IX - SEPOPE

SYMPOSIUM OF SPECIALISTS IN ELECTRIC OPERATIONAL AND EXPANSION PLANNING

Rio de Janeiro – RJ – May – 23rd to 27th – 2004

Weekly Load Curve Simulation with Discrete Control Devices Representation for Voltage Control Performance Evaluation in a Large Scale System

Authors:

João Alberto Passos Filho (CEPEL/COPPE)

Luiz Cláudio de A. Ferreira (ONS)

Nelson Martins (CEPEL)

Djalma M. Falcão (COPPE)

Adriano de A. Barbosa (ONS)

CEPEL 30 anos

ONS Operador Nacional do Sistema Elétrico

COPPE - UFRJ
Programa de Engenharia Elétrica

Presentation Summary

- Introduction
- Automatic Switching of Shunt Banks
- System Load Curve Simulation
- IEEE 14-bus Test System
- Large Scale System
- Conclusions

Introduction

- System load curve simulation – ANAREDE
  - ✓ Improve the system analysis
  - ✓ Evaluation of different conditions for load behavior
  - ✓ Representation of slow control devices
- Use of automatic shunt switching
  - ✓ There is availability of reactive shunt compensation
  - ✓ Keep the system voltage profiles within limits
  - ✓ Choice of the controlled bus voltage
  - ✓ Full Newton representation

Introduction

- Steady-State: system behavior evaluation
  - ✓ Coordination with another control devices
    - LTC´s Transformers
    - FACTS
    - Remote and Secondary Voltage Control
    - Identification of critical settings
  - ✓ Variation of power factor
- Generation balance
  - ✓ Generator participation factor
    - Base case settings

Automatic Shunt Compensation

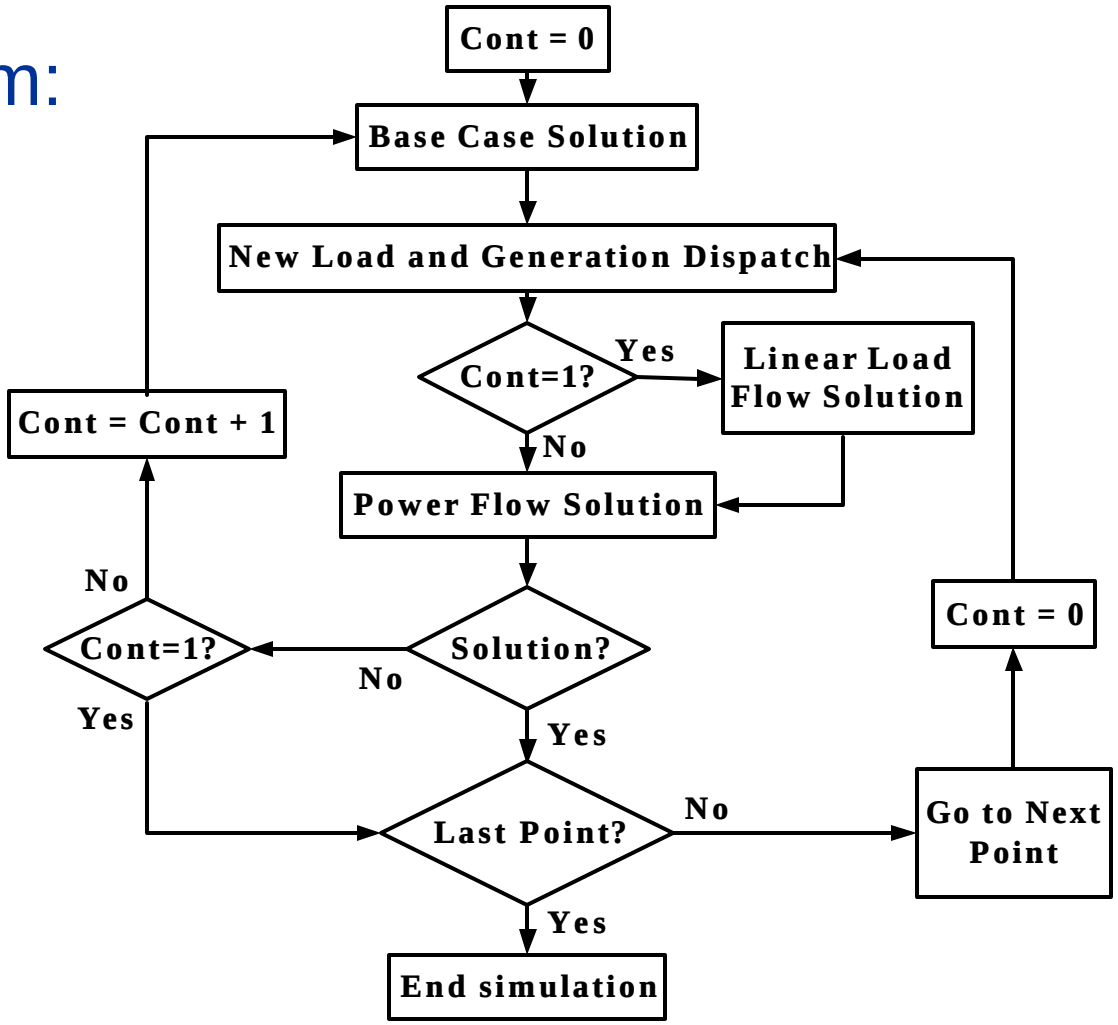
$$\begin{bmatrix} \Delta P \\ \Delta Q \\ \hline \Delta y \end{bmatrix} = \left[\begin{array}{cc|c} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} & \frac{\partial P}{\partial b^{sh}} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} & \frac{\partial Q}{\partial b^{sh}} \\ \hline \frac{\partial y}{\partial \theta} & \frac{\partial y}{\partial V} & \frac{\partial y}{\partial b^{sh}} \end{array}\right] \cdot \begin{bmatrix} \Delta \theta \\ \Delta V \\ \hline \Delta b^{sh} \end{bmatrix}$$

