A New Probabilistic Production Simulation Method of Renewable Energy Generators Farm integrated with ESS

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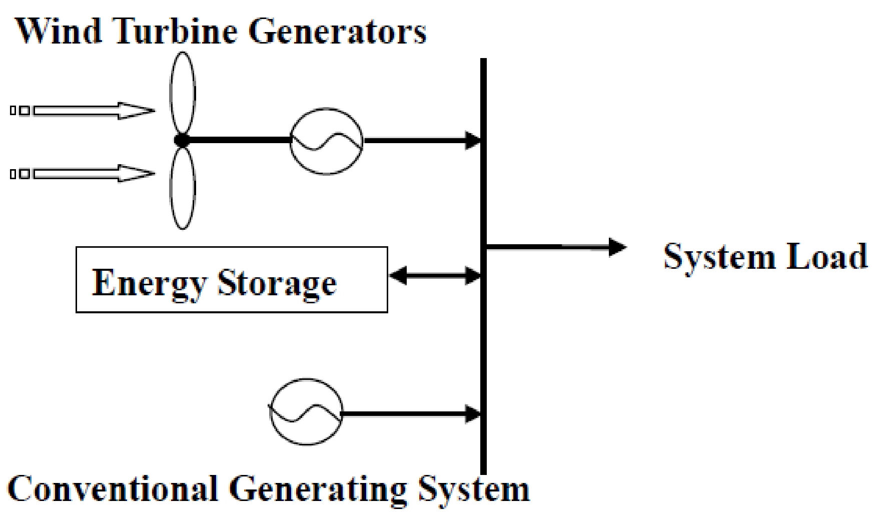
1. Introduction

- Recently, new and renewable energy generators are increasing rapidly. The outputs of these energy generators are highly effected by producing resources.
- They change quickly, and show low accuracy of their expectations on outputs. This is why their following load indices are very low.
- We can reduce the variable power by using energy storage systems(ESS) in the new and renewable energy developing field.
- Developing expected models of outputs considering constraints on operating between new and renewable energy factories, and energy saving facilities is very important. Especially, it is important when related to reliability, and stability. It is necessary that we develop these models.
- We suggest new equivalent model that can smooth the outputs in the case of when ESS is integrated with a wind energy generator, which uses highly unstable and intermittent resources.

2. Developing Models
2.1 Foreign examples Ⅰ

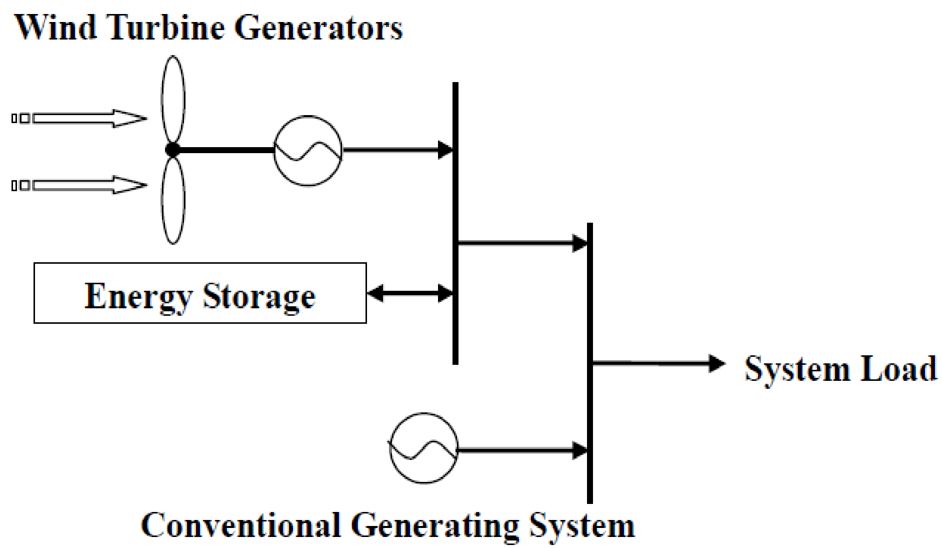
➢We can find the basic system model including wind generator and energy storage system in the figure. It considered all the constraints - various system composition, charging and discharging characteristics, order of power plant operation and safety - in the model



