An Optimal Mix of Wind and Solar Power Plants in a Microgrid

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Abstract

One of the ways for wind and solar power plant integration in power system could be established through microgrid concept. Microgrids, being organized as a one functional entity, provide the possibility of local optimization of renewable energy production as a way to tackle large-scale wind and solar power plant integration issues. A methodology for optimization of installed capacity of wind and solar power plants in a microgrid is developed. Two different approaches are considered: with and without demand side management (DSM). The optimization criterion is the minimization of energy transfer rate between electrical power system (EPS) and connected microgrid. Hence, the power system is observed as a collection of microgrids, which are mutually independent functional entities regarding RES integration. Each of these microgrids has specific characteristics regarding availability of renewable energy sources, as well as load demand, so it represents an optimization space independent of the rest of the EPS.

Objectives

Introducing an approach for maximization of RES hosting capacity and EPS performance in the setting of large scale wind and solar power plant integration.

Methods

The optimal mix of wind and solar power plants is determined by comparing the total energy exchange between utility grid and microgrid during one year for a range of values of their installed capacity. Demand response has be applied by intraday demand shifting with unchanged daily energy consumption. A deferrable demand share for each hour of the year has been obtained by interpolating results obtained in [1] where characteristic load diagrams and their controllable part for each season of the year are presented.

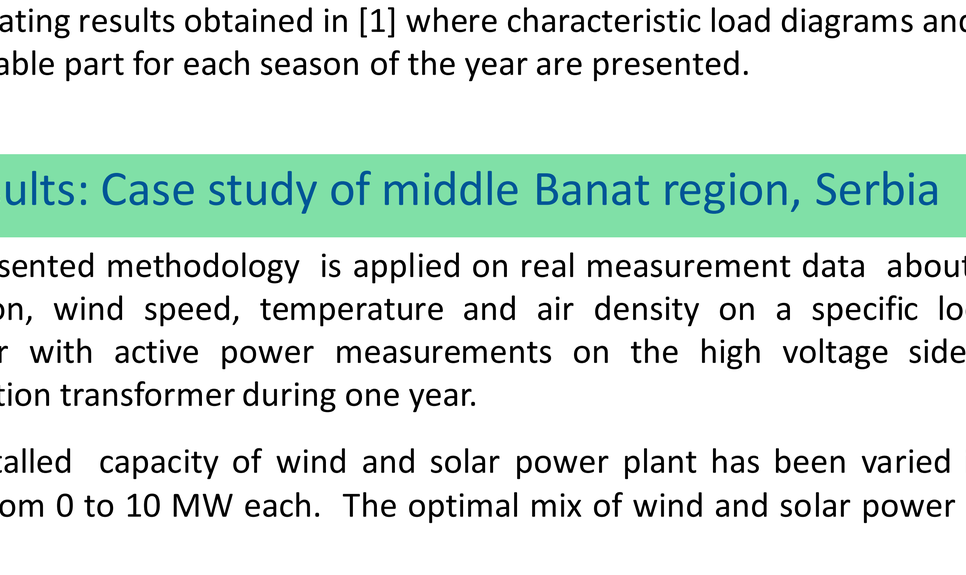
Results: Case study of middle Banat region, Serbia

The presented methodology is applied on real measurement data about solar insolation, wind speed, temperature and air density on a specific location together with active power measurements on the high voltage side of a distribution transformer during one year.

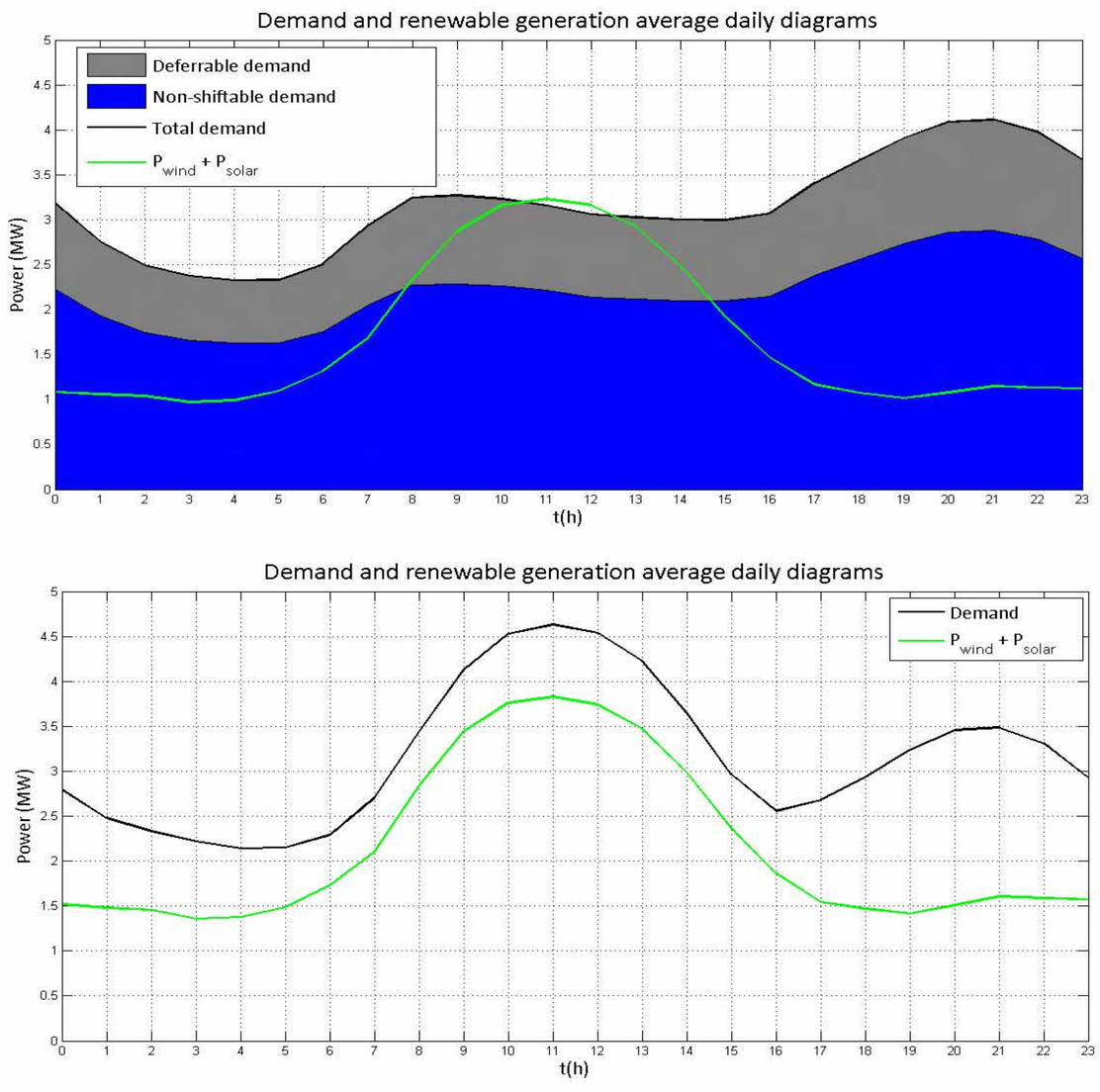
The installed capacity of wind and solar power plant has been varied in the range from 0 to 10 MW each. The optimal mix of wind and solar power plants is:

