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Estimation of the optimal capacity of energy storage system with consideration to REC policy

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Abstract. The Korean Government is promoting the distribution of energy storage systems (ESS) that use new and renewable energy sources by applying the Renewable Energy Certificate (REC) weight factor in relation to the new and renewable energy source. This study estimated the optimal ESS capacity by conducting an economic analysis of the REC weight factor. In the case of solar energy, the weight factors of 5.0 and 4.0 were applied to ESSs set to be charged during the specific time of 10:00-16:00 and due to be installed by 2019 and 2020, respectively. The formula for calculating the optimal capacity is $E.C = 3.64 * P.C - 0.49$ for a weight factor of 5.0 and 4.0. Here, P.C refers to the solar generator capacity while E.C refers to the optimal ESS capacity. Considering the rate of increase of the charged amount per capacity of the solar power generator installed in Daejeon Metropolitan City, the optimal capacity of the ESS installed in the solar power generator is about 3.6 times that of the solar power generator when the weight factor is 5.0.

1. Introduction

While the source of most energy used in Korea is nuclear energy, the Korean government encourages the use of new and renewable energy to overcome the environmental problems caused by particulate matter and waste. However, new and renewable energy has failed to achieve widespread distribution because of the high production cost compared with other energy sources such as nuclear energy. Also, new and renewable energy is greatly affected by natural conditions and the amount of power generation and the timing of development are irregular. As the capacity of the power source increases, it is required to apply the power storage device to compensate the output of the power source which fluctuates severely. By using energy storage systems, it will contribute to effective operation, cost reduction, and activation of the renewable energy industry [1],[2]. Considering ESS supply to new and renewable energy, the average power cost of new and renewable energy has risen by about 25%, suggesting that additional government support is needed [3]. The Korean government enacted the RPS policy which mandates power companies of over a specific size to supply a certain portion of their energy with new and renewable energy sources so as to promote the distribution of new and renewable energy. It also promotes the distribution of the energy storage systems (ESS) by applying different REC weight factors according to the energy source in the case of new and renewable energy linked with an ESS. In the case of solar energy, the weight factor is applied to an ESS charged during the specific time of between 10:00- and 16:00. The weight factor of 5.0 is applied to ESSs that are due to be installed by 2019 and 4.0 to ESSs to be installed in 2020.



There is the need to study the optimal ESS capacity based on an economic analysis since there is no method of estimating ESS capacity linked to new and renewable energy. Therefore, this paper studied the optimal ESS capacity according to the REC weight factor [4].

2. The new and renewable energy policy of the Korean government

The Korean government mandates that power companies that own power generators (except for new and renewable power facilities) of a specific size (500 MW) or more shall distribute a certain percentage of their total power generation in the form of new and renewable energy. Power companies must distribute 5% of their total power generation as new and renewable energy as of 2018, and that figure will increase by 1% per year to reach 10% by 2023. The policy applies the Renewable Energy Certificate, which attests that the power company to which it has been awarded has produced and supplied new and renewable energy, and this is calculated by applying the weight factor to power (in units of MWh) generated by new and renewable facilities. Figure 1 shows the data on the REC weight factor for solar energy [4].

As shown in Figure 2, the REC weight factor is applicable only to solar ESSs charging from 10:00 to 16:00, while the solar power generated at other times is sent to the power exchange instead.

REC Weight Factor	Subject Energy and Criteria	
	Installation Type	Details
1.2	Installed in general ground	Less than 100 kW
1.0		From 100 kW
0.7		Exceeding 3,000 kW
0.7	Installed in forest	-
1.5	Used in existing facilities such as building	3,000 kW or less
1.0		Exceeding 3,000 kW
1.5	Installed afloat on the water surface, such as on a reservoir, etc.	-
1.0	Transaction of electrical power through private power generation facilities	-
5.0	ESS (linked to solar power generation)	2018, 2019
4.0		2020

Figure 1. REC weight factor for solar energy.