y - Control Mismatch Function

b^{sh}- Control Variable

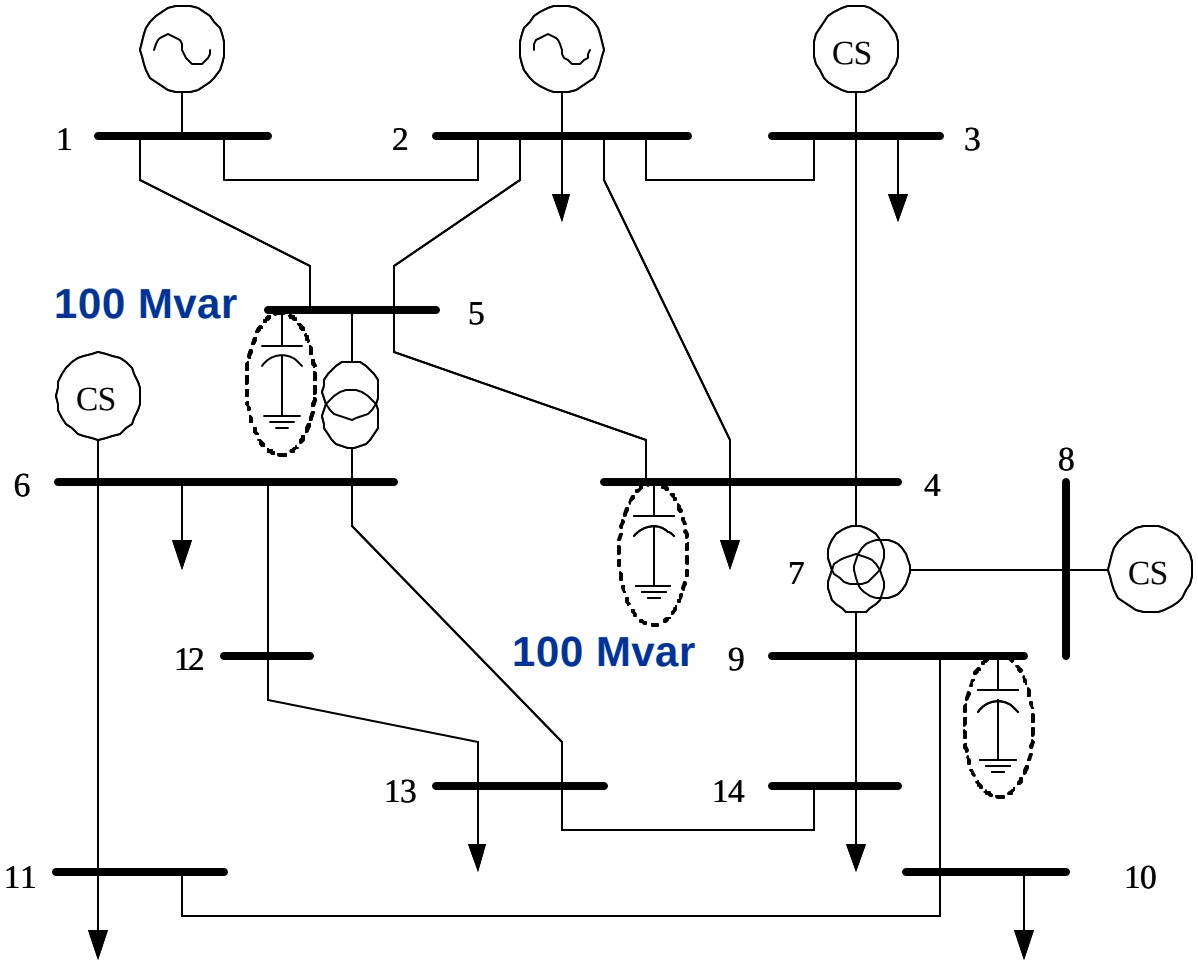
System Load Curve Simulation

Basic algorithm:



IEEE 14-bus Test System

- Topology



IEEE 14-bus Test System

- Use of Optimal Power Flow - FLUPOT
  - ✓ Use of maximum loadability objective function
  - ✓ Voltage limits for all buses
  - ✓ Minimum shunt allocation
    - 92 % of load increase
- Load modeling
  - ✓ Constant-P
  - ✓ Invariant power factor
- Participation factor for generators
  - ✓ Swing bus
- 100 % convergence

IEEE 14-bus Test System

- System Configuration

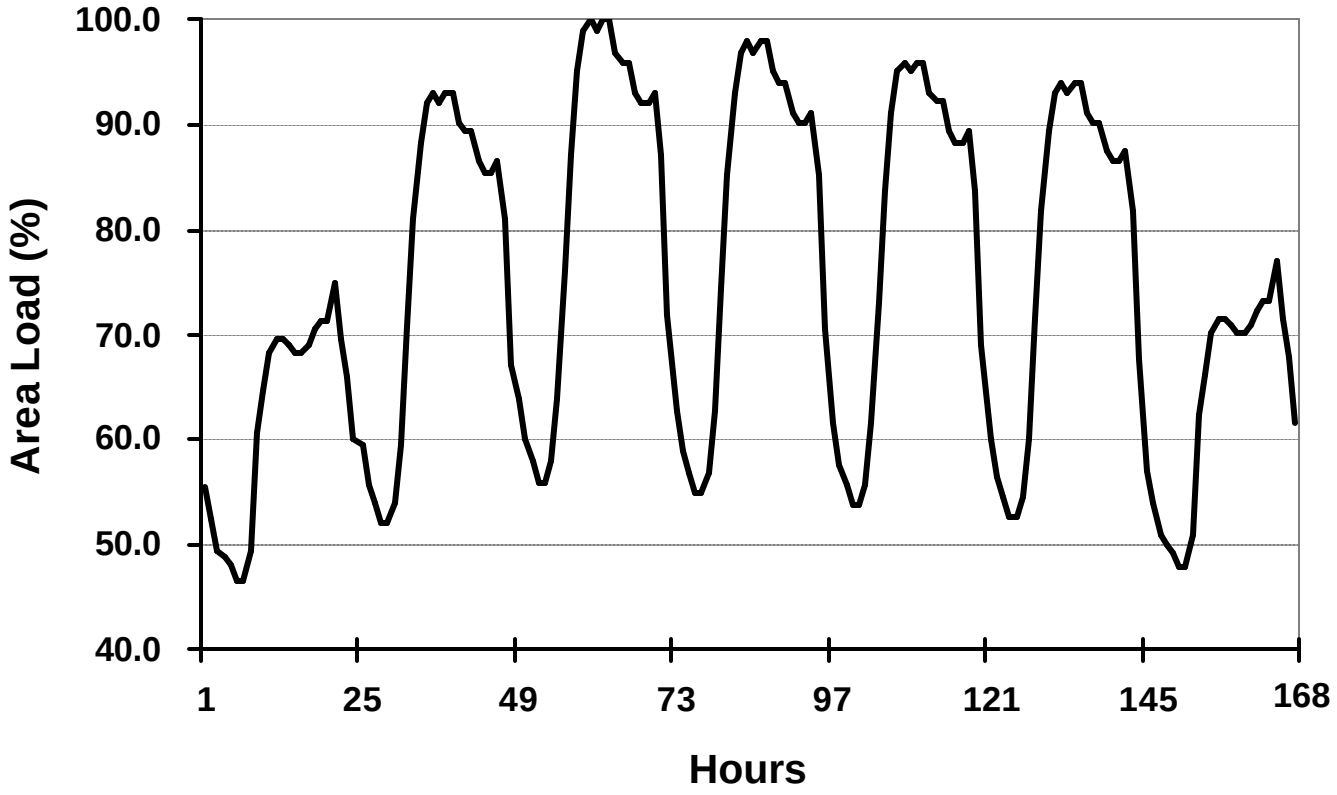
PV Buses	**5**
Circuits	**20**
Active Load	**497 MW**
Active Generation	**560 MW**

