A Review of Algorithmic and Heuristic Based Methods for Voltage/VAr Control

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Overview

- Introduction to National Grid (NG)
- Review of Voltage/VAr Control
- Transition-optimised Formulations
- Implementation and Testing
- Further Work
Introduction

- **NG transmission system**
  - 4,400m overhead lines
  - 400m underground cable
  - Over 300 substations

- **System operator**
  - Connects generators with suppliers
  - Schedules generation to meet demand
  - Adheres to transmission standards
Introduction

- Ten years of deregulation
  - Relocation of generation
  - Regulatory reviews
- Voltage constraints
  - Additional reactive compensation
  - Optimal use of compensation equipment
- NG Control Centre (NGCC)
  - Reactive Management Engineer
  - Transmission Dispatch Engineer
Introduction

SCADA System → State Estimation → VSAC → Scheduling and Dispatch → Load Forecasting

RealPowerSystems

VSAC: Voltage Security Analysis and Control

TORC: Transition-Optimised voltage and Reactive power Control

TORC: Transition-Optimised voltage and Reactive power Control

Interface / Operator
Review

- **Transition-Optimised Voltage and Reactive Power Control**
  - Real-time ORPF analysis [Sharif et al. 1997]
  - Scheduling of Reactive Compensators [Hong & Liao 1995]
- **Voltage and Reactive Power Control**
  - CARD [Chebbo et al. 1995]
  - ACCORD - NGCC [Dandachi et al. 1997]
- ORPF analyses can be run on-line using a snap-shot of the real-time data of the power system [El-Kady et al. 1985]
- ORPF analyses can be run off-line using data forecast for a number of cardinal load points over the day ahead [Corsi et al. 1995]
- Different system models may be used for on-line and off-line studies
Problem Formulations

Hong & Liao 1995 (Taiwan 265-bus system)

\[
\text{Min } \sum_{i=1}^{N} \left\{ C_L(x^i) + \sum_{j=1}^{R} C_D(q^i_j) \right\}
\]

\[ C_L \] - Capitalised MW losses
\[ C_D \] - Depreciation costs

s.t.

- Standard constraints for \( N \) cardinal points
- Transition constraints \((q^i_j - q^{i-1}_j)\) for \( R \) reactive compensators
Problem Formulations

Sharif et al. 1997 (New Brunswick 277-bus system)

\[ \text{Min } \sum_{i=1}^{N} P_L(x^i) t^i \]

- \( P_L \) - Actual MW losses
- \( t^i \) - Time interval

s.t.

- Standard constraints for N cardinal points (CPs)
- No transition constraints

Transition-optimisation fixed a priori via forecast load
Problem Formulations

Problem Formulations

Problem Formulations

- Transition optimisation involves N time intervals
- Large-scale mixed-integer constrained optimisation problem
- Dimensionality of the problem can be reduced via decomposition techniques (i.e., GBDT)
- Coordinated solution of a master problem and N slave problems
  - Slave problem is a standard large scale ORPF involving continuous control variables (i.e., generator bus voltages)
  - Master problem is a pure integer programming problem involving discrete control variables (i.e., switchable capacitors)
- Handling of infeasible solution of slave problems
- Complete problem could also be solved using a sparse linear programming method (SDRS2)
## Testing & Implementation

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<th>POWERWORLD*</th>
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<tr>
<th>No. of buses</th>
<th>9, 24, 30</th>
<th>53</th>
<th>118, 300</th>
<th>706, 1915</th>
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<td>IEEE</td>
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South West Peninsula

Peek demand: 6.5 GW
Local generation: 3.5 GW

Schematic of 400 kV Supergrid
South West Peninsula

Complete 53-bus model including:
Generators & SVCs
132 kV Network
MSCs & Shunt Capacitors
Voltage: Uncompensated

1.0 pu
0.9 pu
Voltage: Compensated

1.0 pu
0.9 pu
Further Work

- Evaluate software for large-scale ORPF analyses
- Compare CPU time for sparse and compact LP methods
- Perform similar ORPF analyses on small and large scale systems with available software
- Perform a range of studies that systematically increase active constraints (ie incremental load increases)
- Implement and test a variety of TORC methods for small and large scale systems
- Include accurate NG reactive forecasts when available
- Compare against NG recorded reactive compensation schedules