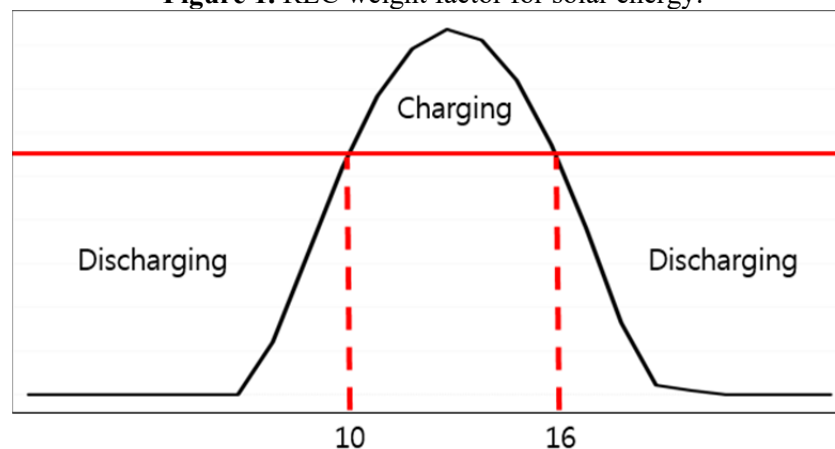


Figure 2. Assignment of REC weight factor for solar energy.

3. Data

KPX(Korea Power Exchange) has annual data for power generation by 1,689 solar power generators. We used the data obtained from 56 generators, including 52 in Jeollanam-do and 4 in Daejeon, the two regions where solar power generators are most widely distributed in Korea as of 2018. The initial generation of solar power by these generators was estimated using the year of installation and the performance degradation factor.

4. Methods

This paper uses the data on solar power generation traded within KPX to estimate and compare the ESS capacity. To calculate the LCOE, the REC weight factors of 5.0 (2019) and 4.0 (2020) were used for ESSs linked to a solar power generator, and was compared with the LCOE for solar power generators not linked to ESSs. Since the lifetime of a solar power generator and that of an ESS are 20 years [5] and 12 years [6], respectively, it is assumed that a solar power generator operates for 8 more years after its 12-year operation as an ESS. Moreover, the uniform discharge was postulated by dividing the total daily accumulated charge by the discharge time (18 hours). Finally, the optimal ESS capacity was determined to be where the LCOE was at its minimum.

4.1. LCOE (Levelized Cost of Energy)

The LCOE is the average cost of power generation per kWh. It is calculated by dividing the present value of the total cost (including the generation facility) by total power generation [7].

$$LCOE = \frac{CAPEX + \sum_{n=1}^T \frac{OM_n + FC_n}{(1+r)^n}}{\sum_{n=1}^T \frac{(1-d)^n \times P}{(1+r)^n}} \quad (1)$$

In the above equation, $CAPEX_t$ includes the solar module, inverter, BOP (balance of plant), ESS, PCS (Power Conversion System), EPC (Engineering, Procurement, and Construction), and other costs. OM means the operation and maintenance cost; FC refers to the interest cost and insurance premium; r refers to the discount rate, d refers to the degradation factor, and P refers to the power generated by solar generators. Table 1 show the conditions for LCOE.

Table 1. Prerequisites for LCOE analysis.

	Photovoltaic ^a	ESS ^b	PCS ^a
CAPEX (\$/kW)	1,600,000	470,106	290,000
OM&FC (%)	2%/year (CAPEX)	3%/year (CAPEX)	3%/year (CAPEX)
Discount rate (r , %)	5.5%	5.5%	5.5%
Performance degradation factor (d , %)	0.8%	-	-
Charge/discharge efficiency(%)	-	95	-
Life (year)	20	12	20

^a Photovoltaic and PCS data cited from [5]

^b ESS data cited from [6]

- ESS installation cost 420(\$/kWh), 2018.09.07 exchange rate 1119.3(₩/\$)

5. Result

Figure 3 shows the annual charge graph according to the change in ESS capacity of a solar power generator installed in Daejeon Metropolitan City. It shows that the slope gradually decreases from the ESS capacity of 330 MW, and it represents the decline of the increase rate of annual charging. The minimum LCOE value occurs at the point where the increase rate decreases, which is the optimal ESS capacity. The installed capacity of the abovementioned solar power generator is 98 kW, and it can be

concluded that the ESS capacity is optimal when it is about 3.3 times the capacity of the solar power generator. Figure 4 shows the result of applying the data to all points.