- Shunt Control Configuration

Bus	Voltage Limits		Bank Configuration
	Min	Max	
4	**0.950 p.u.**	**1.050 p.u.**	**5 x 20 Mvar**
5	**0.950 p.u.**	**1.050 p.u.**	**5 x 20 Mvar**
9	**0.950 p.u.**	**1.050 p.u.**	**1 x 19 Mvar**

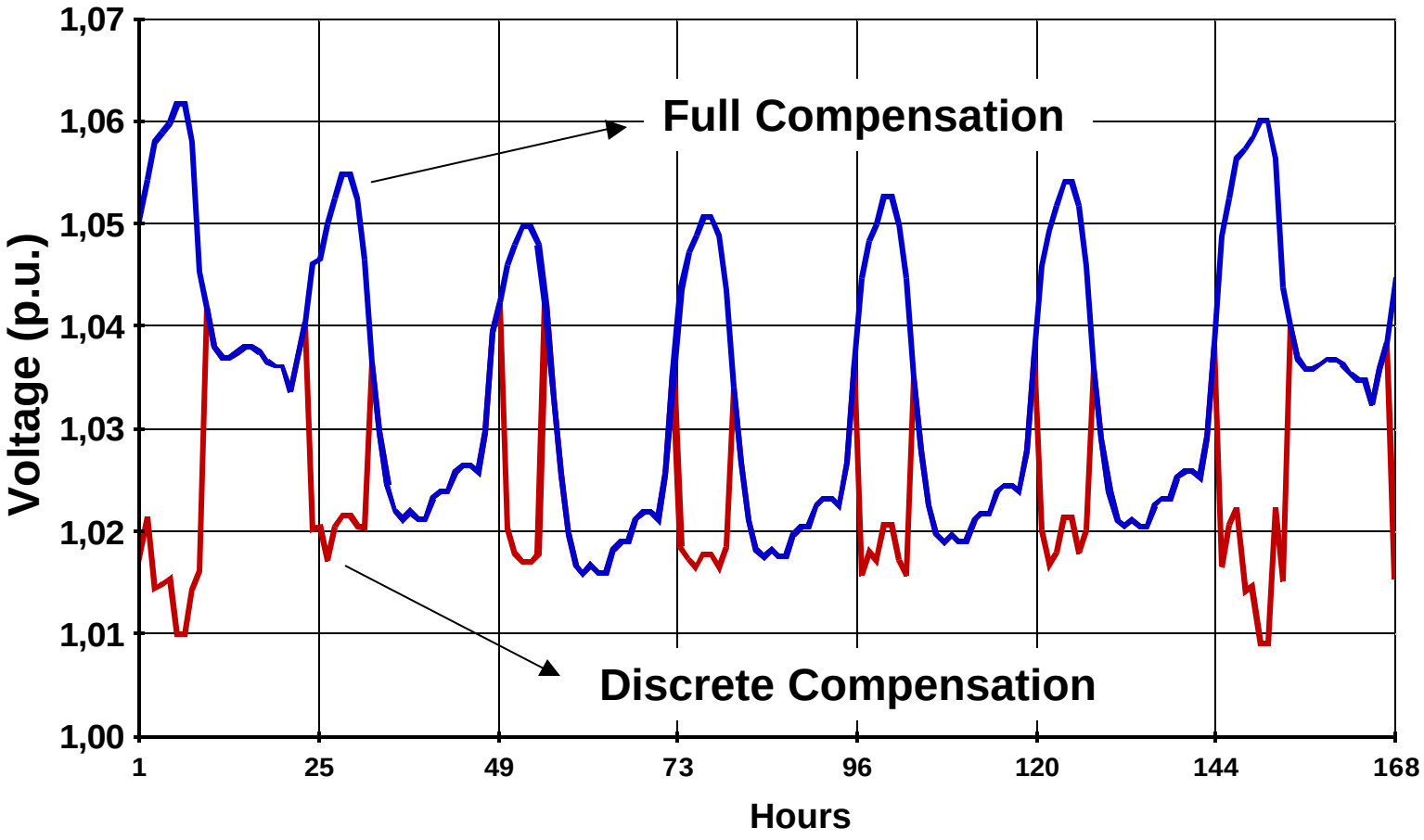
IEEE 14-bus Test System

- Typical load curve during one week
  - ✓ Hourly Simulation ? 168 points



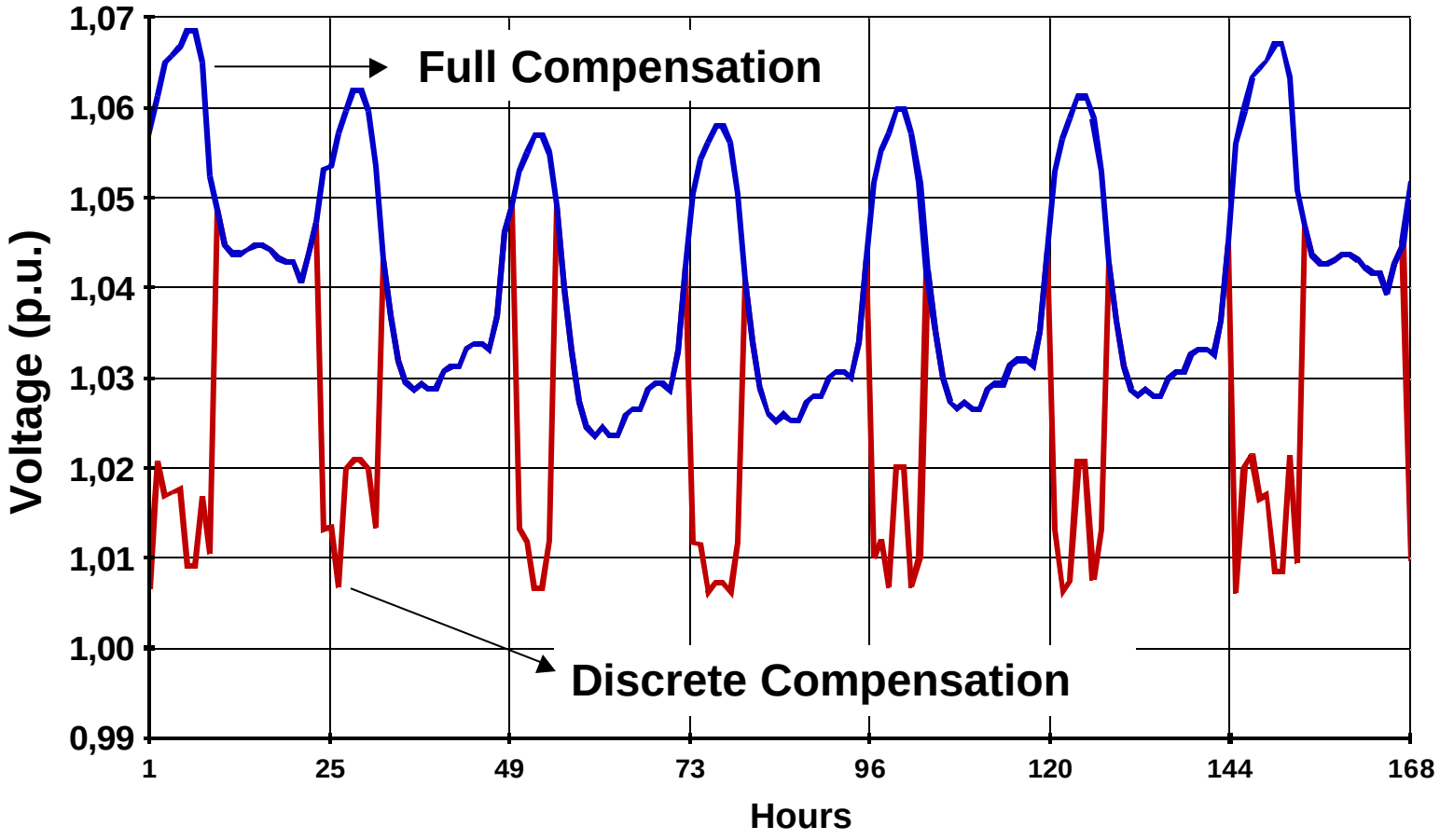
IEEE 14-bus Test System

Voltage Profile – Bus 4



