CHANGING WHAT'S POSSIBLE

Studying Massive Deployment of Distributed Series Reactors in PowerWorld Simulator

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Test System/Model

- Test model: 2014 Summer/ Winter Peak model provided by PJM
- This case in from the PJM Multi-regional Modelling Working Group (MMWG)
- Used PowerWorld Simulator
  - Available Transfer Capability (ATC)
  - Security Constrained Optimal Power Flow (SCOPF)
- Added almost 12,000 contingencies to case
- Monitored 100 kV and above
- Candidate lines selected for DSR deployment
  - About 6,200 possible DSR lines in case – massive deployment system wide was tested

ATC Study

- Selected 16 different source/sink pairs, 32 scenarios, and 80 transfer levels.
- Run without DSRs, and then find the transfer limits.
- Run again with DSRs dispatching on lines that exceeded 90% of their limit in the base case or during ATC iterations. Monitoring 6,200 lines for dispatch.
- Iterated linear step used so that dispatch of DSRs would occur as part of the power flow.

Avg. MW Improvement	Max MW Improvement	Min MW Improvement	Median MW Improvement	Standard Deviation
276.3	639.8	0.9	304.7	229.5

- First limiting element average improvement

Limitations and Improvements

- PJM Methodology might assume different participation factors for generators and limits on source and sink
- Only studied one case
- Only enforced thermal limits (ATC ignores voltages)
- Possibly infeasible to deploy DSRs in this manner
- No generation re-dispatch considered
- DSRs not optimally dispatched

- However, results are encouraging and show that DSRs can push power away from highly loaded lines to lower loaded lines to increase transfer capacity.

Test Case for SCOPF Studies

- 2014 Winter Peak case from MMWG, which represented high load and wind production.
- Added similar number of contingencies.
- All wind generation placed in service with -$20/MWh operating cost.
- Added extreme amount of new wind generation (44 GW) at 87 sites. ($0/MWh cost)
- Used DC power flow as basis for SCOPF.
- Thermal generator cost data added. Hydro considered ad-hoc.
- Phase shifters fixed.
- Similar number of candidate lines for DSRs selected.

SCOPF Study

- Run SCOPF without DSRs (baseline)
- Enable DSRs for dispatch
- Limited number of DSRs to dispatch and looked at operating cost at each DSR dispatch level.

Limit on Number of D-FACTS to Dispatch	Number of D-FACTS dispatched	Total Operating Cost [$/hr]	Aggre. Wind Generator Output (MW)	Aggre. Wind Generator Profit ($/hr)	Aggregate Wind Generator Curtailment (MW)	Decrease in Cost from Base Case [$/hr]	Decrease in Cost from Base Case [$/hr/(D-FACTS unit)]
0	0	2,400,046	31,092	367,441	17,840	N/A	N/A
15,000	15,000	2,327,847	33,123	385,817	15,809	72,199	4.81
30,000	30,000	2,318,350	33,174	386,583	15,758	81,696	2.72
150,000	150,000	2,299,882	33,437	380,374	15,495	100,164	0.67
300,000	300,000	2,298,439	33,412	380,265	15,519	101,607	0.34
Unlimited	303,855	2,296,504	33,432	380,383	15,500	103,542	0.34

Limitations and Improvements

- Did not consider voltage or stability limits.
- Limited contingency information.
- No special protection schemes.
- Significant numerical instability problems. PowerWorld's OPF is a linear programming based OPF. Varying impedances causes generator sensitivities to be constantly changing, which is detrimental for linear programming integration.
- The fewer the number of DSRs available for dispatch the better behaved the algorithm will be.

- Results to indicate that the first DSRs installed have the largest impact in lowering operating cost.

Conclusions

- In both the ATC and SCOPF cases, having a large number of DSRs available on the system does improve both the transfer capability and the operating cost.
- The DSRs accomplish this by increasing the impedance of overloaded lines to reduce the flow on the lines.
- When used system wide, they have the general effect of lowering the flow on higher loaded lines and increasing the flow on other lines.