Preliminary Study on effects of ESS integrated nuclear power plants with increased penetration of renewable energy

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1. Introduction

Fear on nuclear accidents has increased dramatically within the population since the Fukushima accident. Politics have been affected and has led to policies that decrease the use of nuclear energy and expand the use of renewable energy. Plan RE3020 was initiated and renewable energy proportion is targeted to 20% by the year 2030 [1].

With the decrease of baseload power and increase of intermittent energy sources, the grid becomes inherently unstable. In order to mitigate the instability, large scale Energy Storage Systems (ESSs) must be introduced to the grid. Although there has been drastic development in energy storage systems, batteries especially, there is still very limited options when it comes to large scale implementations. Pumped hydro systems are probably the only reasonable option but in a densely populated country like Korea, not many sites are left for such systems.

Therefore, to maintain stability of the grid and also establish a win-win relationship between nuclear and renewable energies, ESS integrated nuclear power plants is proposed.

2. Methods and Results

2.1 Methods

The hourly demand curve of Korea in year 2017 was used as reference. Yearly increase of 1.3% was used as suggested in the 8th Basic Plan for Electricity Supply and Demand [2]. The target years of prediction are 2030, 2040, and 2050.

Supply curve for renewable energy was derived from actual electricity generation data from solar and wind farms. Data from KOSPO (Korea Southern Power) and Korea Rural Community Corporation was used. Totally, data from 41MW of wind power generation and 6.3MW of solar photovoltaic power generation was used.

The supply curve of actual plant generation data was scaled up to meet three target years. The Basic Plan targets 33.5GW of solar power and 17.7GW of wind power by year 2030. Although there are minor sources that compose the renewable energy proportion, it was assumed that solar and wind makeup the whole renewable proportion and a coefficient was multiplied to fill 20% of total generation.

20.4GW of nuclear and 39.9GW of coal is planned for year 2030 and the remaining proportion is filled by LNG power plants. Yearly average increase rate of 1.3% was given identically to all the supply curves. The installed capacity was increased while maintaining the power source ratio.

For year 2040 and 2050, the energy source proportions are all assumed to be identical to year 2030. The capacity of each source is shown in Table I.

Table I: Electricity Generated by Each Source (in GWh)

	2030	2040	2050	
Solar	72,877	82,924	94,358	11.0%
Wind	59,610	67,829	77,181	9.0%
Nuclear	158,322	180,150	204,988	23.9%
Coal	239,139	272,110	309,627	36.1%
LNG	132,487	150,753	171,538	20.0%
Sum	662,434	753,767	857,692	100.0%

Supply from renewable energy was prioritized first. Next was nuclear, the cheaper base load energy, followed by coal. Lastly, LNG was used for peak loading. When oversupply occurs even without peak loading LNG plants, excess energy from ESS integrated nuclear power plants was stored and released when more energy is needed than all the renewable, nuclear and coal combined. Round trip efficiency of 75% was used.

2.2 Results

ESSs can only generate as much energy is stored. Previous studies showed that in year 2030, the oversupply histogram and undersupply histogram cross at the 150-200GWh range. The histograms of year 2050 also cross in the same range thus the maximum energy stored in the ESS was set as 175 GWh to maximize the use of the installed ESS.

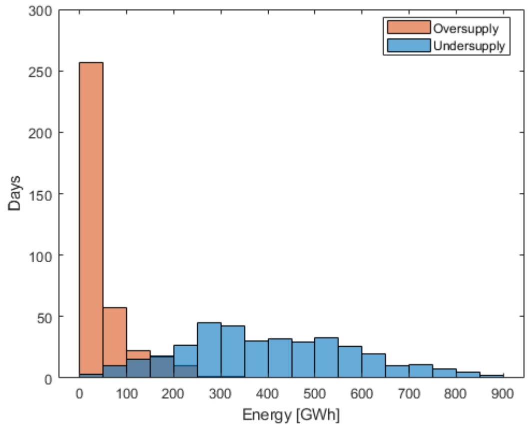

Fig. 1. Histogram of oversupply and undersupply days on year 2030 [3]

