Corrective Resource Management for Voltage Support in Planning and Operation

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Outline

- a. **Objectives of software product**: To enable corrective resource management for reliability and efficiency.
- **b. System optimization software use**: Experience with NETSS extended AC OPF (AC XOPF) in enabling corrective resource management.
- **c. Software product evaluation and validation:** Comparison of NETSS results to others in off-line studies.
- **d. Effort required to implement the application:** Recommendations for planning and operations.
- **e. Who can use NETSS AC XOPF:** RTO, ISO, TO and DO.
- **f. Voltage and reactive power optimization:** Coordinated Voltage Control (CVC) across all voltage levels.

Basic premise

The purpose of an electric power system is to deliver real power to the greatest number of users, at the lowest possible cost and with the least possible pollution, all the time.

Corrective resource management enables this practice.

NETSS AC XOPF (NETSSWorks) implements corrective resource management.

Corrective Resource Management

- Adjust resources as conditions change to guarantee ``all the time'' while maximizing efficiency and minimizing pollution to the extent possible.
- Must operate resources within their limits:
  - thermal and voltage equipment limits.
  - system delivery (voltage and stability) limits.
- The best performance is obtained by adjusting the most resources.

Today's Practice

- … is focused on ``all the time''.
- … follows a preventive approach to resource management that is generally more costly and dirtier than need be, and generally serves fewer users given fixed assets.
- … could be replaced by a corrective approach to serve a greater number of users at a lower cost and with less pollution without adding more assets.

The Role of AC XOPF

- Multi-objective optimization responsive to changing system conditions.
- Responsible for maintaining operation within hardware and system limits.
- Must be AC in order to manage voltage limits and balance reactive power.
- Optimal corrective resource management is highly combinatorial and cannot be carried out by planners and operators using analysis alone.
- Iterative analysis combining DC OPF with AC PF is inadequate because it does not efficiently utilize voltage and reactive power resources.
- Need AC XOPF software to assist the decision makers.

AC XOPF Optimization Objectives

Reliability

- Maintaining compact voltage profile
- Serving the greatest load
- Responding to contingencies and intermittent resources
- Balancing power flow and maintaining operation within the limits

Efficiency

- Economic dispatching
- Reducing volatility of electricity prices
- Enabling most economical transactions
- Eliminating conservative proxy transfer limits
- Avoiding Reliability Must Run (RMR) rules
- Implementing responsive demand
- Loss minimization

Importance of voltage optimization

- Many resources (generators, FACTS, DC lines, transformers, shunts) can control voltage requiring AC XOPF for their optimization
- Without voltage optimization some assets can not be utilized up to their thermal limits
- Voltage optimization enables serving a greater number of users at a lower cost and with less pollution without adding more assets, all the time.
- Illustrations on IEEE 14 bus system.

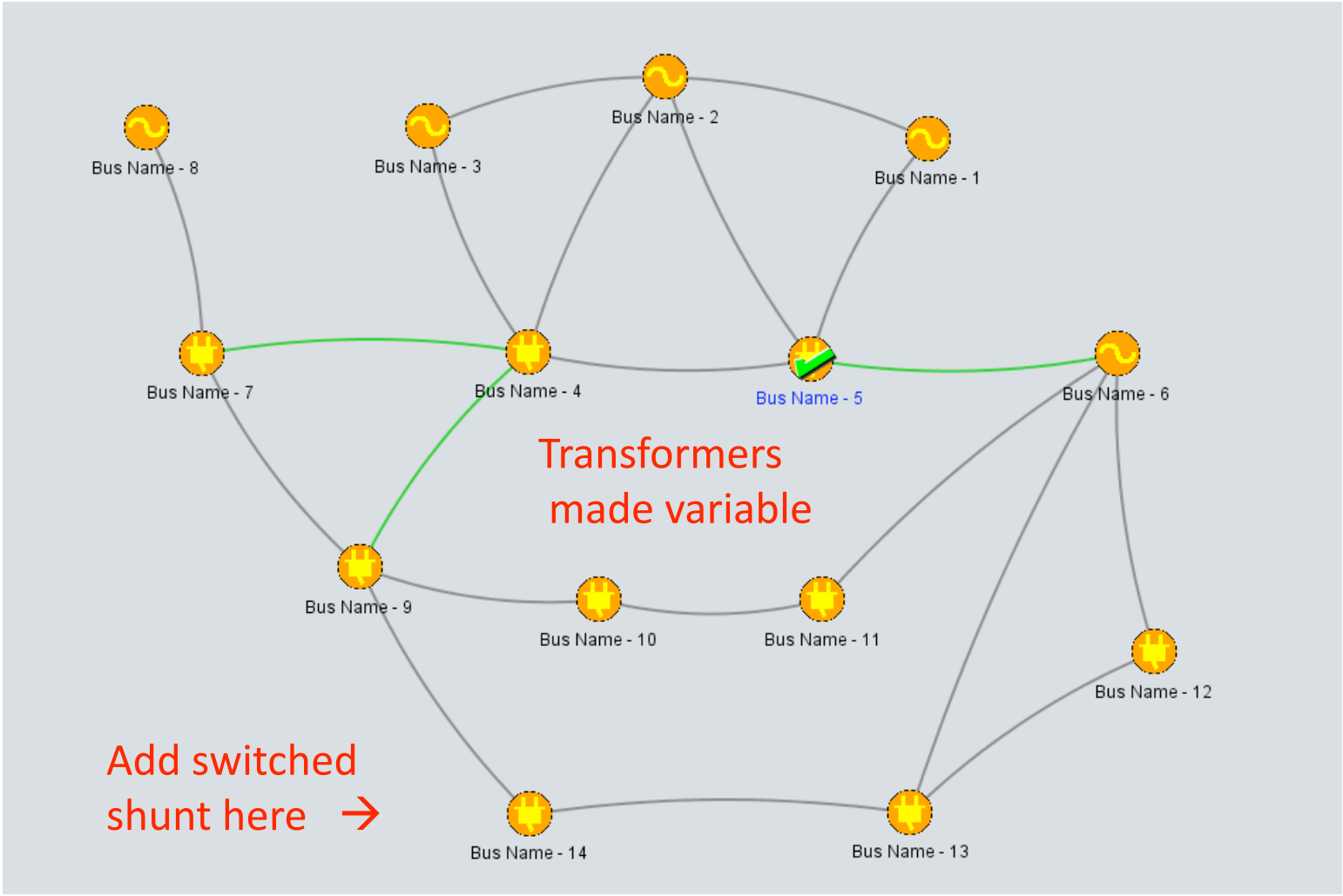
Corrective Resource Management for Reliability