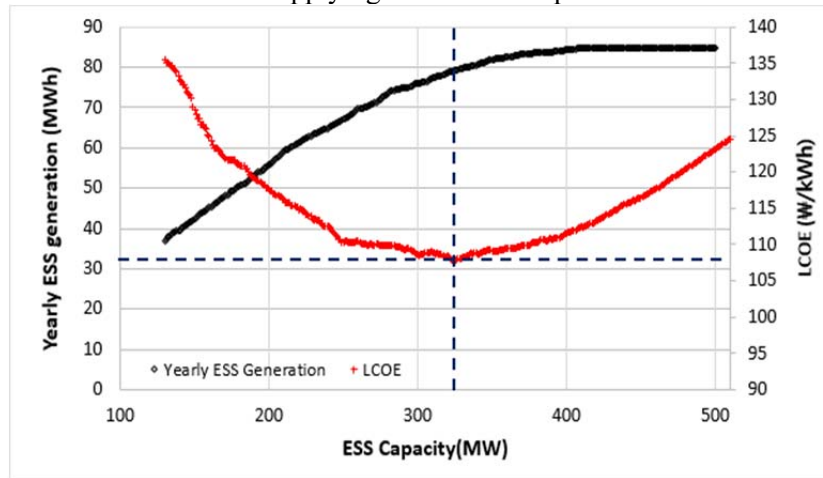


Figure 3. Annual ESS charge and LCOE according to the change of ESS capacity.

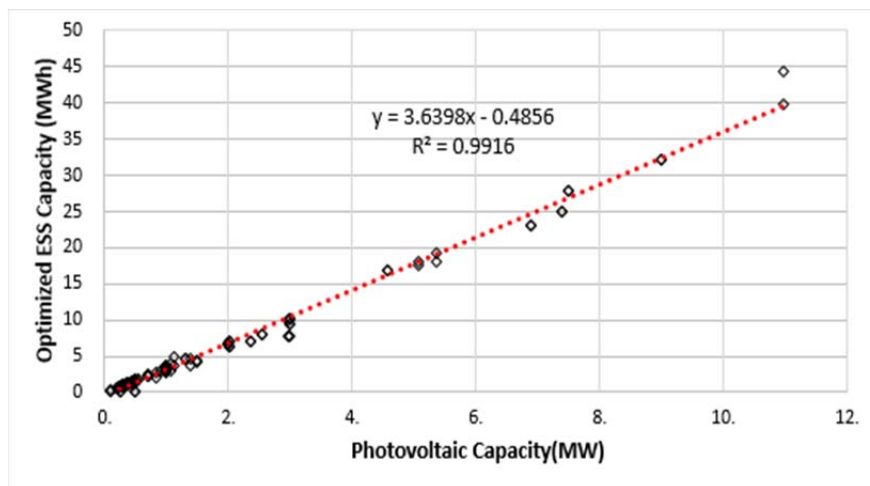


Figure 4. photovoltaic - optimal ESS capacity.

Figure 5 shows the result of the correlation analysis between the solar power generator and optimal ESS capacity when the REC weight factor was 5.0 and 4.0 in 2018-2020. The optimal ESS capacity of the data of 56 solar power generators used in this study is 3.64 times that of the solar power generator. The optimal ESS capacities linked to solar power generation were similar even when the REC weight factor was different because the increase rate decreases when the annual charging of a solar power generator is 3.6 times its installed capacity. The correlation coefficient R^2 was 0.992 indicating a high correlation and confirming the correlation between the installed capacity of a solar power generator and the installed capacity of an ESS. In this case, the PCS capacity was calculated based on the maximum charging and discharging.