➢ Basic model for a wing-coventional generating system including energy storage

2. Developing Models
2.1 Foreign examples II

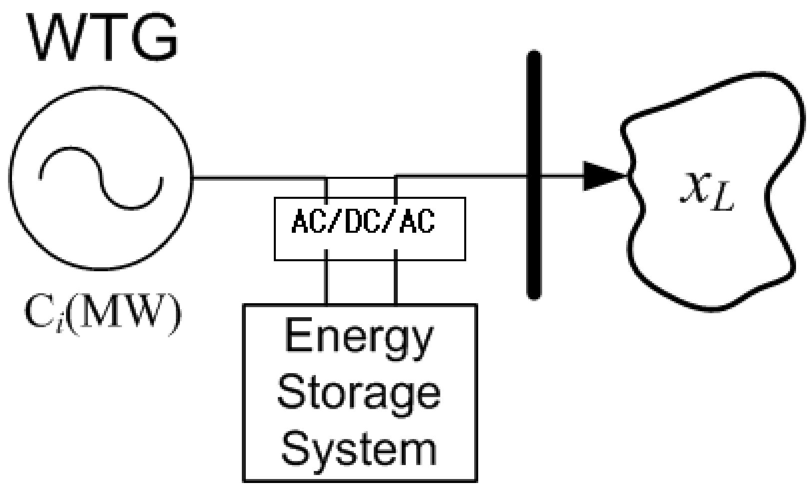
- We can find the newly revised wind power model in the figure. Energy storage plant is located near the wind farm and connected mutually by power cable. A system operator or sub-system operator can control the energy saving plant.



- Realistic model for a wind-conventional generating system including energy storage

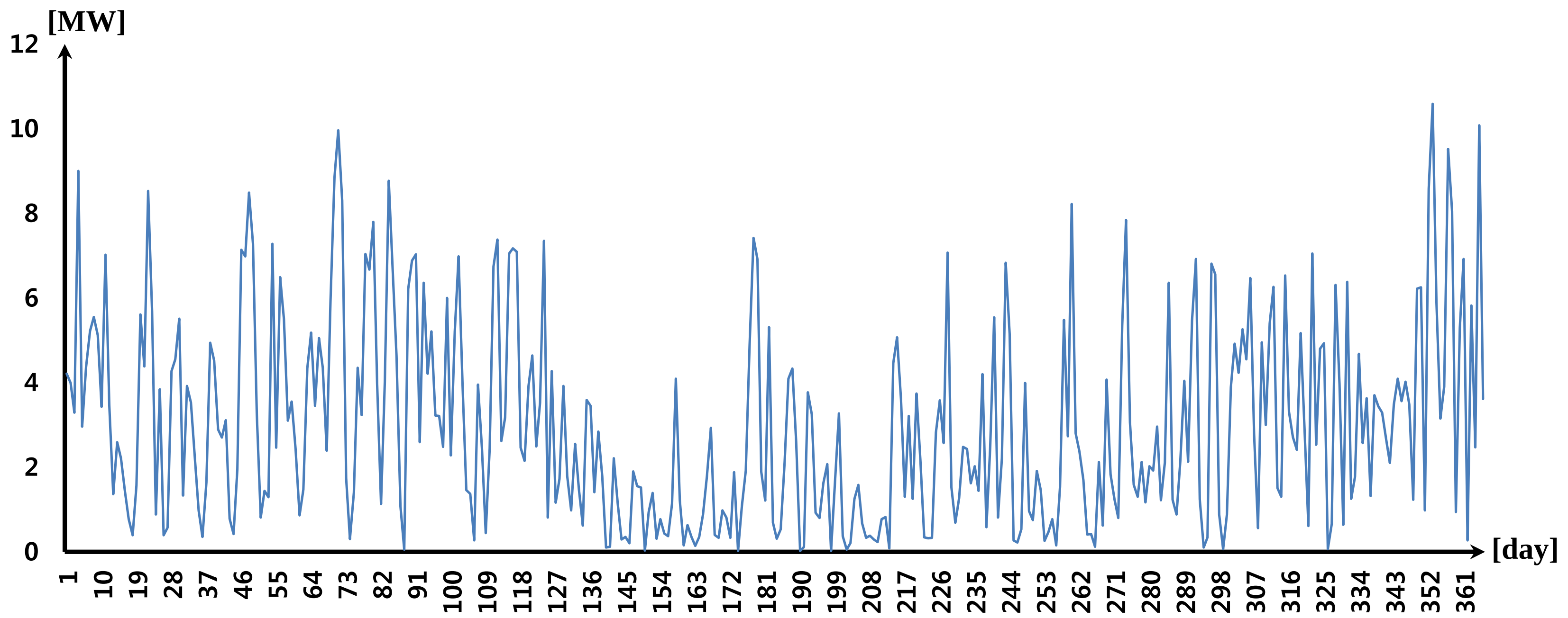
2.2 Wind turbine generator model combined with ESS