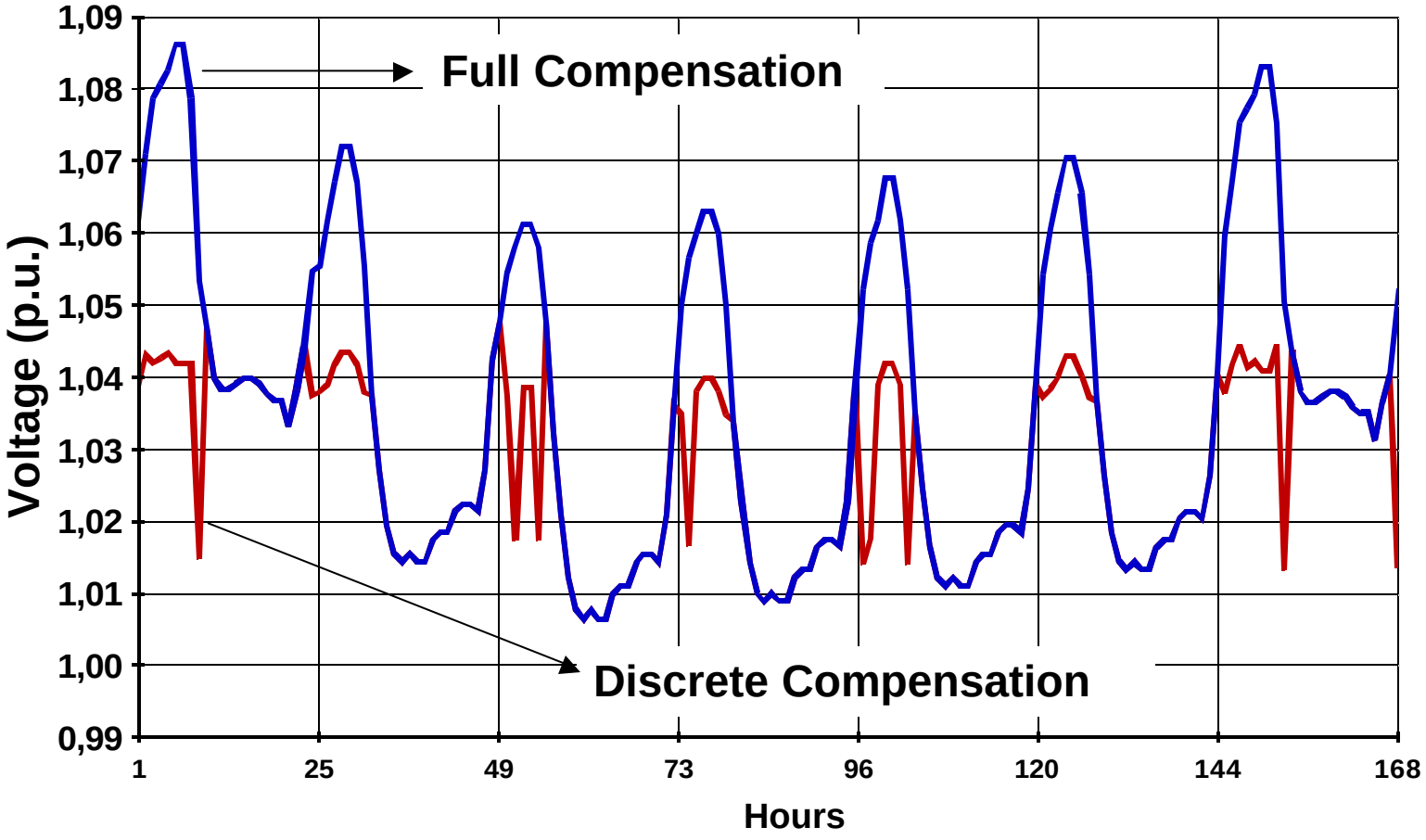
IEEE 14-bus Test System

Voltage Profile – Bus 5



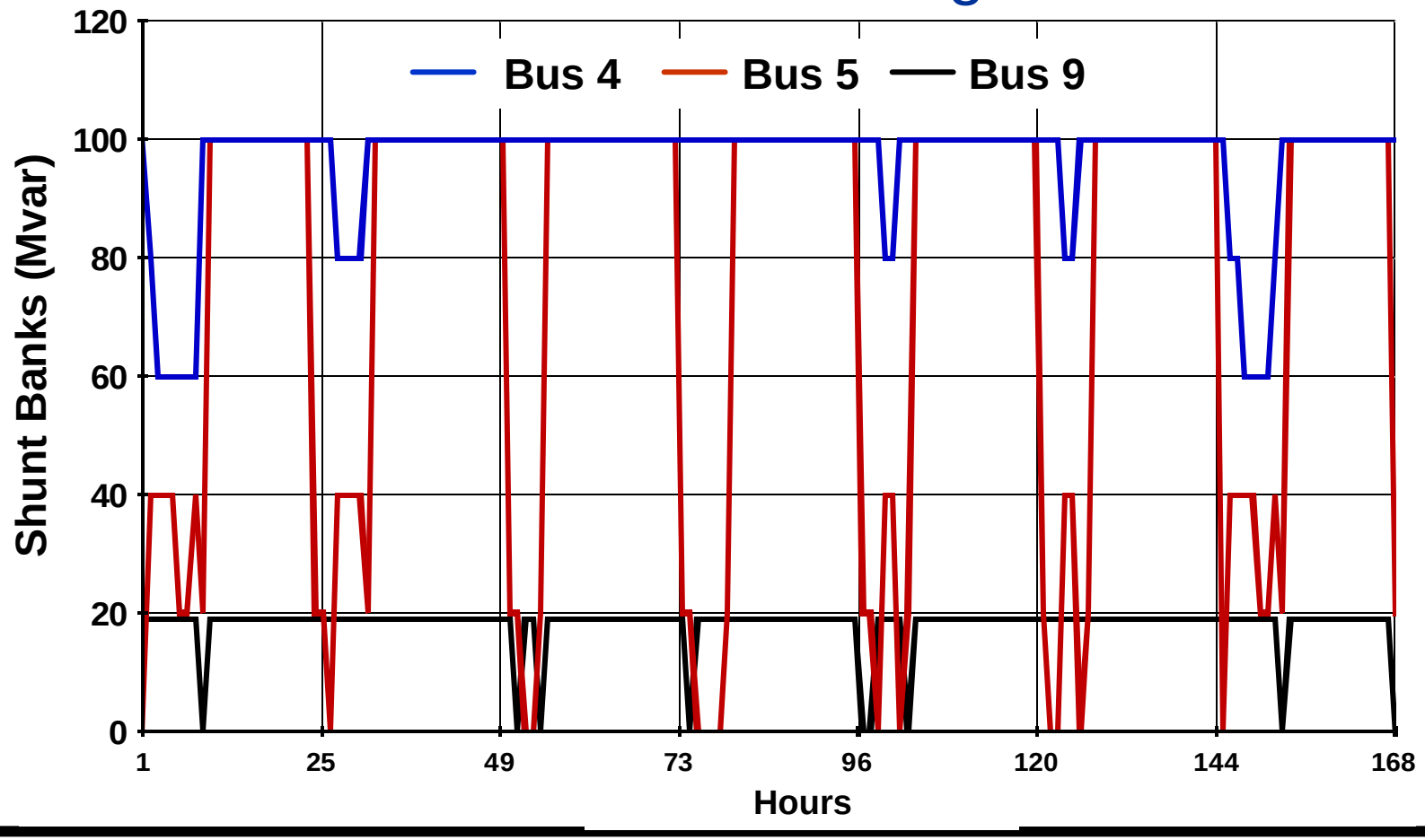
IEEE 14-bus Test System

Voltage Profile – Bus 9



IEEE 14-bus Test System

Shunt Switching



Large Scale System

- North-south Brazilian interconnected system
  - ✓ Configuration of April 2003 – Heavy Load (ONS)
  - ✓ Evaluation of Rio Area
- System Configuration

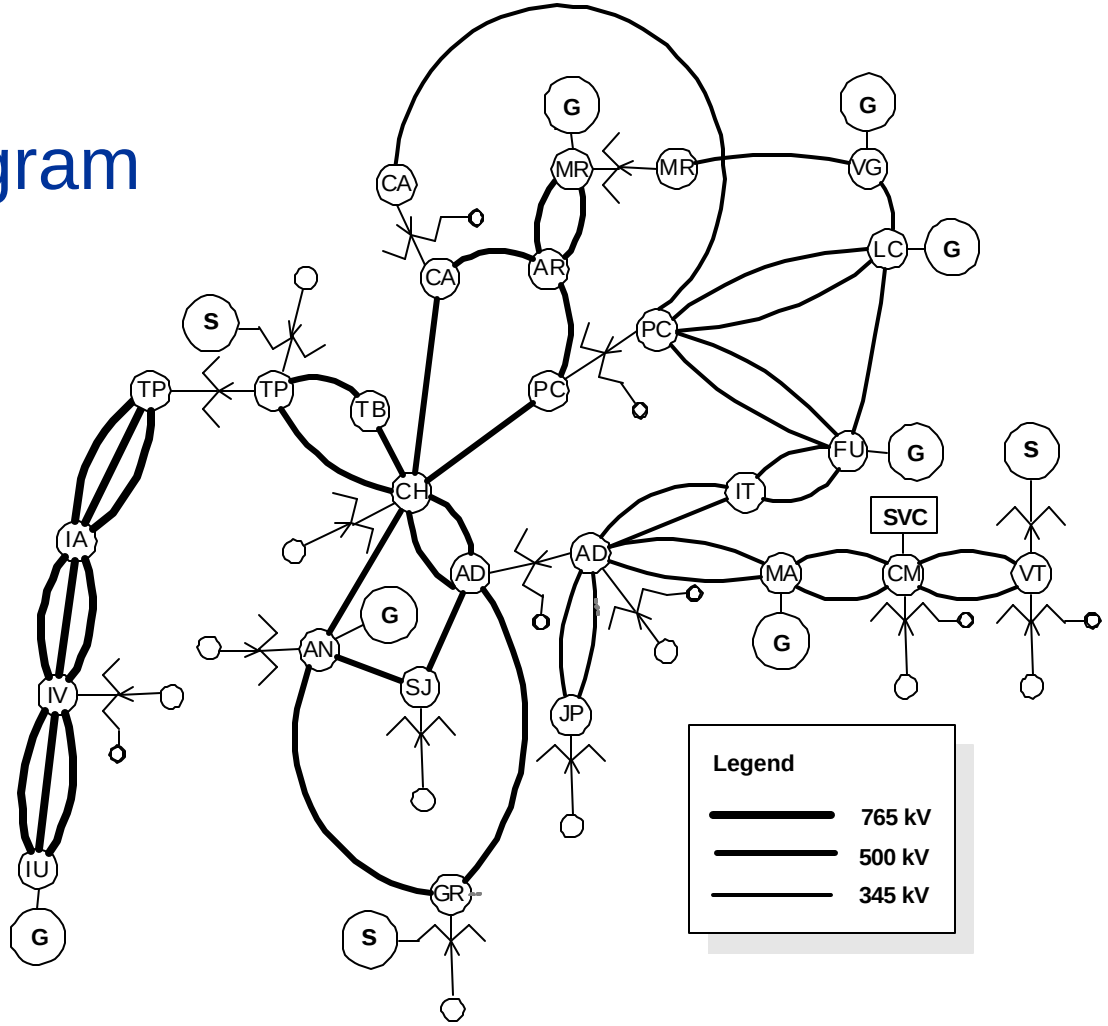
Buses	**2485**
Circuits	**3563**
Generators / Remote Control / SVC´s	**242 / 10 / 5**
Transformers / LTC´s	**1064 / 544**
Active Load – System	**42 923 MW**
Active Load – Rio Area	**7 100 MW**

Large Scale System

- Rio Area
  - ✓ Big load center
  - ✓ Coordination between control devices
- Load modeling
  - ✓ Constant-P and invariant power factor
- Participation factor for generators
  - ✓ The same of base case for major generation plants
- System simulation
  - ✓ Large variations of load (max: -40 %)
  - ✓ Discrete compensation

