Impact of energy storage systems on the power grid

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Introduction

- Main problem with sustainable sources is that they depend on natures conditions. In order to solve that problem, in the last couple of years, solutions like Energy Storage Systems (ESS), has been offered.
- The idea behind ESS is to store the energy, produced by sustainable sources during low demands, and use it when it is needed. With ESS, significant amounts of energy could be saved, which will be shown in this paper.
- At this moment, there are many types of ESSs like: Pumped Hydroelectric Storage (PHS), Compressed Air Energy Storage (CAES), Conventional Batteries and Flow Batteries, Hydrogen-Based Energy Storage System (HESS), Flywheel Energy Storage System (FESS), Superconducting Magnetic Energy Storage (SMES), Supercapacitor Energy Storage System, etc.

Problem formulation

- AC power flow model has nonlinear nature because the power flow into load impedances is a function of the square of the applied voltages.
- In many cases non-linearity can be avoided by using DC power flow model, but it should be mentioned that DC model is not accurate as AC power flow model. In this case, we used DC power flow model for calculation of starting values.

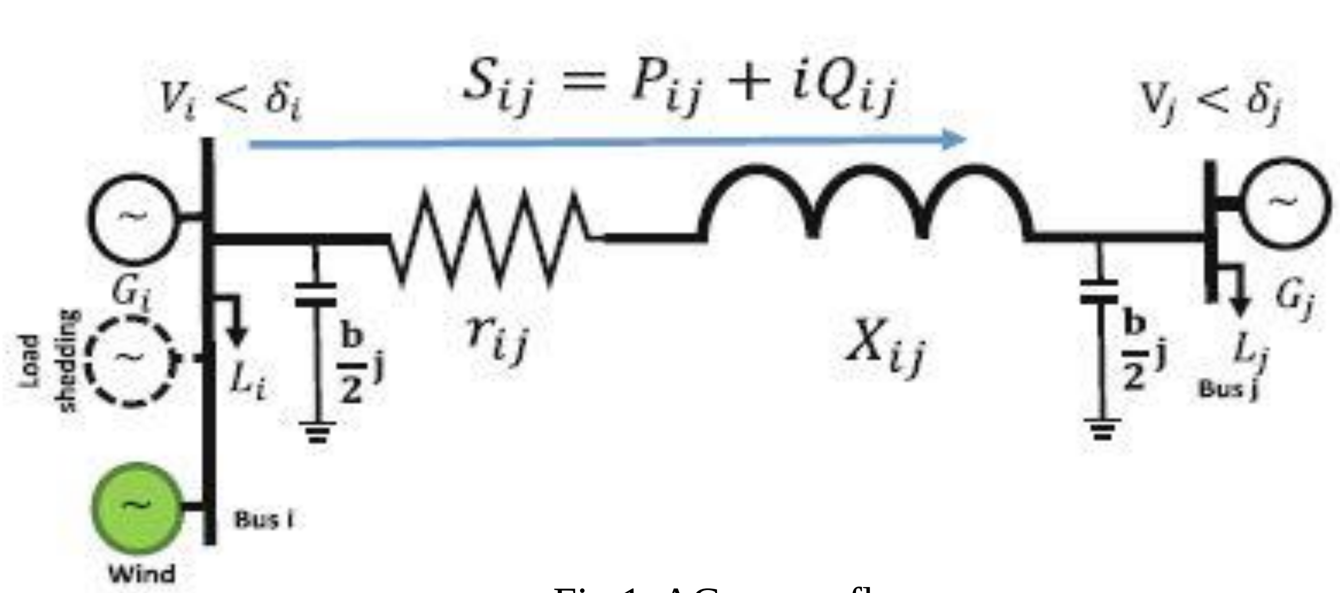

Fig 1. AC power flow

- Optimal function for minimization of power lost in transmission lines is formulated as follows

$$OF = \sum_{i=1}^{k} [g_{mn}(V_m^2 + V_n^2 - 2V_m V_n \cos(\theta_{mn}))]$$

Case study

- For our test network, we used IEEE24 modified test bus system with 3 wind turbines in nodes 8,19,21.
- Using GAMS, we calculated that minimal power losses without ESS are 0.987 [pu]. Furthermore, we done 2 more cases.
- In case A, we placed ESSs of different fixed power in non-generating nodes
- In case B, we found optimal nodes for ESS with different power.

Table I. Numerical results for case A

Nodes	Power of ESS [MW]							
	100	200	300	400	500	600	800	100
4	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
5	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
6	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
10	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
9	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
3	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
24	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
12	0,985	0,984	0,984	0,983	0,982	0,981	0,98	0,979
11	0,986	0,986	0,986	0,986	0,986	0,986	0,986	0,986
14	0,987	0,987	0,987	0,987	0,987	0,987	0,987	0,987
20	0,982	0,978	0,974	0,971	0,967	0,964	0,958	0,952
17	0,986	0,986	0,985	0,985	0,985	0,984	0,984	0,984

Table II. Numerical results for case B

Power of ESS [MW]	Minimal number of ESS in one node	Total number of ESS in grid	Total power losses	Optimal nodes
20	5	5	0,978	23-5
20	10	10	0,97	23-10
20	15	15	0,962	23-15
20	20	20	0,954	23-20
20	30	30	0,939	23-30
20	40	40	0,925	22 -1, 23-39
20	50	50	0,911	22 -4, 23-46

Conclusion

- The presented results show that with the proper analysis, for the specific network, ESS can have significant impact.
- Value of total power losses depends on location of the ESS in the grid, and its capacity.

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