- Optimization objective function depends on the system conditions

  - maintain compact voltage profile when all loads can be served (NETSSWorks Manage Extreme Voltages (MXV))

  - serve the greatest number of loads when the load cannot be served (NETSSWorks Optimized Load Distribution (OLD))

IEEE 14 bus system



Maintaining Compact Voltage Profile

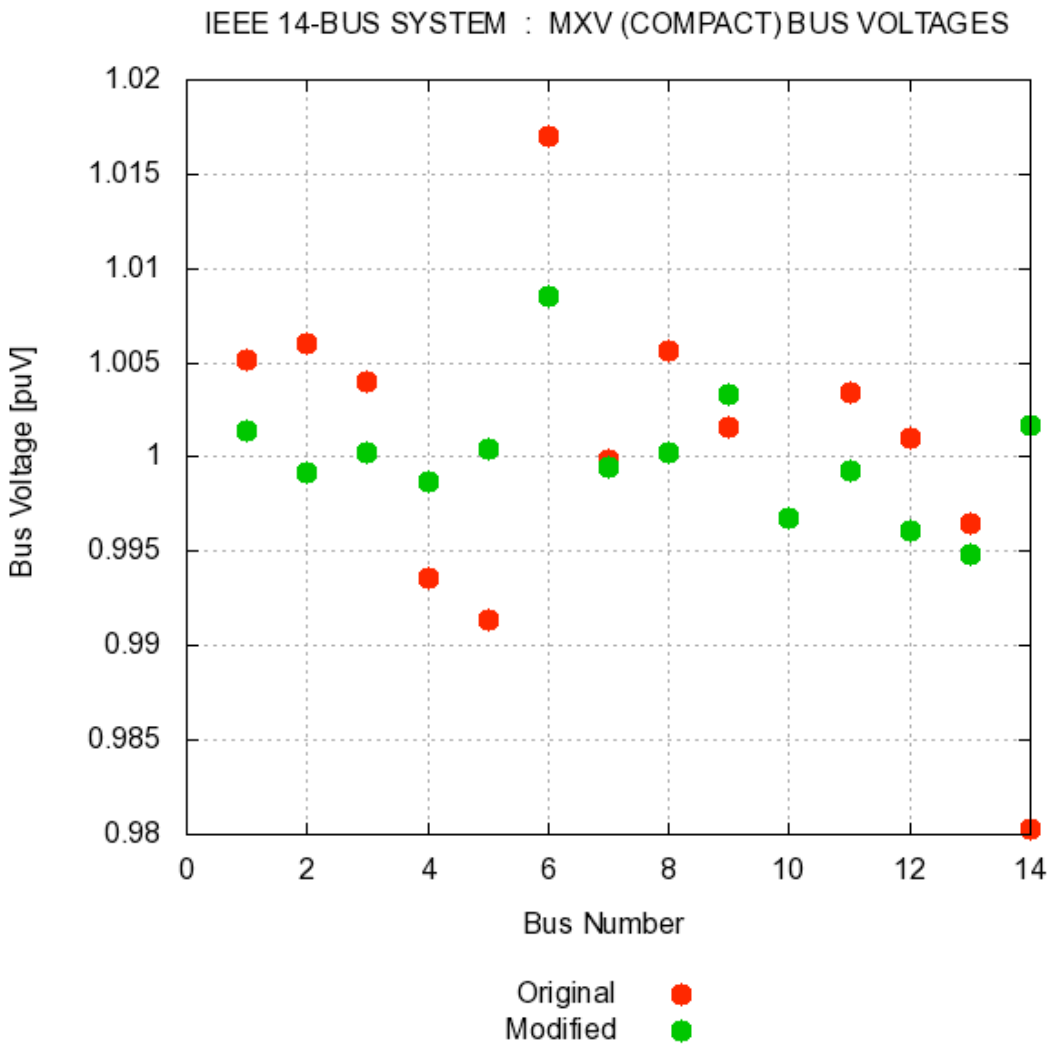
- Equipment requires less maintenance and has generally longer useful life-time when voltage is close to nominal

