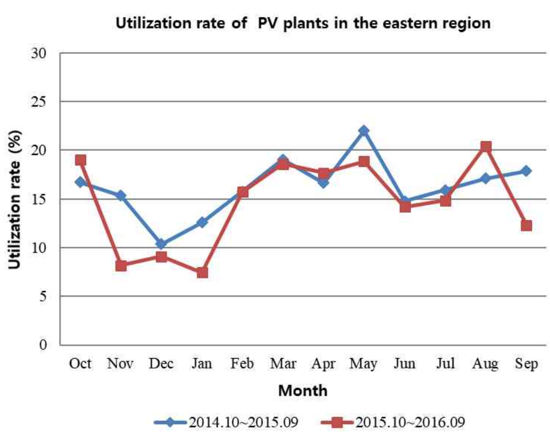

Fig. 4 Average utilization rate of PV plants in the eastern region of Jeju Island

3.2 Peak power contribution of PV plants in the eastern region

The average utilization rate of PV plants in the eastern region is shown in Fig. 4. The result was obtained by analyzing the generation data of six PV plants in the eastern region of Jeju during the period from 2014. 10. 01 to 2016. 09. 30.

Table 3 shows the average contribution of six PV plants in the eastern region of Jeju to the top 12.5%, 25.0%, and 37.5% of peak power in the Jeju region during July and August in 2015 to 2016.

The summer peak power contribution in table 4 is the value which is the contribution of electric power generated by self-generation capacity of the PV plants. In 2015, they contributed 27% to the top 12.5%, and 27% to the top 25.0% and 12% to the top 37.5%. In 2016, they contributed 28% to the top 12.5%, 28% to the top 25.0% and 12% to the top 37.5%.

3.3 Peak power contribution of PV plants in the southern region

The average utilization rate of PV plants in the eastern region is shown in Fig. 5. The result was obtained by analyzing the generation data of four PV plants in the eastern region of Jeju during the period from 2014. 10. 01 to 2016. 09. 30.

Table 5 shows the average contribution of four PV plants in the eastern region of Jeju to the top 12.5%, 25.0%, and 37.5% of peak power in the Jeju region during July and August in 2015 to 2016.

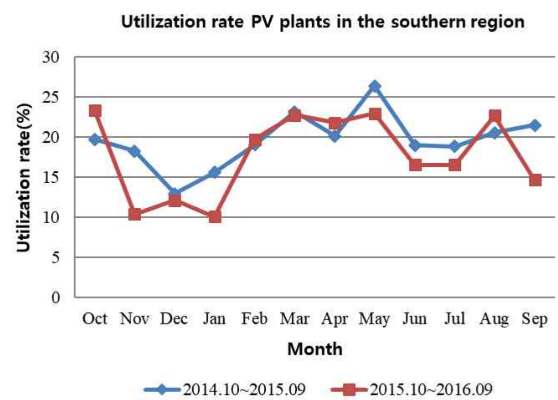

Fig. 5 Average utilization rate of PV plants in the southern region of Jeju Island

Table 5 Average peak power contribution of PV plants in the southern region of Jeju Island

Division of max. load time band	Summer peak power contribution rate (%)		
	2015	2016	Average
12.5%	27	28	28
25.0%	27	27	27
37.5%	12	12	12

The summer peak power contribution in table 5 is the value which is the contribution of electric power generated by the self-generation capacity of the PV plants.

In 2015, they contributed 27% to the top 12.5%, and 27% to the top 25.0% and 12% to the top 37.5%. In 2016, they contributed 28% to the top 12.5%, and 27% to the top 25.0% and 12% to the top 37.5%.

3.4 Peak power contribution of PV plants in the western region

The average utilization rate of PV plants in the eastern region is shown in Fig. 6. The result was obtained by analyzing the generation data of nine PV plants in the eastern region of Jeju during the period from 2014. 10. 01 to 2016. 09. 30.