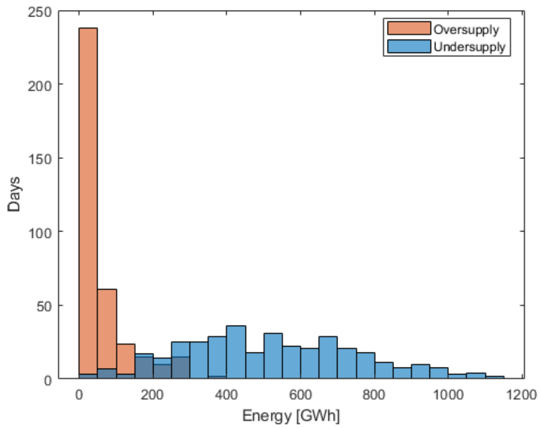

Fig. 2. Histogram of oversupply and undersupply days on year 2050

Capacity oversupply in week 40 is shown in Fig. 3. Week 40 is the week when ESS utilization is maximized. Maximum oversupply in year 2030 is 27GW for the given week while the maximum increases to 35GW in year 2050. The maximum undersupply in year 2030 is 37GW for the given week while the maximum increases to 48GW in year 2050.

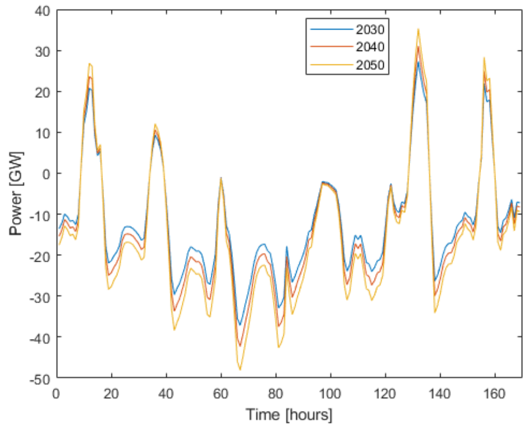

Fig. 3. Oversupply and undersupply occurring at year 2030, 2040, and 2050 at week 40

Fig. 4 shows the oversupply curve with the ESS in action. Compared to Fig. 3, there is very minimal oversupply occurring. Most of the excess energy is stored in the ESS to be used when there is a shortage of power.

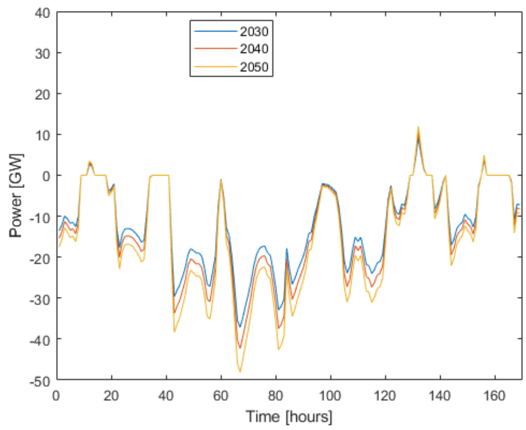

Fig. 4. Oversupply and undersupply of year 2030, 2040, and 2050 mitigated with ESS

Two major expectations from the implementation of ESS are profit from electricity arbitrage and Green House Gas (GHG) reduction.

This profit only accounts for electricity sales. Actual profit will be affected by the cost of ESS installation. This installation cost is also affected by what technology is implemented and what the actual round trip efficiency is. Comprehensive analysis must be conducted to compare different ESS technologies and the option of base load curtailment.

GHG emission reduction can be calculated with life cycle GHG emission of each sources. If we multiply the total peak load LNG energy (2000 gCO_2eq/kWh) replaced by nuclear ($4gCO_2eq/kWh$) [4], we can calculate the total GHG emission reduced. Out of the 98.5 million tCO_2eq reduction allocated to the power sector by the government, the implementation of ESS can manage 27.3% of reduction by year 2030. Additional measures should be taken to reduce emissions from fossil fuel plants.

Table II: Expectations from ESS usage

	Profit from electricity arbitrage (KRW)	Reduced Green House Gas (tCO_2eq)
2030	255 billion	26.9 million
2040	286 billion	30.2 million
2050	321 billion	34.0 million

3. Conclusions

With increase of renewable energy and reduction of base load energy, measures must be taken to stabilize the grid. ESS integrated nuclear power plants can become an option. If implemented in the Korean grid, we can expect 321 billion KRW of profit from electricity sales and 34 million tons of CO_2 emission.

ACKNOWLEDGEMENTS

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