- Corrective actions to maintain compact voltage using NETSSWorks Manage Extreme Voltages (MXV) optimization

  -- Can be achieved by optimized combination of generator power and voltage

  -- Can also be improved with optimized transformer and shunt tap settings

Compact Voltage Profiles



Serving the Greatest Load by Corrective Resource Management

- (N-2) contingency --Loss of Generator 6 and Transformer 5-6
- Minimizing load shedding for reliable service within tight (pre-contingency) voltage limits 0.98-1.02pu; no adjustable taps
- Effect of corrective taps on increased load served
- Effect of relaxing voltage limits on load served during contingencies

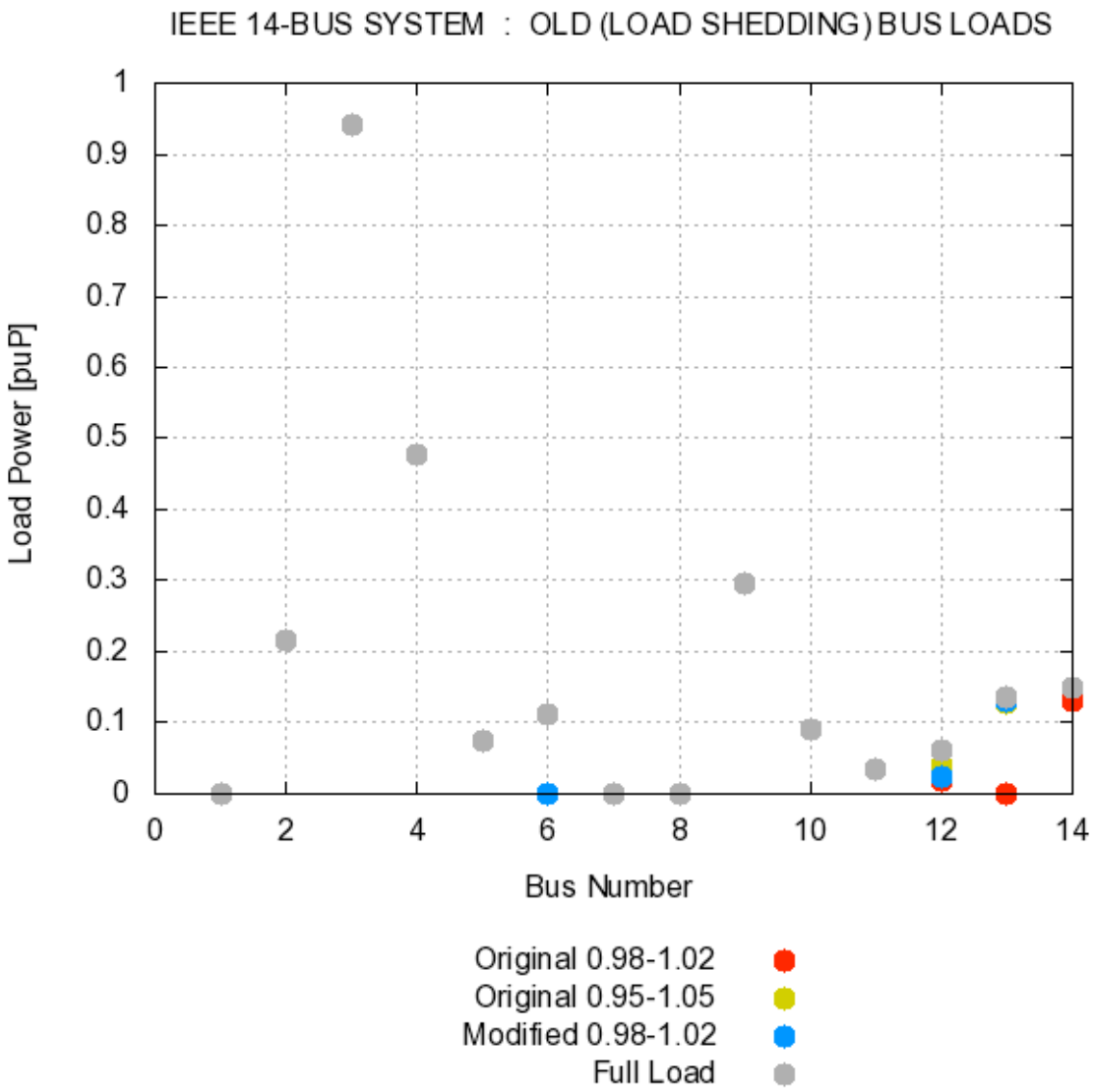
  -reliable within 0.95-1.05pu with taps; no load shedding; w/o taps load shed