Table 6 shows the average contribution of nine PV plants

Table 6 Average peak power contribution of PV plants in the western region of Jeju Island

Division of max. load time band	Summer peak power contribution rate (%)		
	2015	2016	Average
12.5%	33	33	33
25.0%	33	34	34
37.5%	15	15	15

in the eastern region of Jeju to the top 12.5%, 25.0%, and 37.5% of peak power in the Jeju region during July and August in 2015 to 2016.

The summer peak power contribution in table 6 is the value which is the contribution of electric power generated by self-generation capacity of the PV plants.

In 2015, they contributed 33% to the top 12.5%, 33% to the top 25.0% and 15% to the top 37.5%. In 2016, they contributed 33% to the top 12.5%, 34% to the top 25.0% and 15% to the top 37.5%.

4. Discussion

Let's compare the results of the summer peak power contribution of the PV plants in the 4 regions from Fig. 3 to Fig. 6. This is summarized in the Table 7. First, we can see that the summer peak power contribution rates of the PV plants are not high. The average yearly utilization rate for an hour with the maximum output usually is over 40% in Jeju[5]. A previous study on the contribution of renewable energy plants showed that the 12.5% summer peak power contribution rate of nation-wide PV plants in South Korea during the years 2003-2005 was 34.5% [9]. The low summer peak power contribution rate of PV plants in Jeju in this study is due to

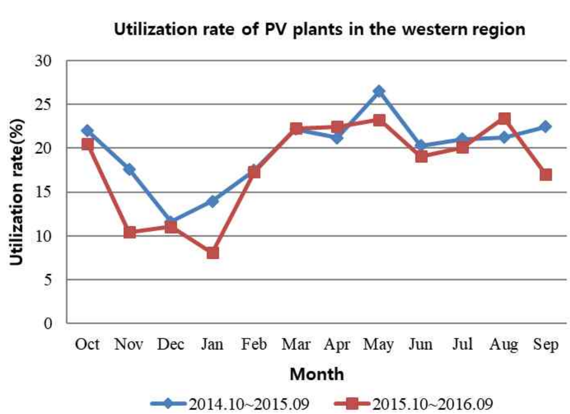

Fig. 6 Average utilization rate of PV plants in the western region of Jeju Island

Table 7 Comparison of average peak power contributions of the PV plants in the 4 regions of Jeju Island

Division of max. load time band	Average summer peak power contribution rate of PV plants in the respective region (%)			
	Northern	Eastern	Southern	Western
12.5%	28	28	28	33
25.0%	27	28	27	34
37.5%	12	12	12	15

※The contribution is averaged for 2 years, 2015 and 2016

the fact that the time bands with no generation by the PV plants is in the max. load time band.

The results from Fig. 3 to Fig. 6 and Table 7 show that the western region has a higher contribution rate than the other regions. Of course, that was due to longer sunshine duration of the western region than the others. We can see by comparing Fig. 6 with Fig. 3-5 that this can be attributed to the fact that the western region had a much higher utilization rate during July and August in 2015 and 2016 than the others.

5. Conclusion

We divided Jeju Island into four regions and chose 24 PV plants. The average contribution of the PV plants to electric power utilization in the respective region during the summer peak times was investigated.

First, electric power peaks in July and August of 2015 and 2016 were analyzed. As a result, the power peak was the highest in 2016, and the peak power was found to increase as the year went on. Jeju has a wide peak power range from 11:00 to 21:00 during the summer.

It was found that the summer peak power contribution of the PV plants on Jeju Island was not high in comparison to other provinces. The best average summer peak power contribution rate during the 12.5% maximum load period was obtained from the PV plants in the western region, and the value was 33% during the years, 2015 and 2016.

In the future studies, estimating the summer peak power contribution of the PV plants utilizing past long-term climate data in Jeju will be added.

Acknowledgments

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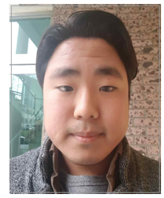

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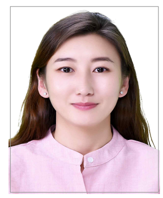

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