Bips innovative research for the power industry

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

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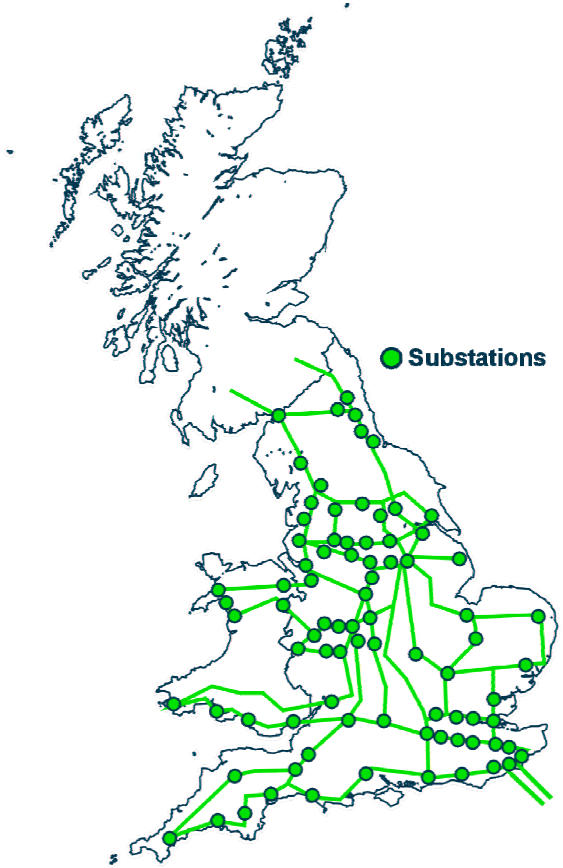
Overview