  -reliable within 0.91-1.09pu w/o tap adjustments

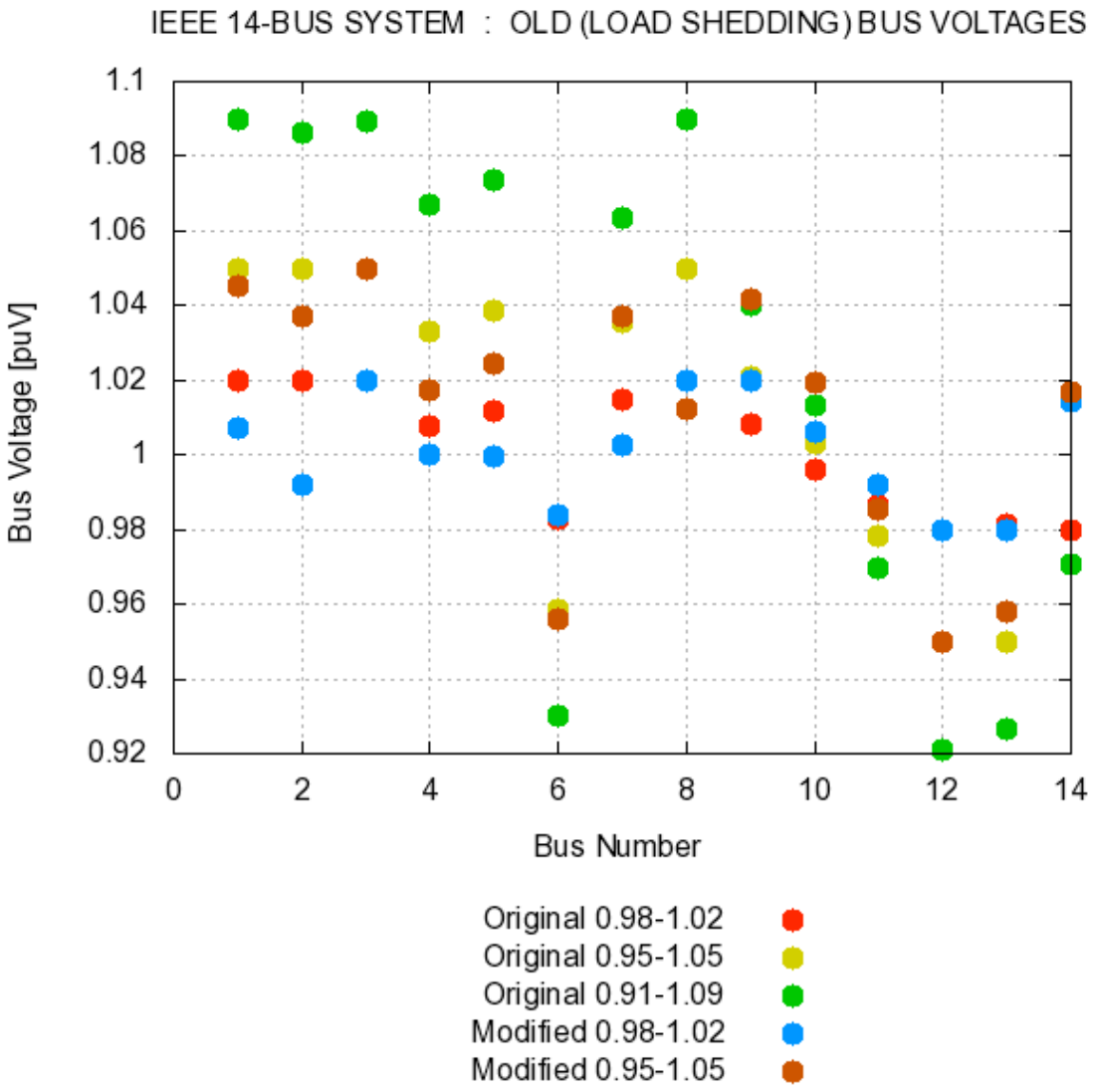
Load Service Illustration

System condition	Load served
0.98-1.02pu voltage range; no taps optimization	228MW out of 259MW
0.98-1.02pu voltage range; with taps optimization	244 MW out of 259MW
0.95-1.05 pu voltage range; no taps optimization	245MW out of 259 MW
0.91-1.09 pu voltage range; no taps optimized	Full load service
0.95-1.05 pu voltage range; taps optimized	Full load service