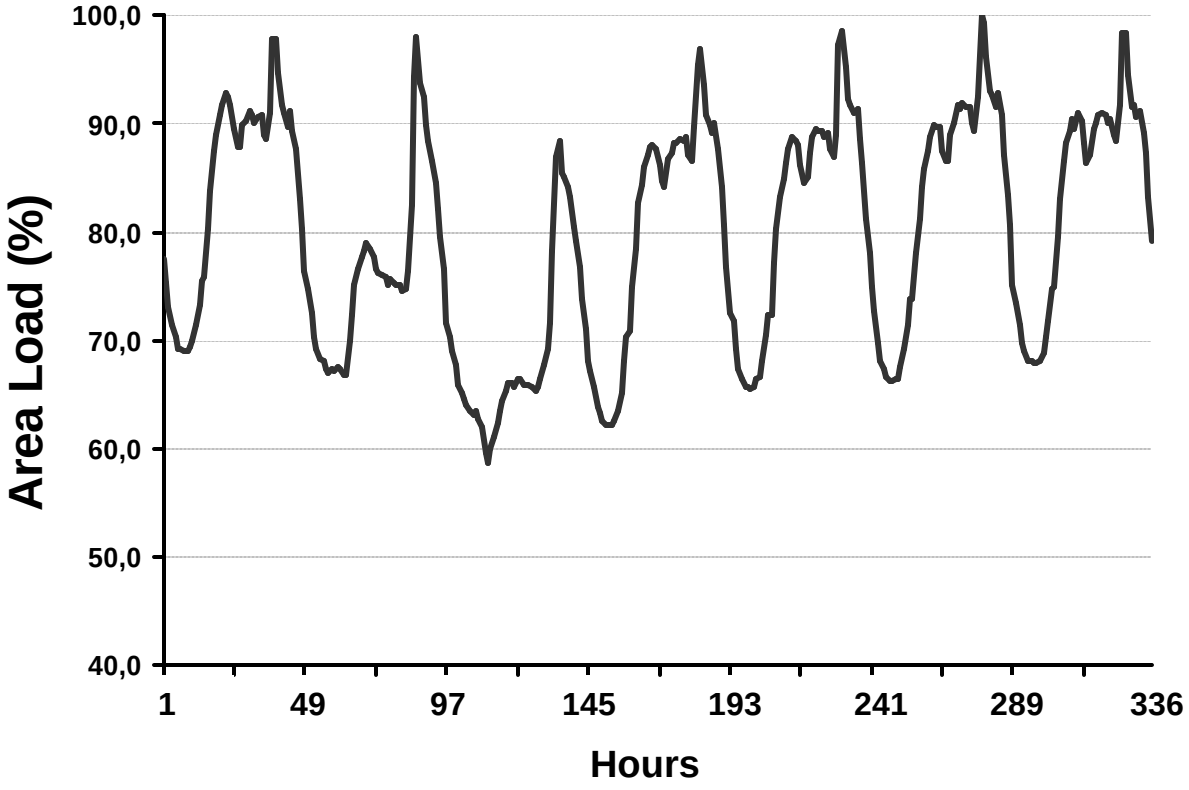
Large Scale System

- Rio Area
  Simplified Diagram



Large Scale System

- Typical load curve during one week – April 2003
  - ✓ Intervals of 30 minutes ? 336 points