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

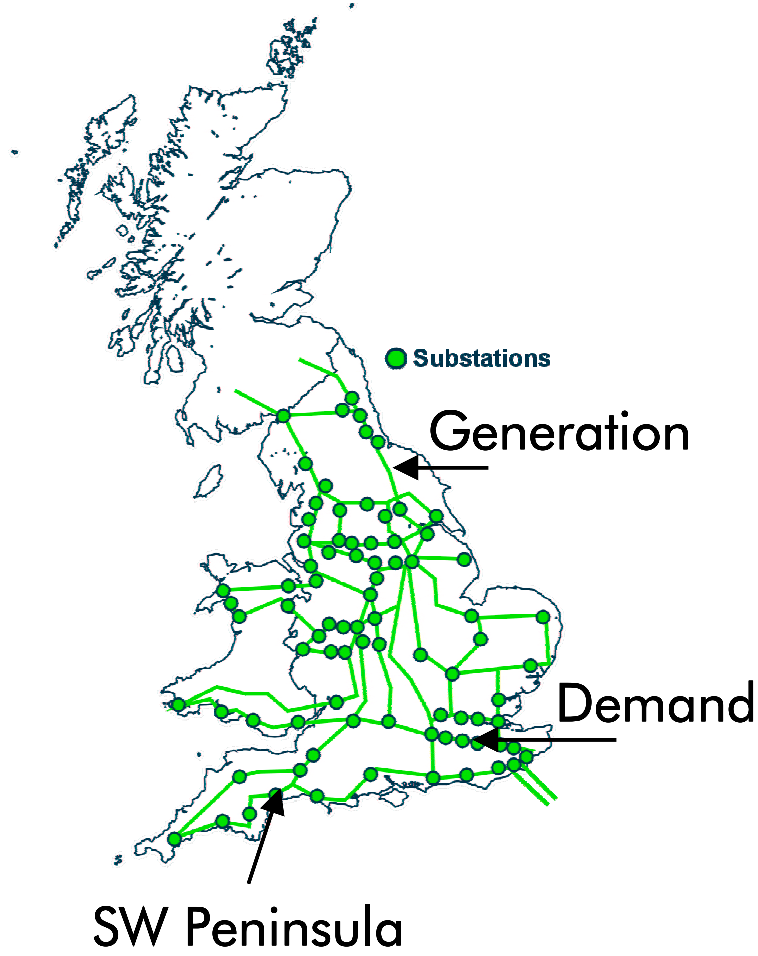
Introduction

- 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

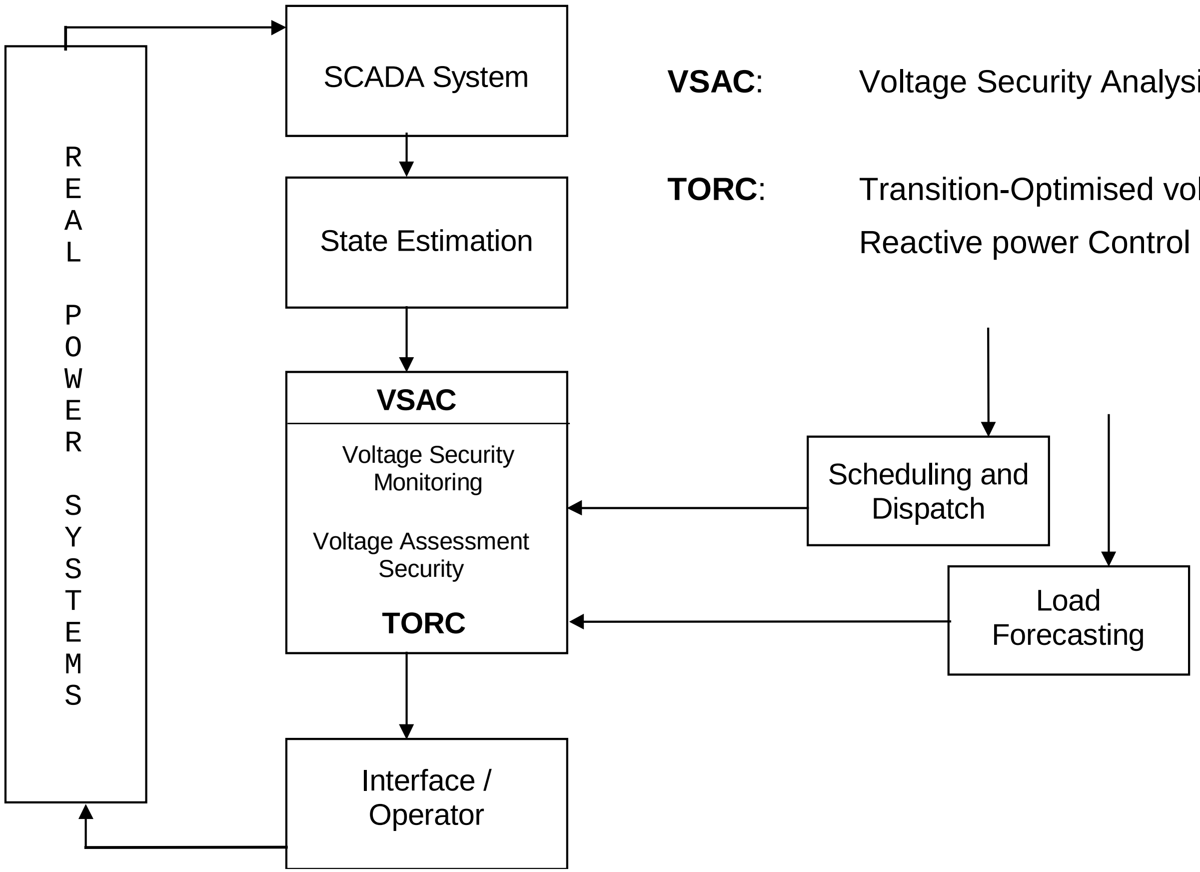


Introduction

- 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



VSAC: Voltage Security Analysis and Control

TORC: Transition-Optimised voltage and Reactive power Control

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)

$$Min \sum_{i=1}^{N} \left\{ C_L(\mathbf{x}^i) + \sum_{j=1}^{R} C_D(\mathbf{q}_j^i) \right\}$$

C_L - Capitalised MW losses

C_D - Depreciation costs

s.t.