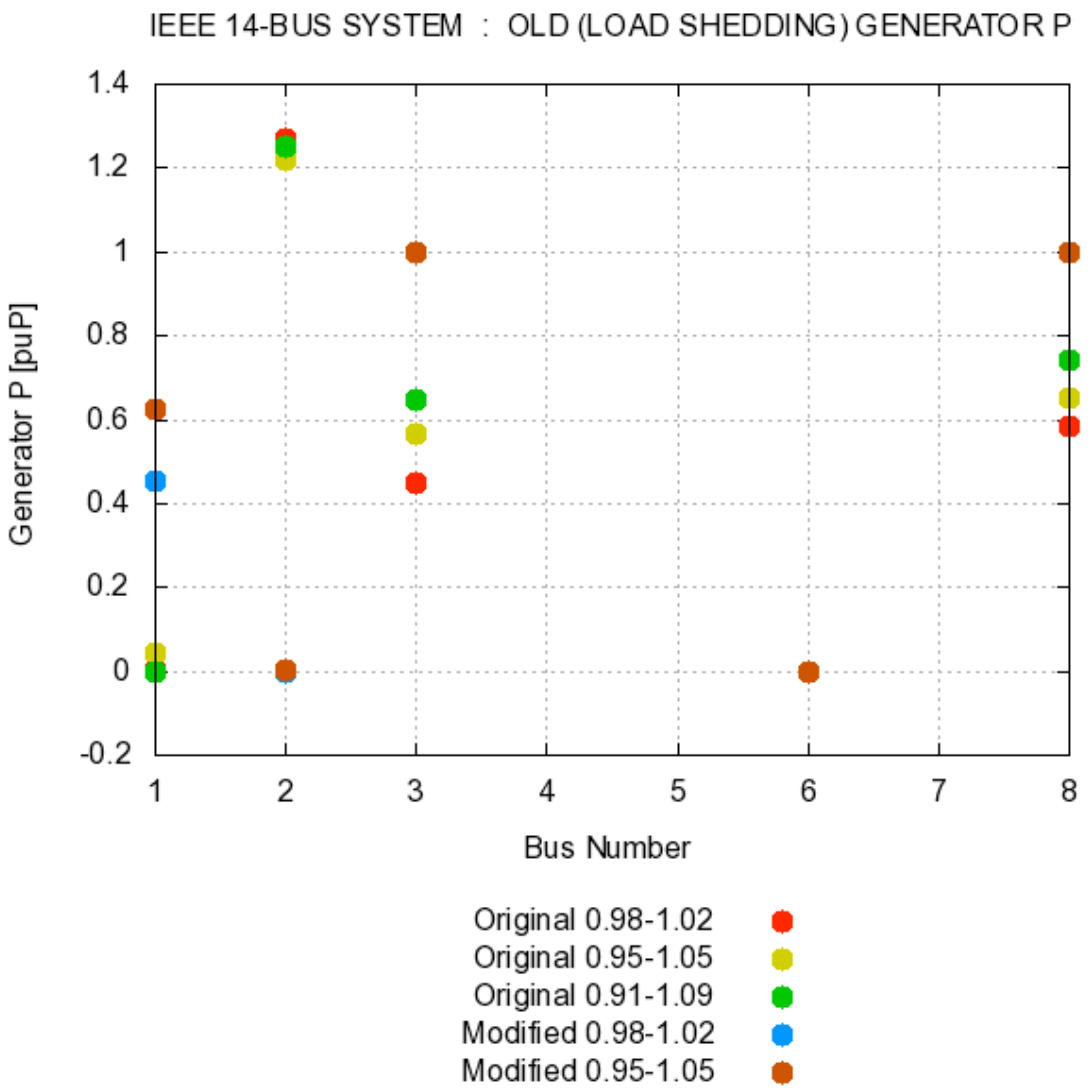
Load Service



Optimized Voltages



Optimized Generation



Justifiable Voltage Profiles

- Systematic corrective resource management is needed in planning and operations to optimize voltage profiles as conditions change.
- Dependent on system conditions
- Dependent on corrective resource management (PG, VG and taps)
- Maintenance reduction generally requires near-nominal (compact) voltage profile. Near real-time corrective management of resources generally requires relaxed voltage limits in order to maximize load service.
- Possible to optimize these profiles for balancing the costs of maintenance and un-interrupted service.