$$P_{wind} = 5 \text{ MW}, P_{solar} = 5 \text{ MW} \text{ when DSM is not applied.}$$
$$P_{wind} = 5.5 \text{ MW}, P_{solar} = 7 \text{ MW} \text{ when DSM is applied.}$$

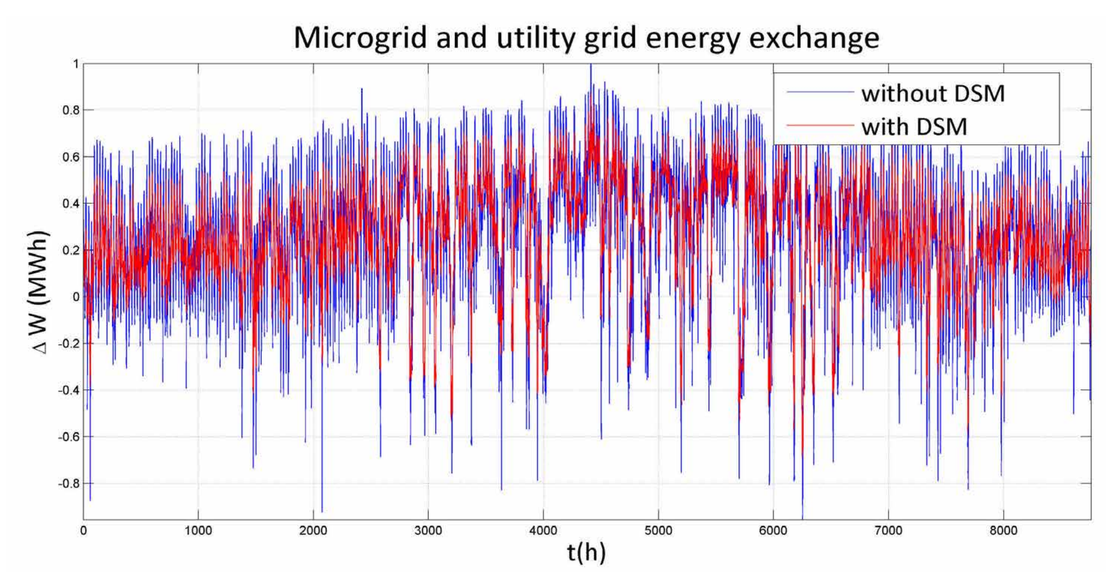
Optimal structure of installed wind and solar power plant capacity



The saddle point represents the optimal structure of installed wind and solar capacity by the criterion of minimal energy exchanged with utility grid during one year when DSM is applied in the microgrid.



Intraday demand shifting throughout the year has resulted in more correlated demand and generation average daily diagrams. Pearson's correlation coefficient of 0.86 is achieved.



Energies exchanged between utility grid and the microgrid during each hour of the year, for the cases of optimization of RES installed capacity structure with and without DSM, are compared. The effect of introducing DSM is the decrease of the load on the feeder supplying the microgrid while the optimal capacity of the installed renewable sources increased from 10 MW to 12.5 MW.

Conclusions

The proposed methodology for optimization of total rated capacity and individual share of solar and wind power plants gives a strong correlation of renewable energy generation with load demand in considering microgrid when demand side management is applied on daily horizon. As a result, the autonomy of considered microgrid is increased as well as the network capacity for installing more RES without reaching supply feeder overload.

The proposed methodology suggest the development of EPS as a hierarchically organized structure of microgrids with high level of energy independence. A structure like this, using smart grid, would provide efficiency and stability improvement of EPS performance and maximization of the penetration level of RES in EPS.

References

1. Public Enterprise " Elektromreža Srbije" development programme "Smarter grid" – Study of the demand response potential and possible effects on the transmission system of the Public Enterprise "Elektromreža Srbije", 2016.