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

Problem Formulations

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

$$Min \sum_{i=1}^{N} P_L(\mathbf{x}^i)\, t^i$$

P_L - Actual MW losses

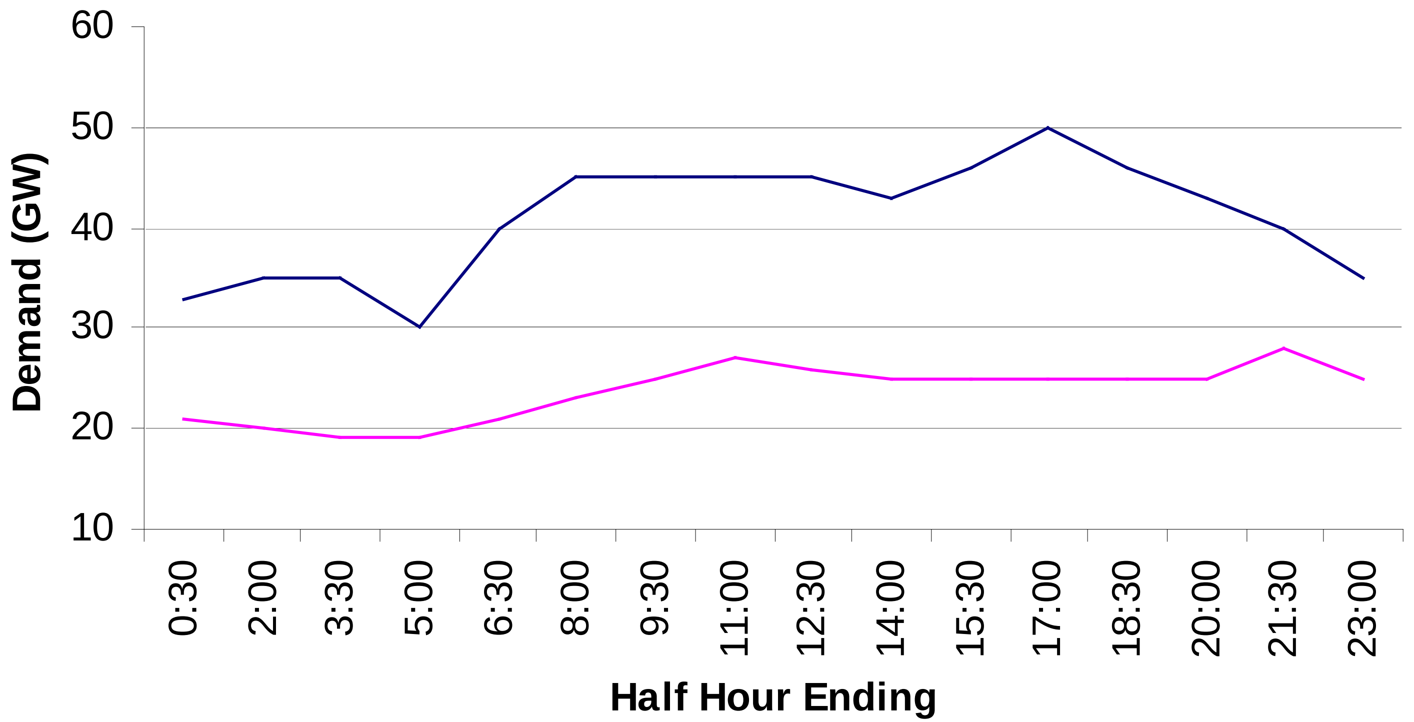
t^i - Time interval

s.t.