Corrective Actions Management for Efficiency

- Optimization depends on economic objective

  - Minimize total generation cost (Optimal Power Flow (OPF))

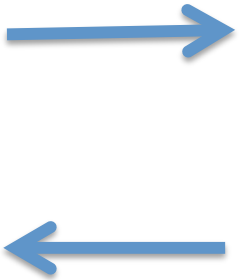
  - Support points-to-points transfer (Optimal Load Distribution (OLD); sender and receiver are balanced loads)

- The best AC OPF cost depends on the voltage profile

- Generally a tradeoff exists between compact voltages and efficiency-optimal voltages

AC OPF Illustration

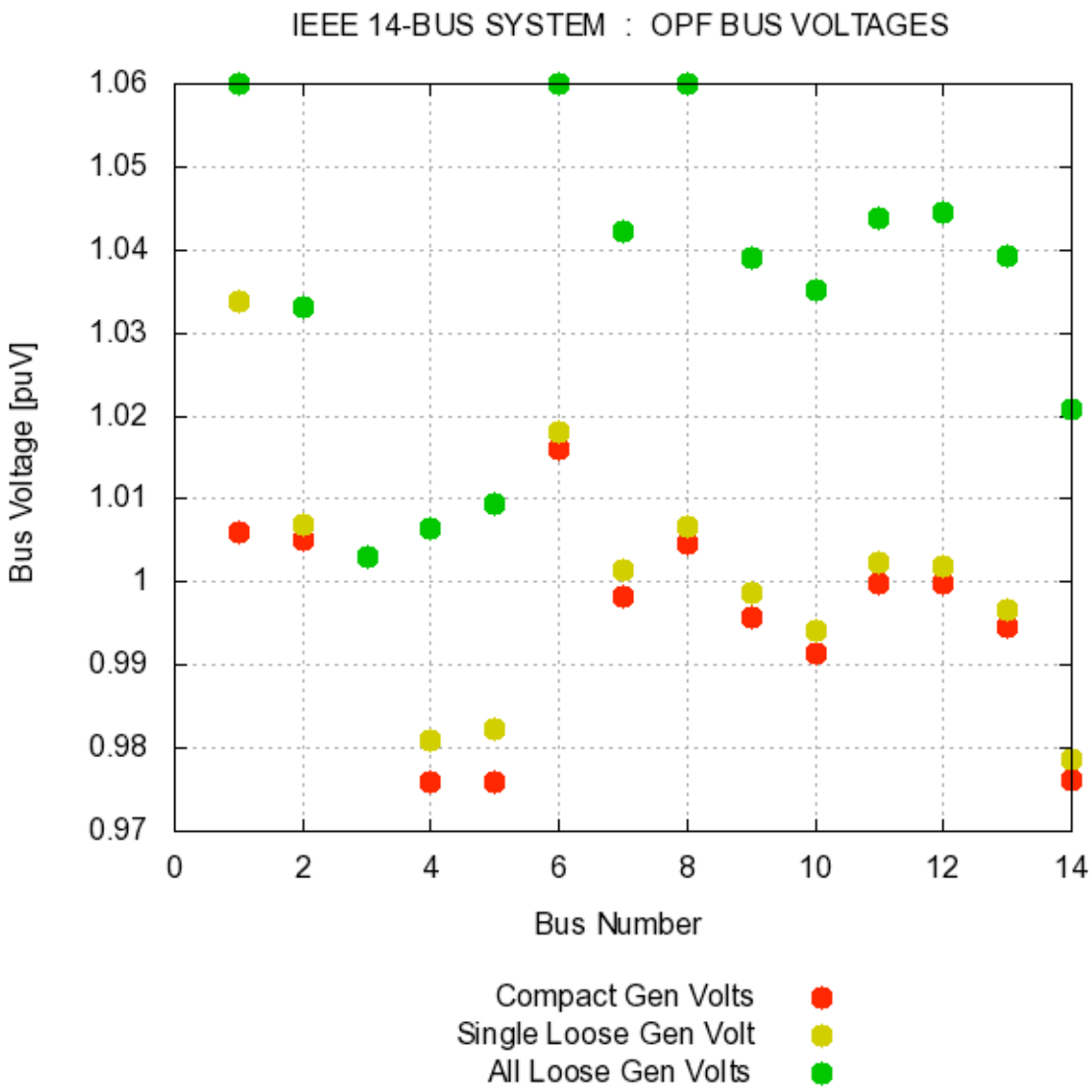
System condition	Cost ($)
Compact voltages (from MXV)	7540
Variable voltage at Generator 1	6383
All variable generator voltages	5499