- **Outputs of wind turbine generators change randomly. Therefore, they can not satisfy loads continuously. Although we can not control the outputs of wind energies, we can use ESS when we do not get enough outputs from wind turbine generators.**



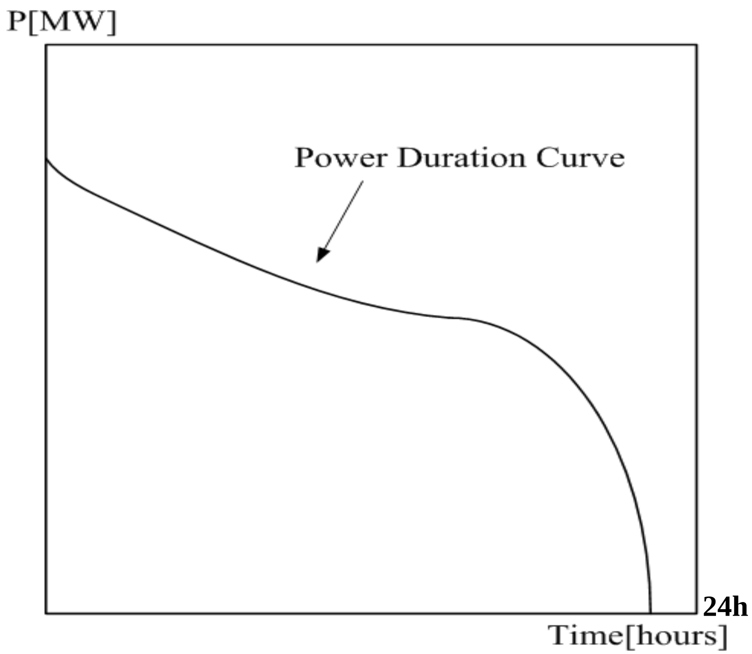
- A concept of adjusting ESS to a wind turbine generator