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

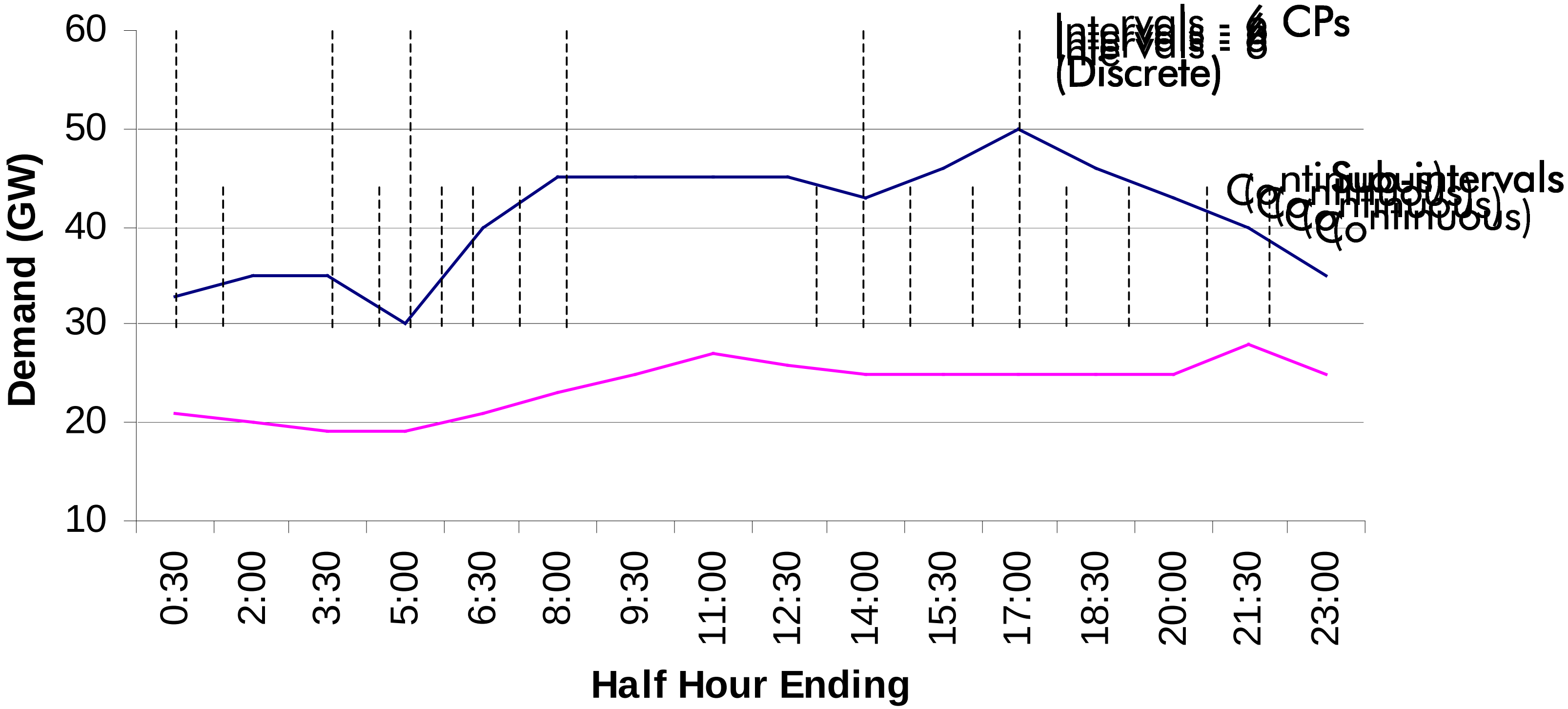
Transition-optimisation fixed a priori via forecast load