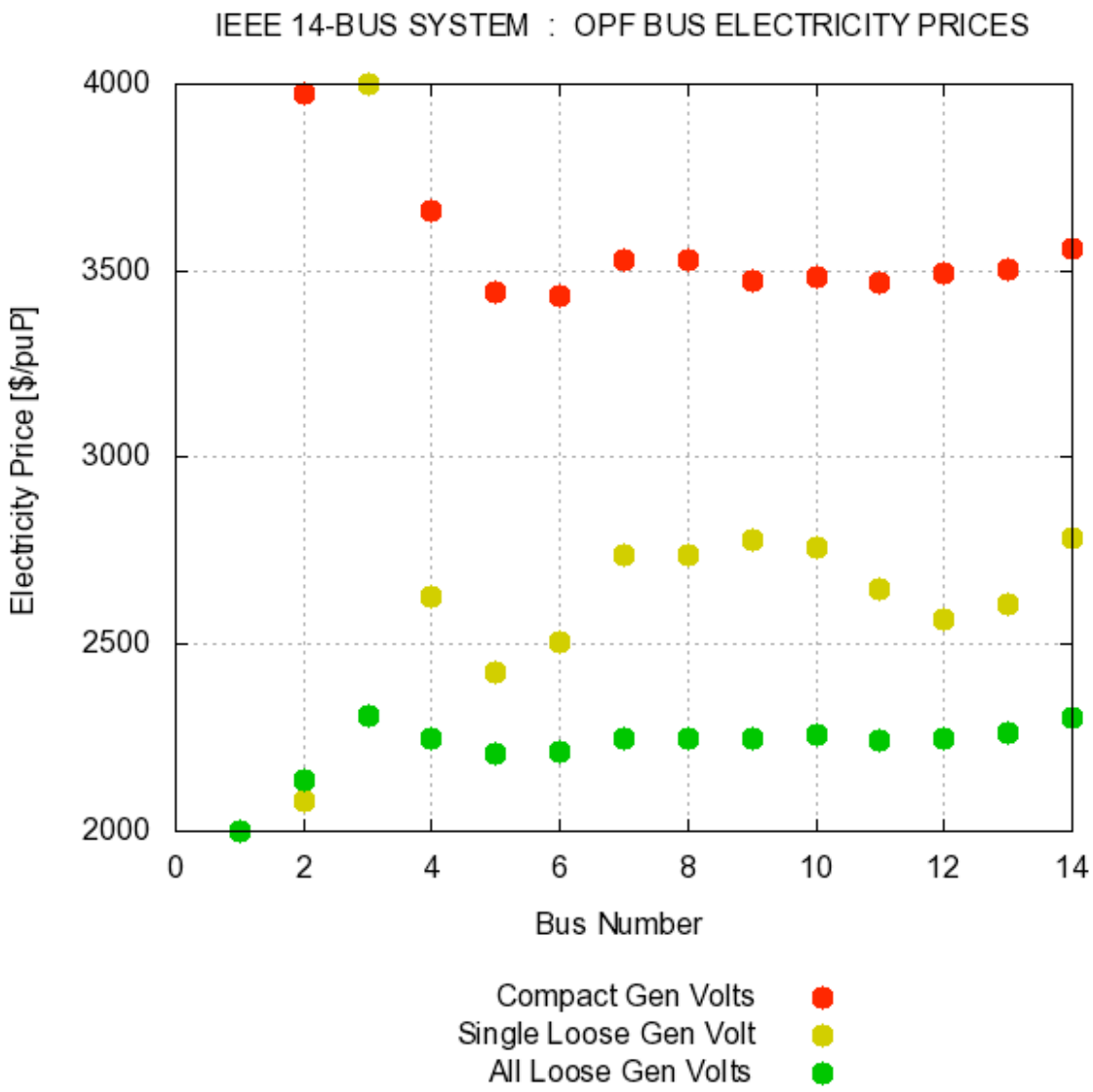
Generator Bus	OSV ($/puV)
1	-136938
2	124206
3	4775
6	6116
8	1874