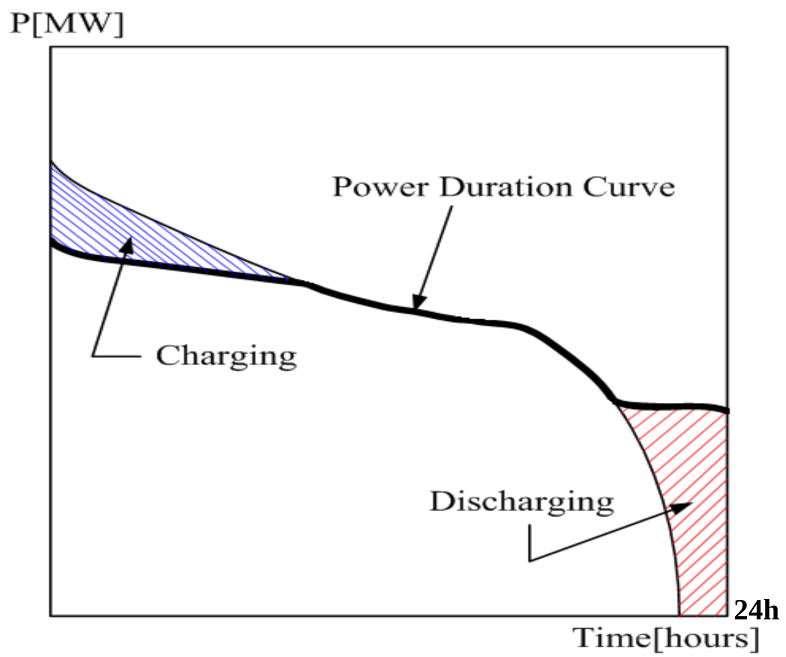
2.3 Wind turbine generator's output model (1)



➢ A power variation curve of wind turbine generator

2.4 Wind turbine generator's output model (2)

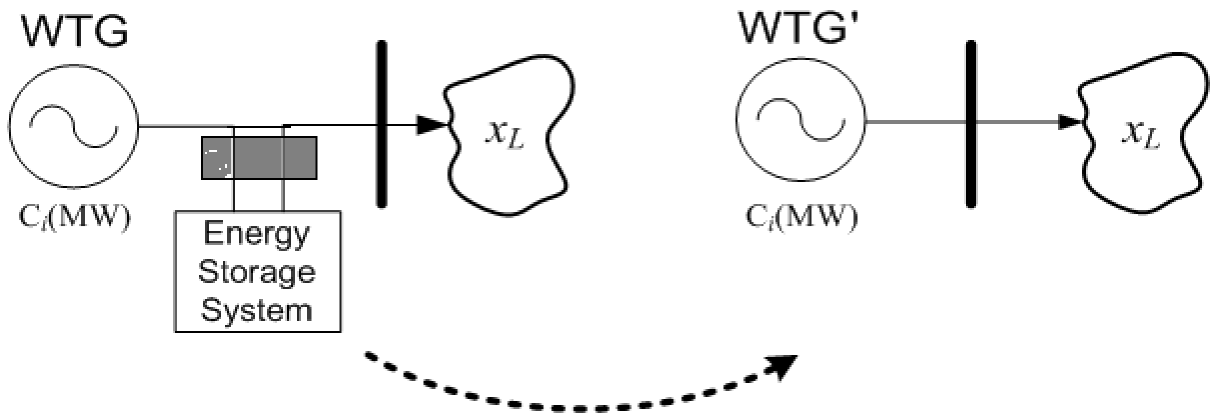




- A power duration curve of wind turbine generator
- A power duration curve with a wind turbine generator's generated amounts when ESS was adjusted

