MODELLING ANALYSIS FOR OPTIMAL INTEGRATION OF SOLAR PV IN NATIONAL POWER GRID OF JAPAN

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Overview

Renewable energy is expected to play an essential role as a socially preferable technical option for energy security and environmental challenges, and currently in Japan, alternative energy sources compensating nuclear energy have shown a considerable increase such as solar PV. Since July, 2012, the Japanese government started to implement a Feed-in Tariff (FIT) system for renewable electricity, and particularly after the FIT implementation together with continual PV cost reduction, cumulative installed PV capacity in Japan shows explosive growth from 6.6 GW in 2012 to 43 GW in 2016, which ranked the third largest installed capacity in the world. For the future, furthermore installation of PV is expected in Japan, and therefore, policy and technology should be discussed for achieving optimal PV integration in the nation-wide power system. This paper analyzes an optimal power generation mix in Japan's national power grid by considering the possibility of large-scale PV integration. The study is performed by developing an optimal power generation mix model (Figure 1), and the model developed here is suitable to the discussion of optimal power system planning for promoting solar PV and transforming power grid of Japan

Methods

The authors try to develop an optimal power generation mix model (Figure 1) under various technical constraints employing linear programming technique based on the authors' previous work [1][2][3]. the highlight of the model consists in detailed geographical resolution derived from 352 nodes and 441 high-voltage power transmission lines except for Okinawa region and in detailed hourly temporal resolution in a whole year. Based on the information [4], the topology of power transmission network in Japan is explicitly considered in the model as shown in Figure 2. As energy storage technology, the model incorporates the possible deployment of sodium-sulfur battery (NAS battery) and Li-ion battery as well as pumped-storage hydro power. In the model, active power flow is considered through a direct current (DC) method. The minimization of the objective function, comprised of facility and fuel cost, enables us to identify the best mix for power generation and capacity of the country's power plants. Regional wind and PV output are estimated at 10-min resolution using a detailed meteorological database called AMeDAS in Japan.

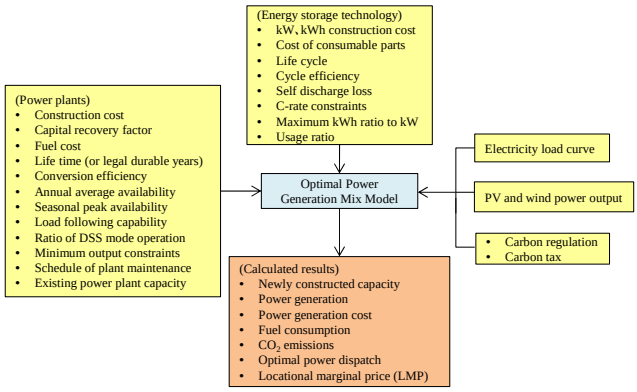

Fig.1 Outline of optimal power generation mix (OPGM) model

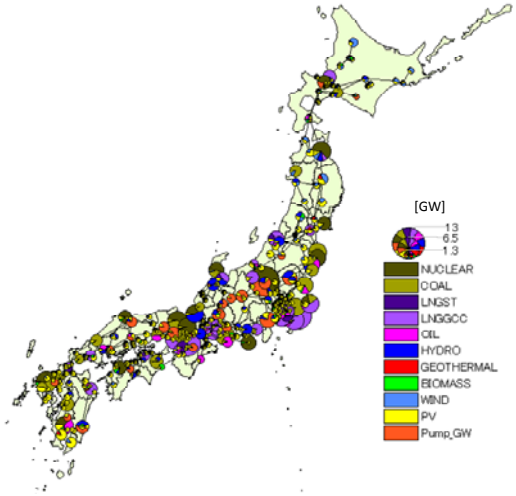

Fig.2 Power grid topology and locational distribution of power generation units in Japan

Results

Computational simulation is conducted under two scenario associated with the allocation of PV capacities into the nodes in power grid. In the first case, called as “PV Base” case, PV capacities are allocated into each node of power grid in a top down manner, reflecting existing endorsed capacities in FIT system of Japan and installable potential assessed by Ministry of Environment of Japan. That is, PV capacities are exogenously given to each nodes of the grid as shown in Figure 3. In the second case, reffered as “PV Opt” case, the allocation of PV capacities into the grid is endogenously determined through the optimization, and in this case, PV capacities in the nodes are treated as decision variables and specified through the cost minimization. The results of optimal PV allocation in PV Opt is illustrated in Figure 4. As an assumption, total PV power generation of Japan in PV Opt is constrained to be identical to that in PV Base (110[TWh]). Therefore, total PV power outouts are the same in both cases. In PV Opt case as shown in Figure 4, PV tends to be integrated around the area such as Tokyo and Kansai where electricity demand is intensive in the country, because, due to large-scale installation of PV on the place where electricity is extensively consumed, electricity transmission loss and total power system cost can be largely reduced. In addition, backup thermal capacity such as LNG combined cycle enough to control PV output variability can be available in demand-intensive area like Tokyo and Kansai, and that encourages optimal PV allocation in those area as well.

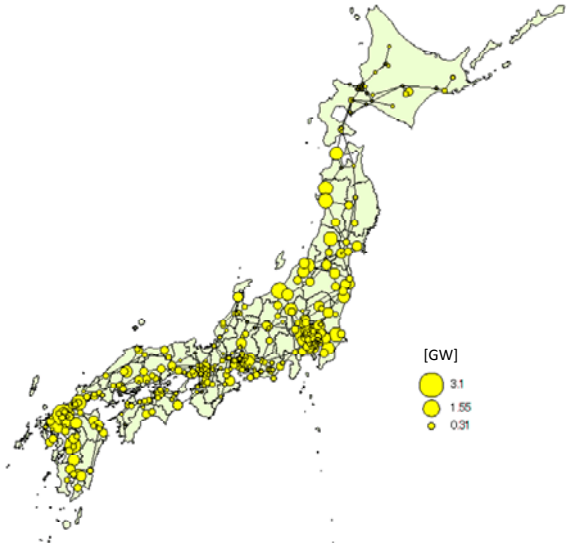

Fig.3 PV capacities’ allocation in PV Base case

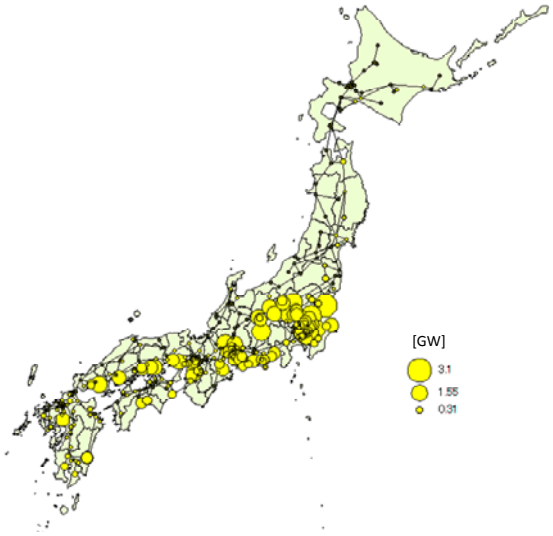

Fig.4 PV capacities’ allocation in PV Opt case

Conclusions

Increased integration of renewable energy is a technical challenge due to its uncertain variable output. For the assessment of the renewable energy integration into power system, this paper develops an optimal power generation mix model characterized by 352 nodes with 441 high-voltage power transmission lines and detailed hourly temporal resolution in a whole year. The results suggest that optimal integration of solar PV into power grid largely contributes to enhance the economic efficiency of the whole power system in Japan.

Acknowledgment

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References

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