Problem Formulations



NG Maximum and Minimum Daily Demand: 1999/2000

Problem Formulations



NG Maximum and Minimum Daily Demand: 1999/2000

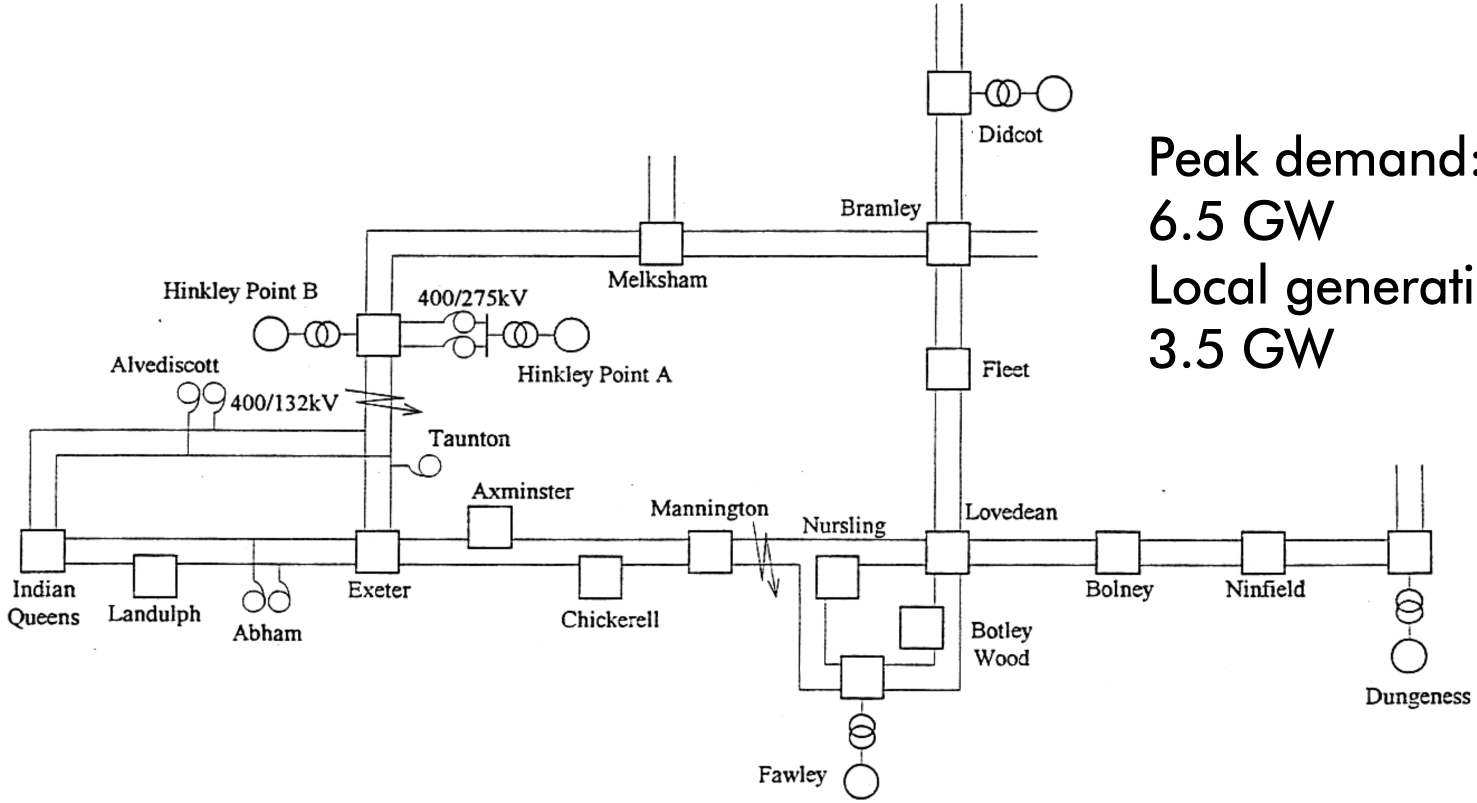
Problem Formulations

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

Testing & Implementation

POWERWORLD*	PF	PF	PF	PF
MATPOWER	OPF	OPF	NA	NA
CARD	OPF	OPF	OPF	OPF
SCOPE	OPF	OPF	OPF	OPF
No. of buses	9, 24, 30 IEEE	53 NG	118, 300 IEEE	706, 1915 NG