3. Case Study I

3.1 Wind turbine generator output model combined with ESS

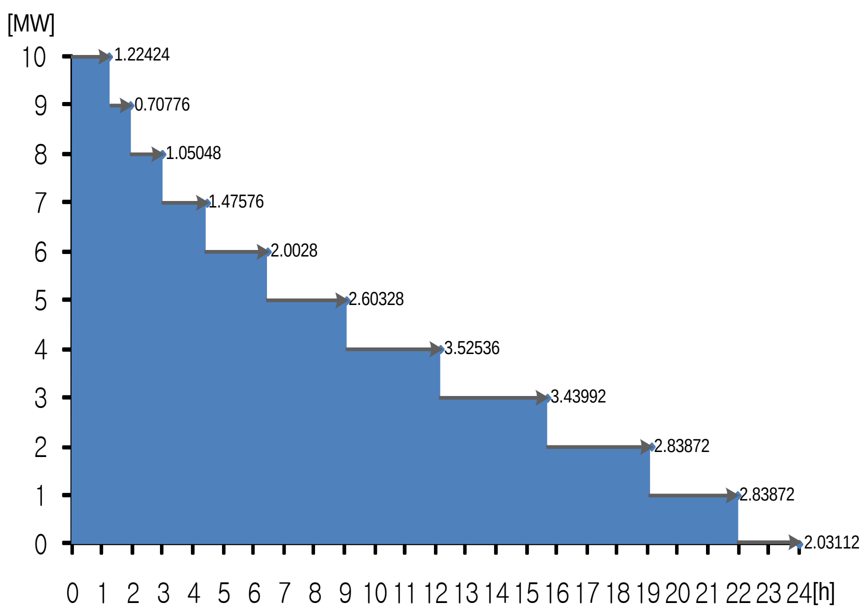


➢ An euivalent model of wind turbine generators, considering ESS

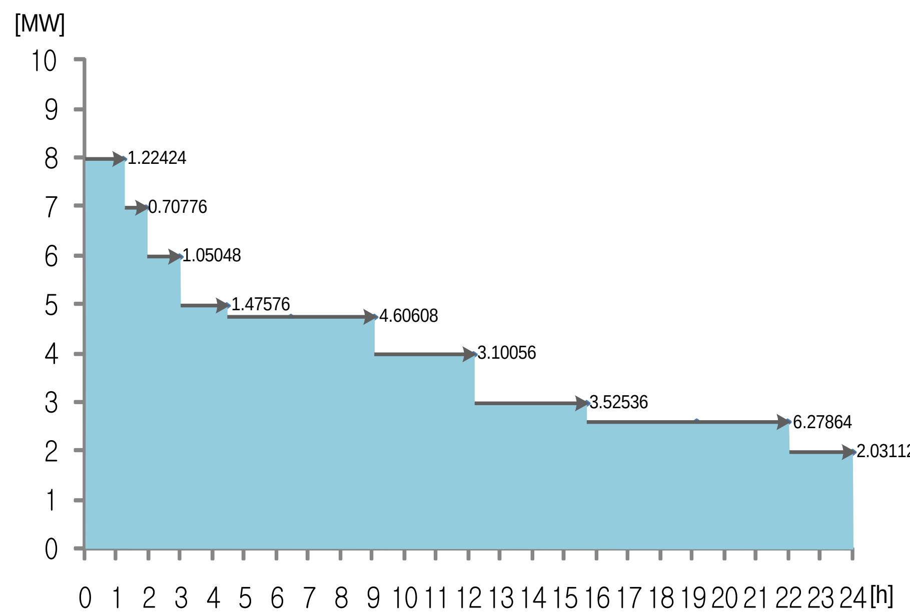
✓ Characteristics of ESS

ESS Capacity[MW]	ESS Energy[MWh]	Efficiency of ESS[%]
2	12	90

3.2 The output before and after adjusting ESS

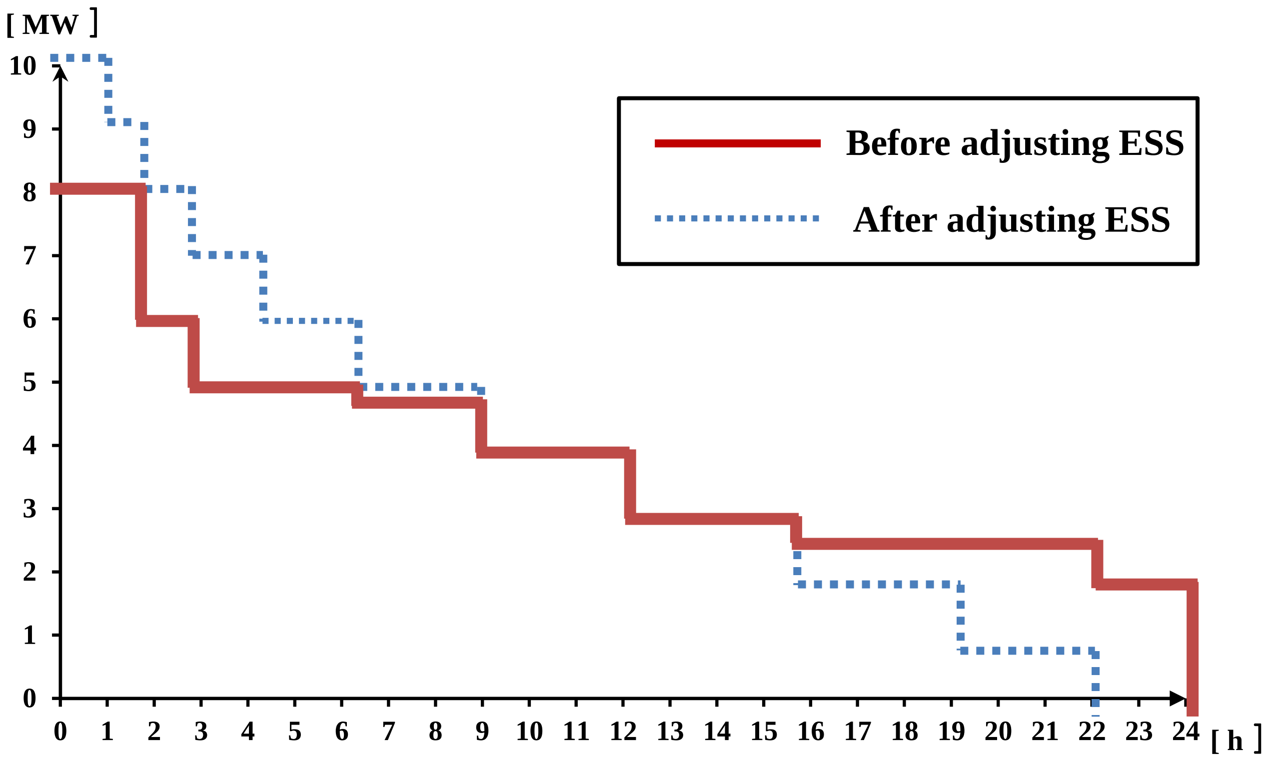


➢ The output before adjusting ESS



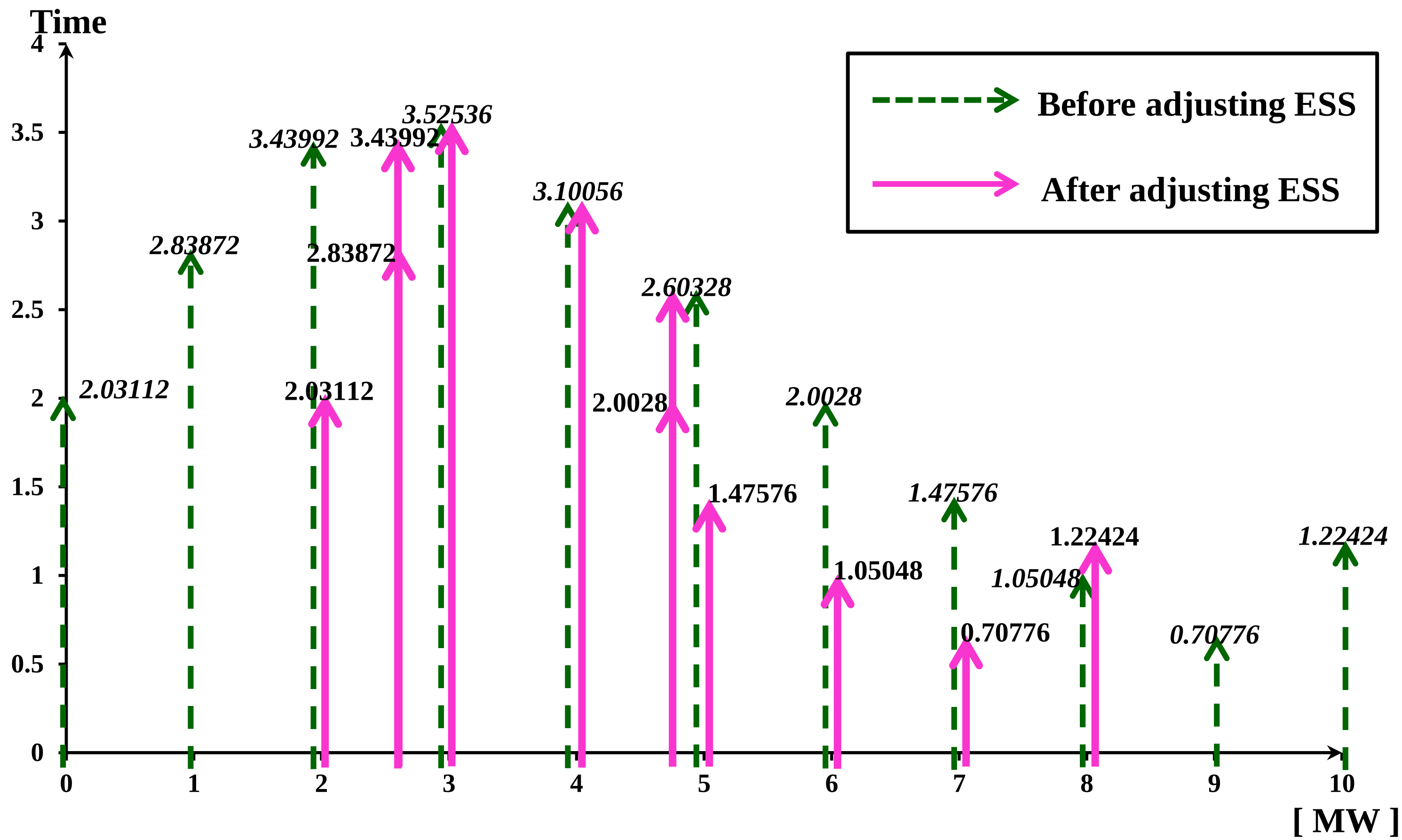
➢ The output after adjusting ESS

3.3 Comparison between before and after ESS adjustment