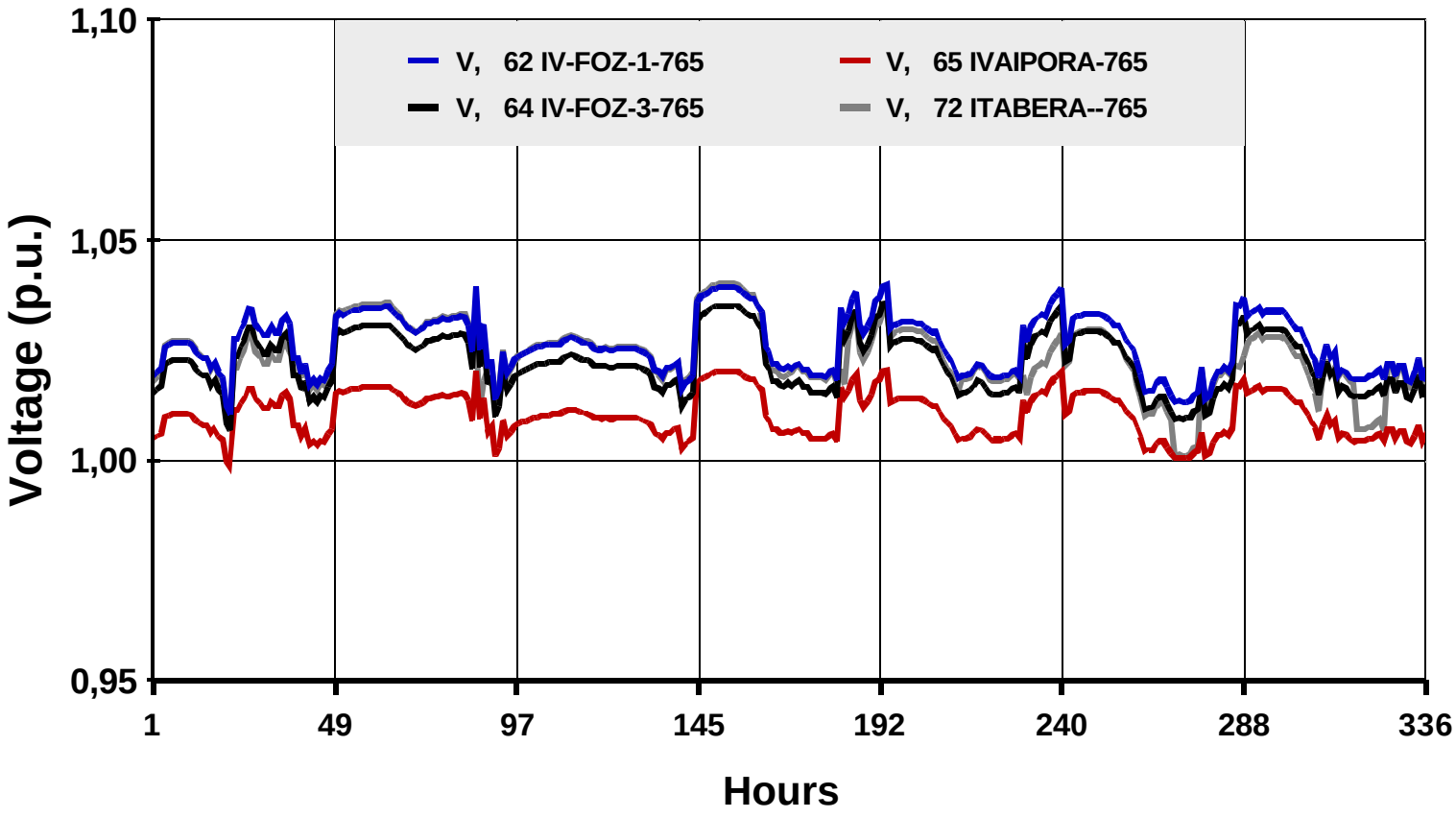
Large Scale System

- Shunt Banks: Main Devices

Bus Name	Number of Banks	Configuration (Mvar)	Bus Name	Number of Banks	Configuration (Mvar)
IVAIPOR-R540	3	-180	CAMPOS---138	2	50
IVAIPOR-R540	3	-180	CM-TER1-3C10	3	10
T.PRETO--345	8	200	CM-TER1-2R25	2	-25
TPRE-69-R360	2	-180	CM-TER2-3C10	3	10
PCAL13.8-R50	2	-25	CM-TER2-2R25	2	-25
CAMP13.8-R50	2	-25	VITORIA--345	2	-60
CAM13.8-R100	2	-50	V.REDONDA138	2	67,5
MAR13.8-R100	2	-50	Z.INDUSTRIAL	1	67,5
C.PAULIS-500	1	-136	PALMARES-138	2	67,5
C.PAULIS-138	2	75	MAGE------69	2	14,4
PCA13.8-R100	2	-50	R.LEAO---138	3	1x37,2+1x23,3+1x30,0
ADRIANO--500	1	-136	TERESOPOL138	1	16,4
ITUTINGA-345	1	200	UTEC------69	1	13,3
ADRIANO--345	2	162,5	CMP.DIST.-69	1	19,7
S.JOSE---138	2	250	ITALVA----69	1	26
JACAREP--138	2	100	ALAGE-1-34.5	2	10,8
ADRIAN-T-T1B	1	40	BFERREIR-138	1	26,7
ADRIAN-T-T2A	1	40	CACHOEIRO138	1	26,7
JAC-13.8-R30	1	-30	CARAPINA-138	3	26,7
JAC-13.8-R30	1	-30	CEASA----138	1	26,7
JAC-13.8-R30	1	-30	GUARAP.T-138	2	26,7
ADR-13.8R100	2	-50	J.NEIVA--138	1	26,7
CAMPOS---345	2	-60	N.VENECIA138	1	26,7
CAMP-CAP-345	2	60	PITANGA--138	2	26,7