The comparison of the LCOE without ESS installation and the LCOE of optimal ESS capacity showed that the difference of LCOE decreased by 5.1 (¥/kWh) and 4.3 (¥/kWh) when the utilization rate increased by 1%. The power generated outside the designated charging time was 37% in the case of a solar power generator with a utilization rate of 20%, and 24% when the utilization rate was 14%. It indicates that the LCOE gradually decreases since the power generated outside the designated

charging time increases as the utilization rate increases. Moreover, when the REC weight factor is 4.0 and/or the utilization rate is over 19%, it is more economical not to install an ESS since the LCOE yields less.

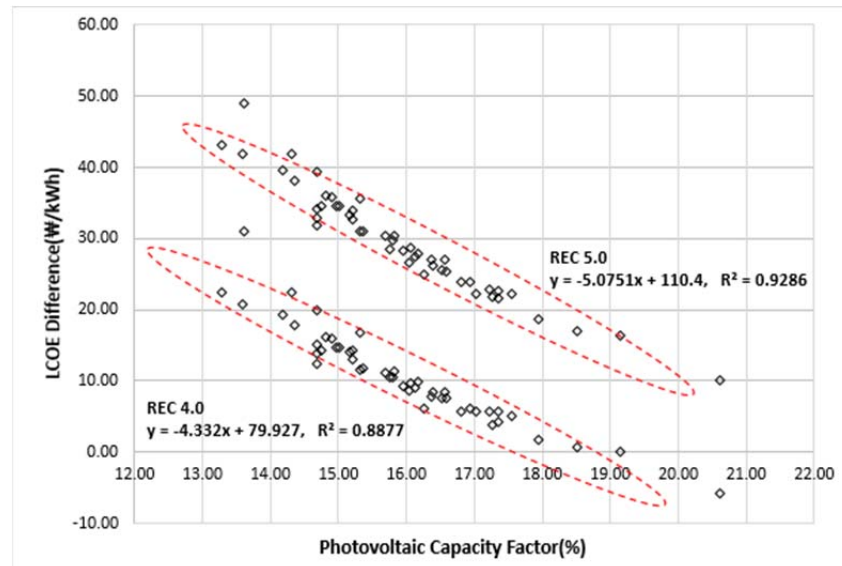


Figure 5. Difference in LCOE between ESS existence and nonexistence.

6. Conclusions

This paper calculated the optimal ESS capacity according to the REC weight factor, using data obtained from 56 locations. The results show that the LCOE value increased as the increase rate of the annual charging according to the change in ESS capacity decreased, beginning when it was about 3.4 times the capacity of a solar power generator. Although the rate of optimal ESS capacity compared to the capacity of the solar power generator remained constant, the benefit of installing an ESS is likely to decrease as the utilization rate of solar power generator increases because the economic factor decreases as the rate of power generated outside the designated charging time increases.

References

- [1] Sung-In LEE 2014 A Study on the Analysis of Energy Storage System (ESS) Demand Management *KEEI* 2014-12
- [2] Tae-Yong Jung, Yu-Tack Kim, Jung-Hee Hyun 2017 An Economic Analysis of a Hybrid Solar PV-Diesel-ESS System for Kumundhoo, Maldives *Korea and the World Economic* **18(S1)** 109-134, 2017-2
- [3] Yong-Bong LEE, Jeong-Ho Kim 2015 Economic Feasibility of Energy Storage System connected with Solar/Wind Power Generation *Journal of Energy Engineering* **24(3)** 74-81
- [4] Korea Energy Agency, www.energy.or.kr
- [5] Jae-Kyun LEE 2017 Study on strengthening flexibility of power system in preparation for spread of renewable energy *KEEI* 2017-06
- [6] Electricity Storage and Renewables:Cost and Markets to 2030 *IRENA* 2017
- [7] Chul-Yong LEE 2016 Development and operation of price forecasting methodologies of Renewable Energy Certification(REC) *KEEI* 2016-06