➢ Comparison between before and after ESS adjustment

3.3 Comparison between before and after ESS adjustment



➢ Output time distribution function before and after ESS adjustment

3.4 Compare Outputs between before and after ESS adjustment

✓ Before adjusting ESS

Capacity [MW]	Time [Hours]	Capacity × Time [MWh]	Total Energy [MWh]	Standard Deviation [MWh]
0	2.03112	0	95.076	4.25329
1	2.83872	2.83872		
2	3.43992	6.87984		
3	3.52536	10.57608		
4	3.10056	12.40224		
5	2.60328	13.0164		
6	2.0028	12.0168		
7	1.47576	10.33032		
8	1.05048	8.40384		
9	0.70776	6.36984		
10	1.22424	12.2424		

✓ After adjusting ESS

Capacity [MW]	Time [Hours]	Capacity × Time [MWh]	Total Energy [MWh]	Standard Deviation [MWh]
2	2.03112	4.06224	93.876	2.77996
2.621	2.83872	7.44028512		
2.621	3.43992	9.01603032		
3	3.52536	10.57608		
4	3.10056	12.40224		
4.76537	2.60328	12.40559241		
4.76537	2.0028	9.544083036		
5	1.47576	7.3788		
6	1.05048	6.30288		
7	0.70776	4.95432		
8	1.22424	9.79392		

✓ Outputs before and after adjusting ESS

	Without ESS	With ESS
Total Energy [MWh]	95.076	93.876
Average Generator Power [MW]	3.9608	3.9115
Standard Deviation	4.25	2.78
Peak Generator Power [MW]	10	8
Generator Power Factor[%]	39.6	48