$0.94 \leq$ Load voltages ≤ 1.06

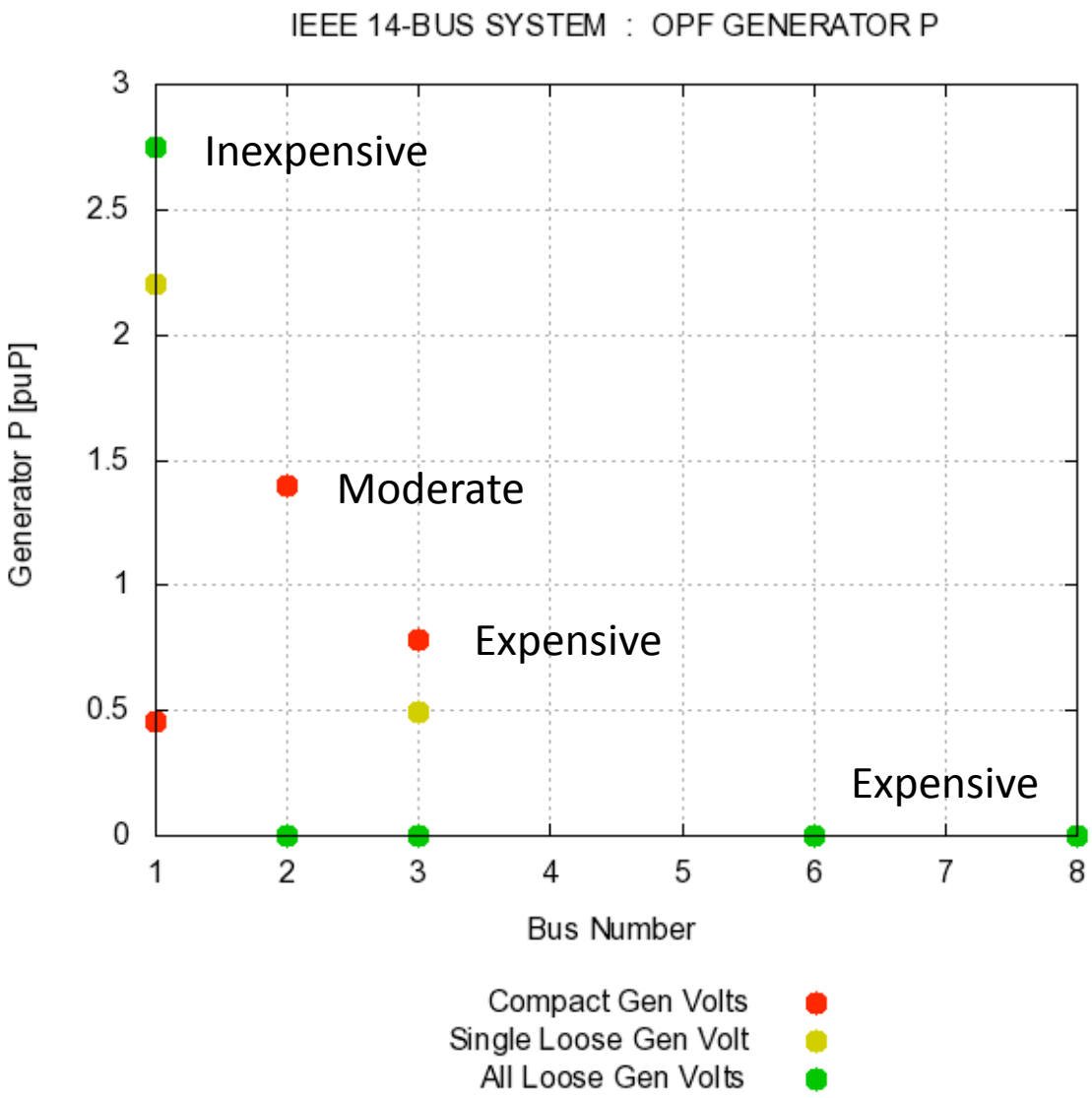
Bus Voltages



Electricity Prices

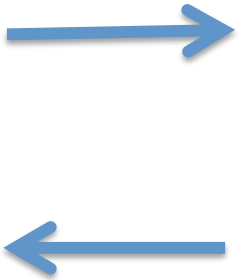


Power Generation



Point-to-Point Transfer Illustration

System condition	Power Transfer
Compact voltages (from MXV)	0.35 MW *17.14 MW
Variable voltage at gen 3	1.03 MW *26.20 MW
All variable generator voltages	4.65 MW *73.78 MW



Generator Bus	OSV (MW/puV)
1	-13
2	-80
3	133
6	-22
8	-91

.94≤ Load voltages ≤ 1.06

*Slack bus is gen 8

NETSSWorks Status

- **Use**
- --Extensive studies done to assess potential benefits from corrective resource management.

  --Software used to simulate systems up to 40,000 bus.
- **Evaluation and validation**

  --Validated by the industry sponsors using PSS/E and PSLF through off-line studies.

  --Currently under evaluation for use by the utilities.
- **Effort required to implement**

  --NETSSWorks ready for testing, including GUI

  --Communications for remote sensing, estimation and dispatch of controllable equipment needed

  --Tariff design for value-based voltage support needed.

Potential NETSSWorks Users

- RTOs, ISOs, TOs, and DOs can benefit from using NETSSWorks for Corrective Research Management
- The software works well for both transmission (low loss) and distribution (high loss) systems
- NETSSWorks can be used to coordinate seams following a divide-and-conquer strategy. This requires the exchange of BA adjustment curves at value to support near-optimal AC OPF.

Conclusions

- Voltage optimization is very beneficial to minimizing cost and serving greater loads all the time.
- Multiple optimization are useful in managing resources.
- Optimized voltage support generally reduces volatility of electricity prices.
- Justifiable voltage profile change with system conditions and depend on the type of controllable equipment used.
- Should consider implementing corrective actions in support of justifiable voltage profiles.