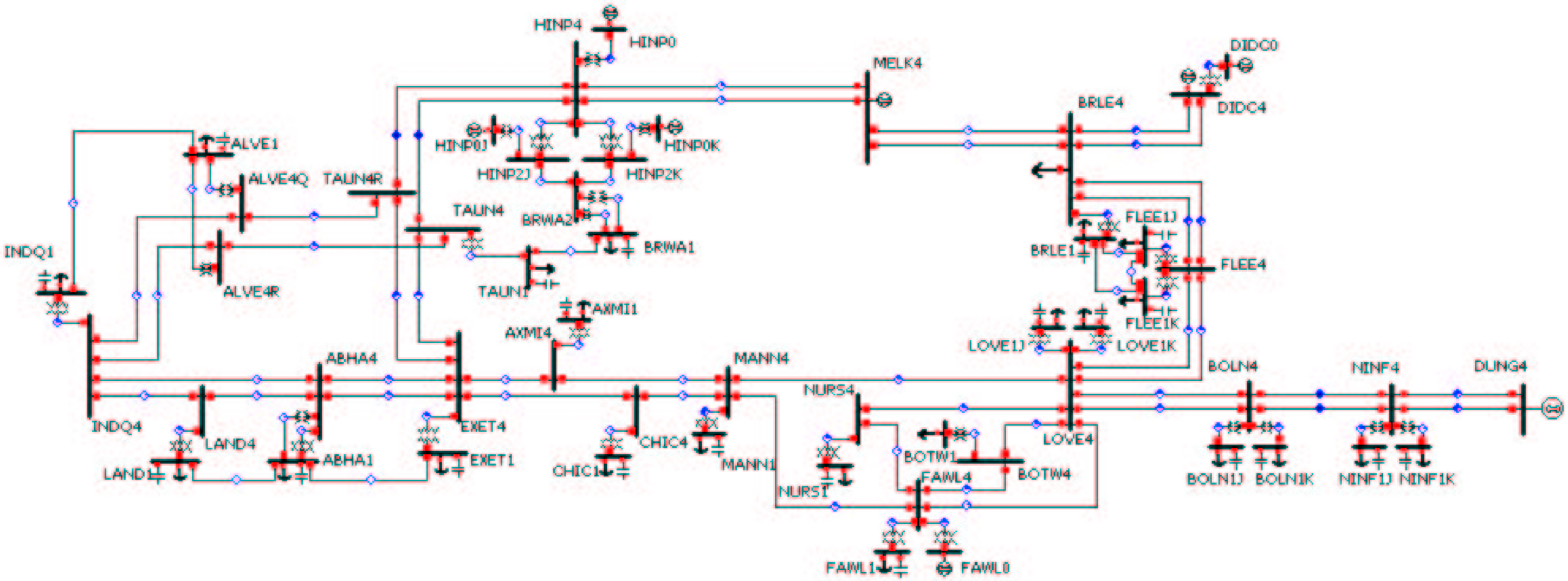
South West Peninsula



Peak demand:
6.5 GW
Local generation:
3.5 GW

Schematic of 400 kV Supergrid

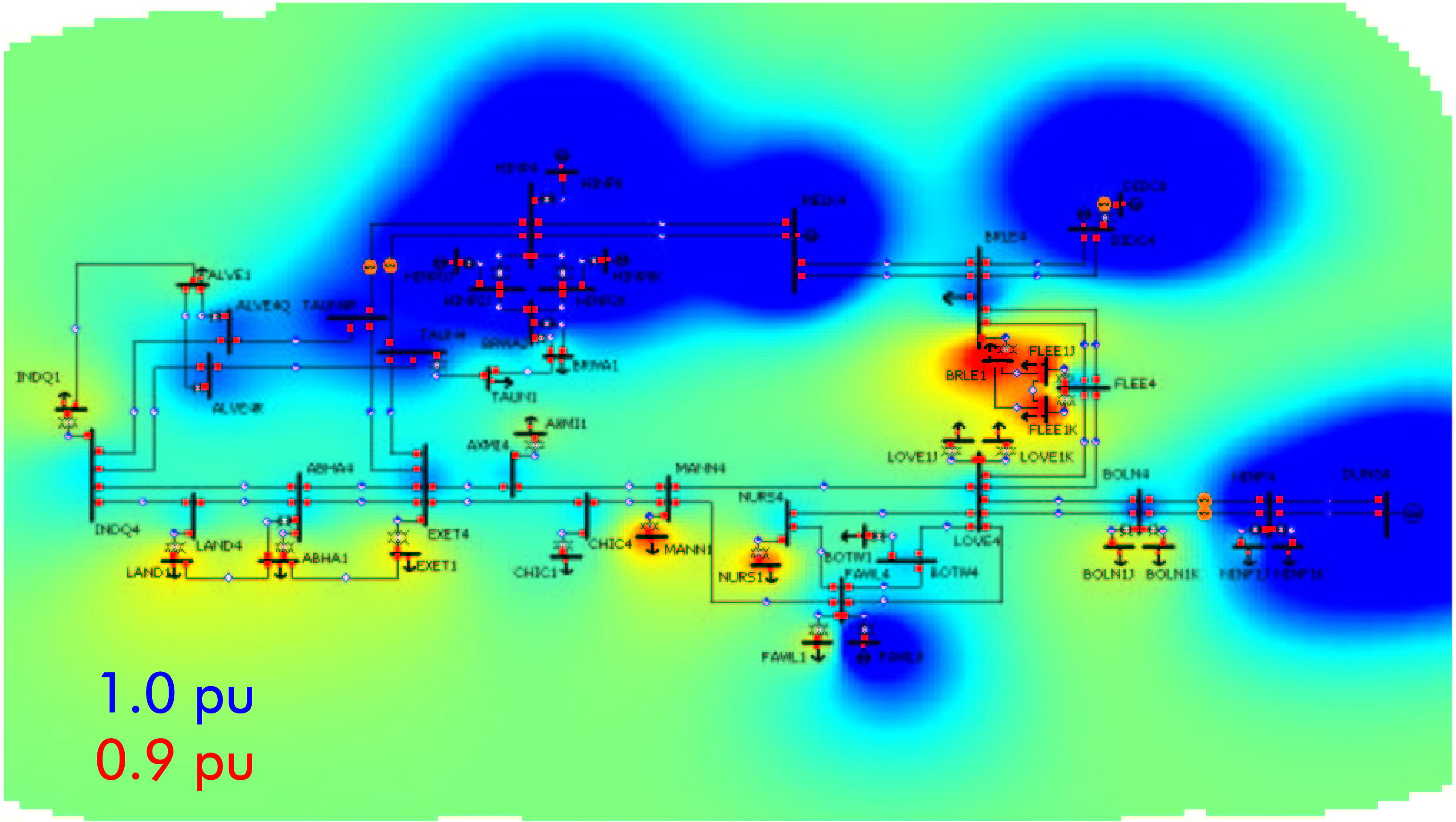
South West Peninsula