- **The output rate of the wind turbine generator before ESS is adjusted is 39.6[%]. When ESS is adjusted, the rate increase up to 48[%]. That is about 10[%] increase. This means the facility is operating well as base outputs increase and peak outputs decrease when ESS is adjusted.**

$$GF = \frac{GP_{Average}}{GP_{Peak} \times 24} \times 100\,[\%]$$

Where,
GF: Generator power Factor
$GP_{Average}$: Generator power average
GP_{Peak} : Generator power peak

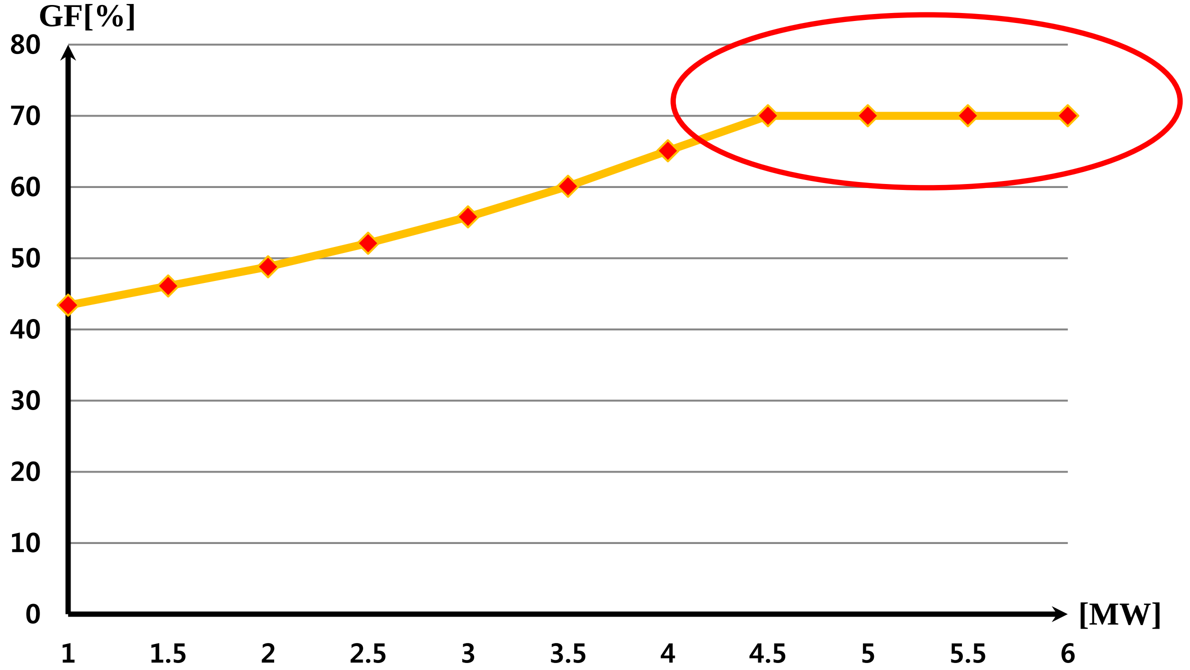
Case Study II

➢ We studied the generator power factor in accordance with ESS Capacity variation, where ESS efficiency is 0.9 and total capacity of ESS is 12[MWh]

✓ **Generator power factor in accordance with ESS Capacity Variation**

ESS Capacity[MW]	GF[%]	ESS Energy[MWh]	Efficiency of ESS[%]
1	43.4	12	90
1.5	46.1		
2	48.0		
2.5	52.1		
3	55.8		
3.5	60.1		
4	65.1		
4.5	70		
5	70		
5.5	70		
6	70		

✓ **Generator power factor curve in accordance with ESS Capacity Variation**



6. Conclusions

- We developed a base model that calculates an output state possibilities function of wind turbine generators, considering ESS

- It turned out the peak output of wind turbine generators when ESS was adjusted got lower than before the adjustment

- It is considered that if we use this theory, characteristics of outputs that ESS is adjusted will be also used for developing new and renewal energies such as solar, and tidal energies.

- Using the proposed equivalent model of ESS integrated WTG, a reliability algorithm will be developed to evaluate its reliability considering ESS in near future.

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