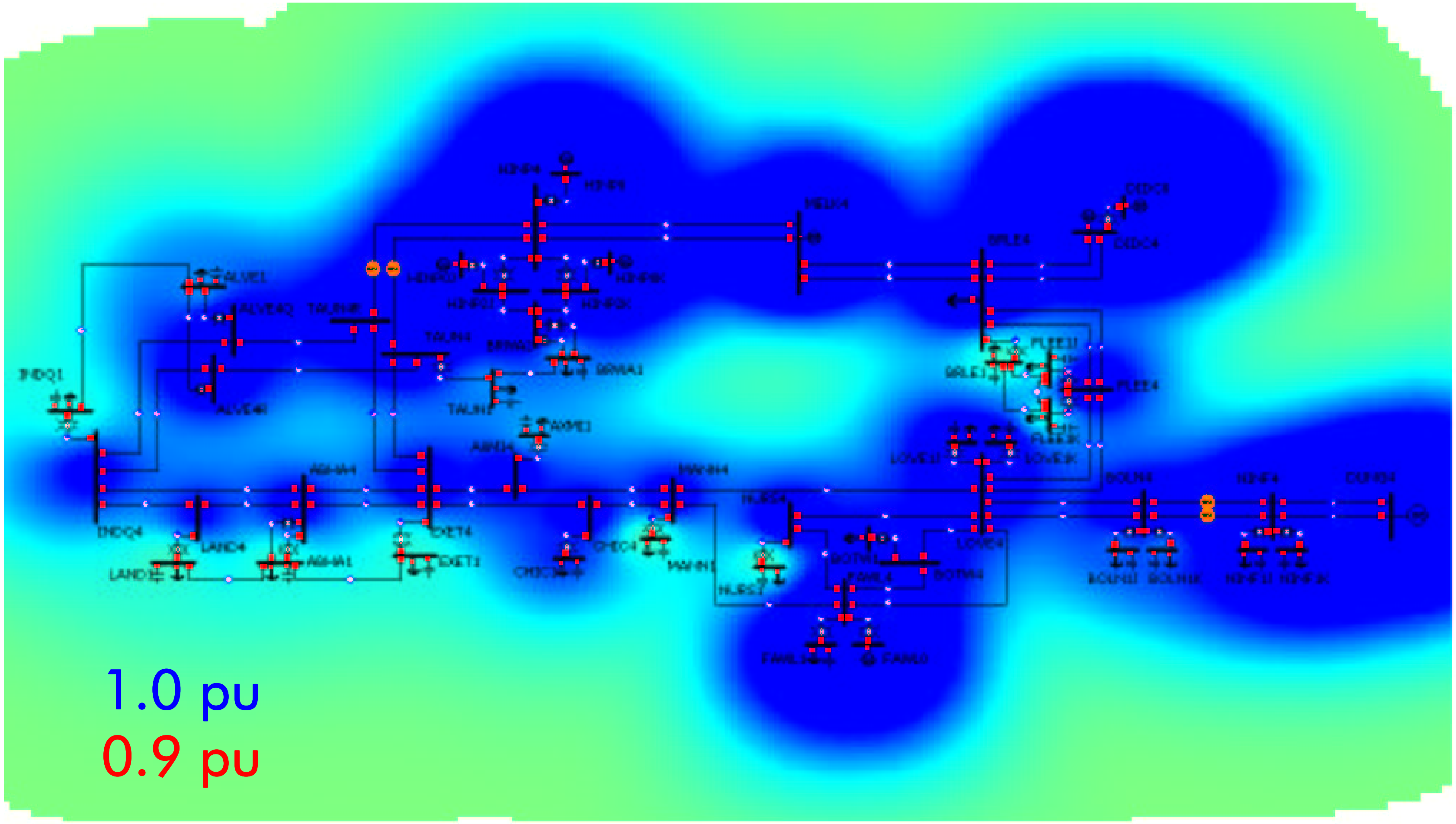
Complete 53-bus model including:

Generators & SVCs
132 kV Network
MSCs & Shunt Capacitors

Voltage: Uncompensated



Voltage: Compensated



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