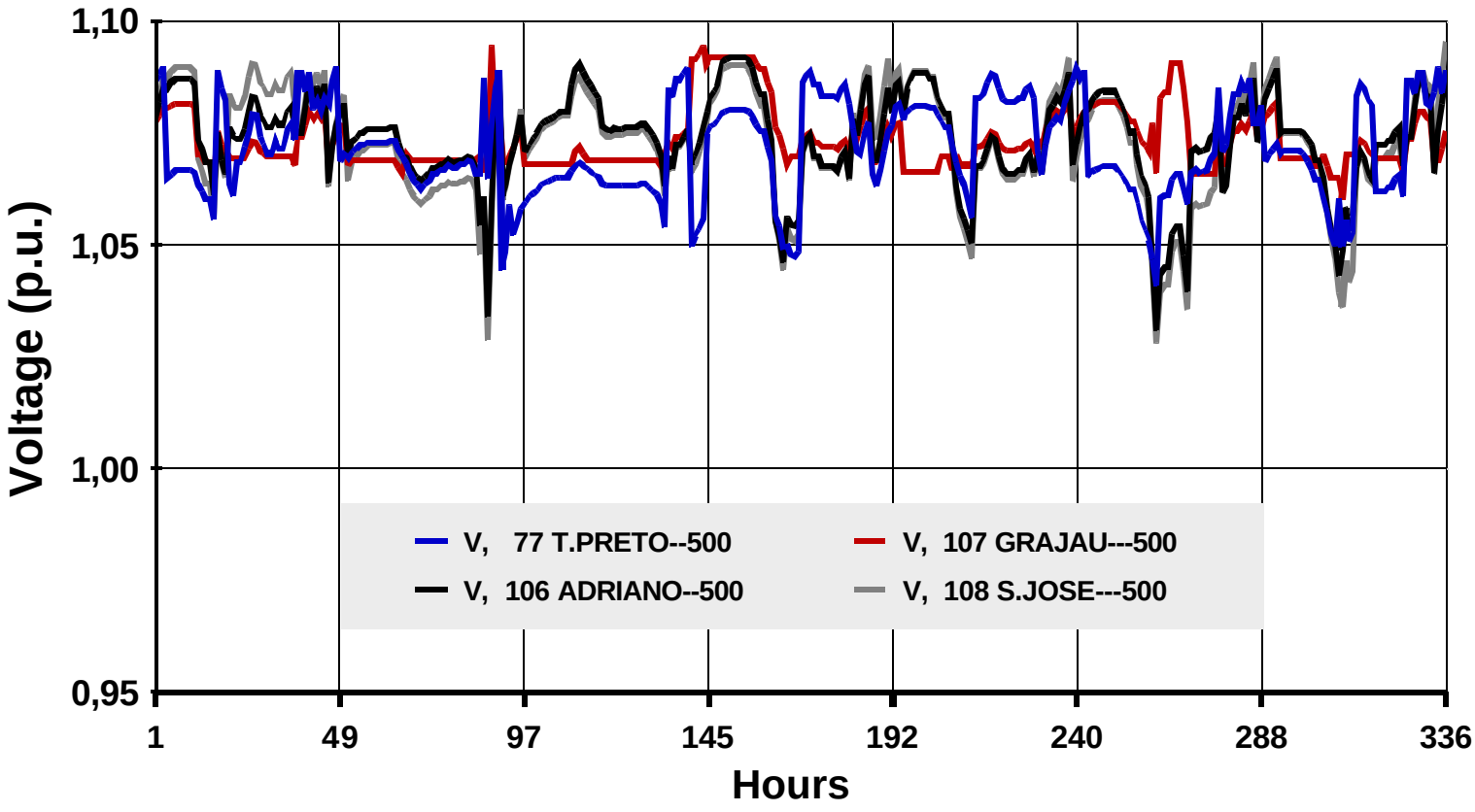
Large Scale System

Voltage Profile for major 765 kV Buses



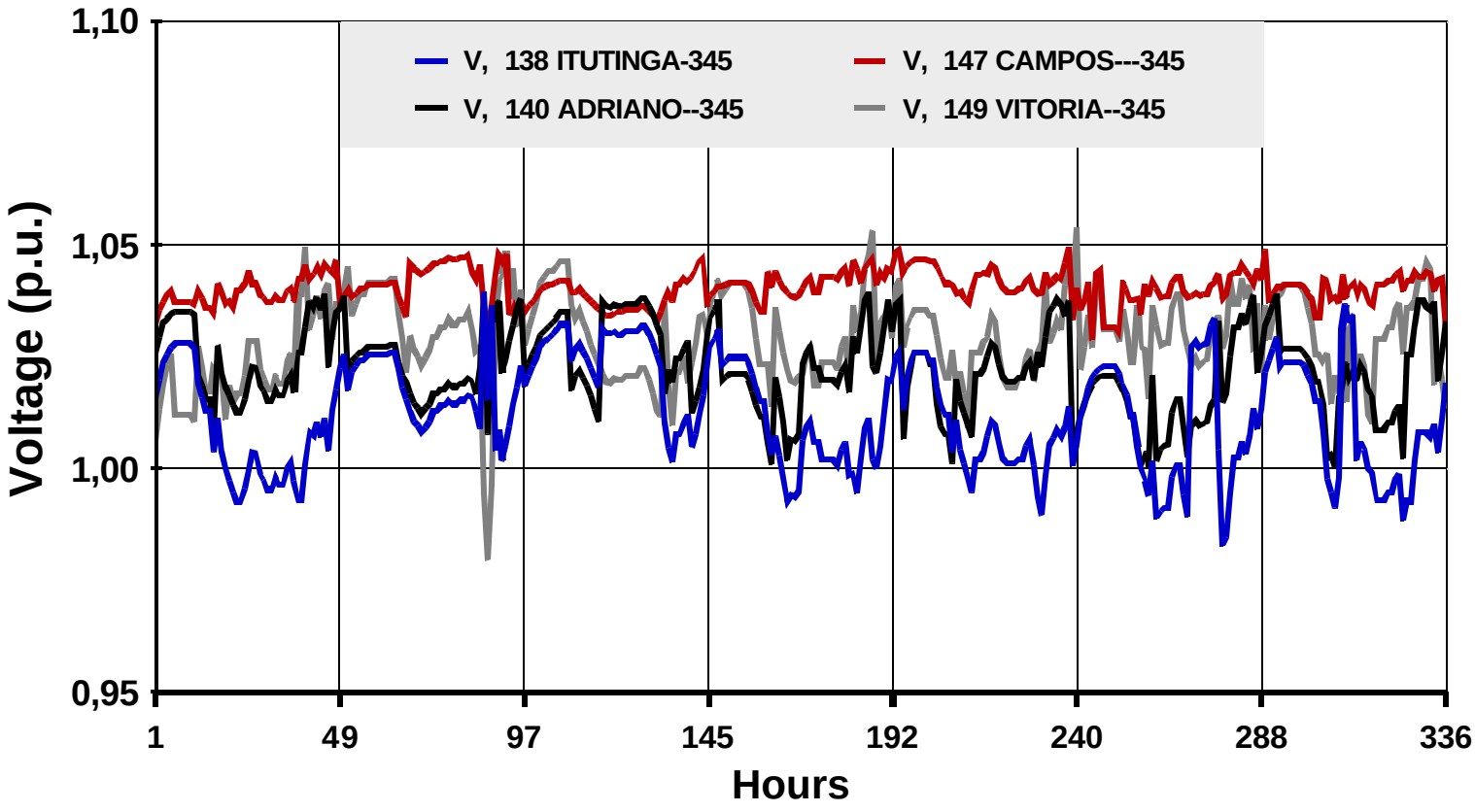
Large Scale System

Voltage Profile for major 500 kV Buses



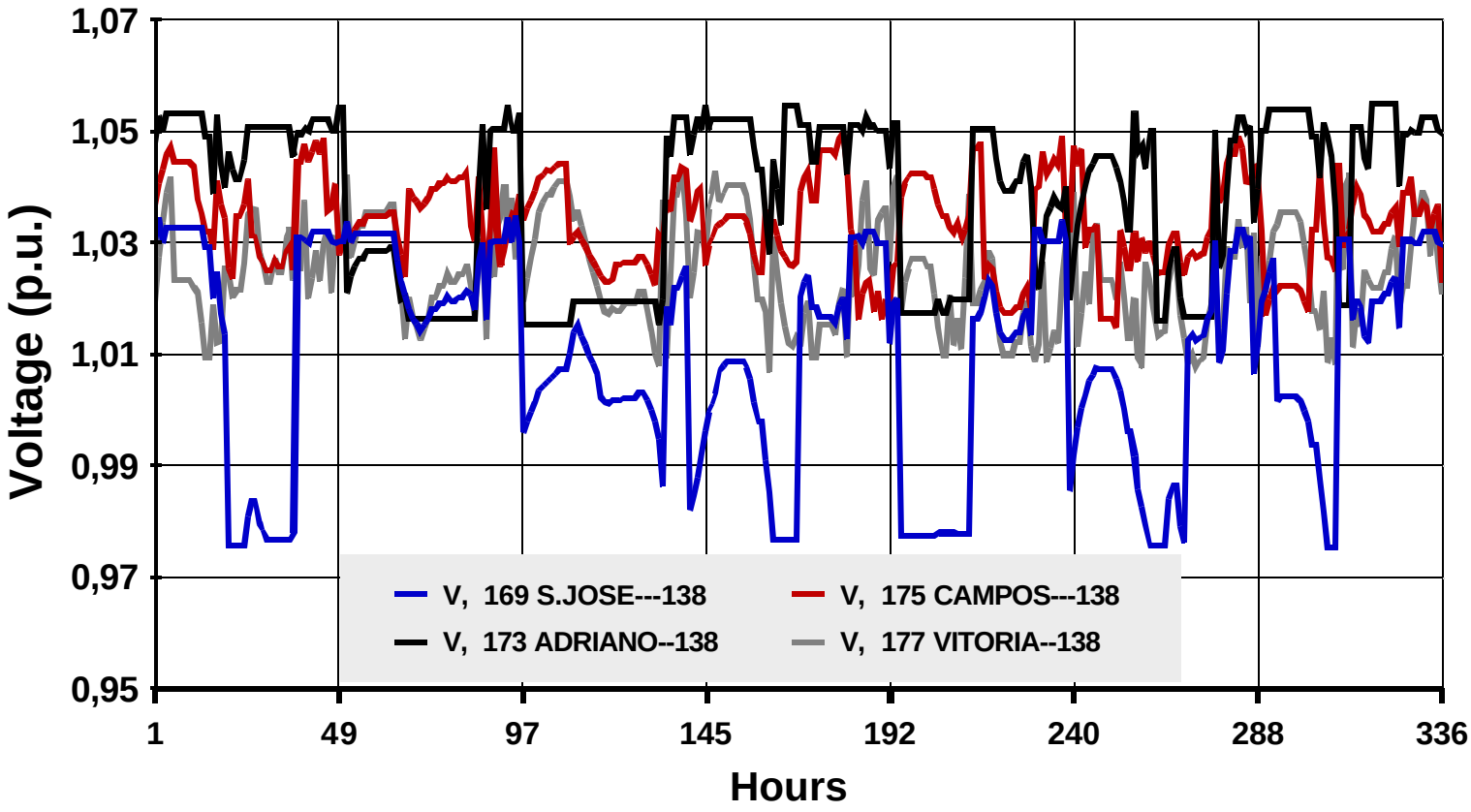
Large Scale System

Voltage Profile for major 345 kV Buses



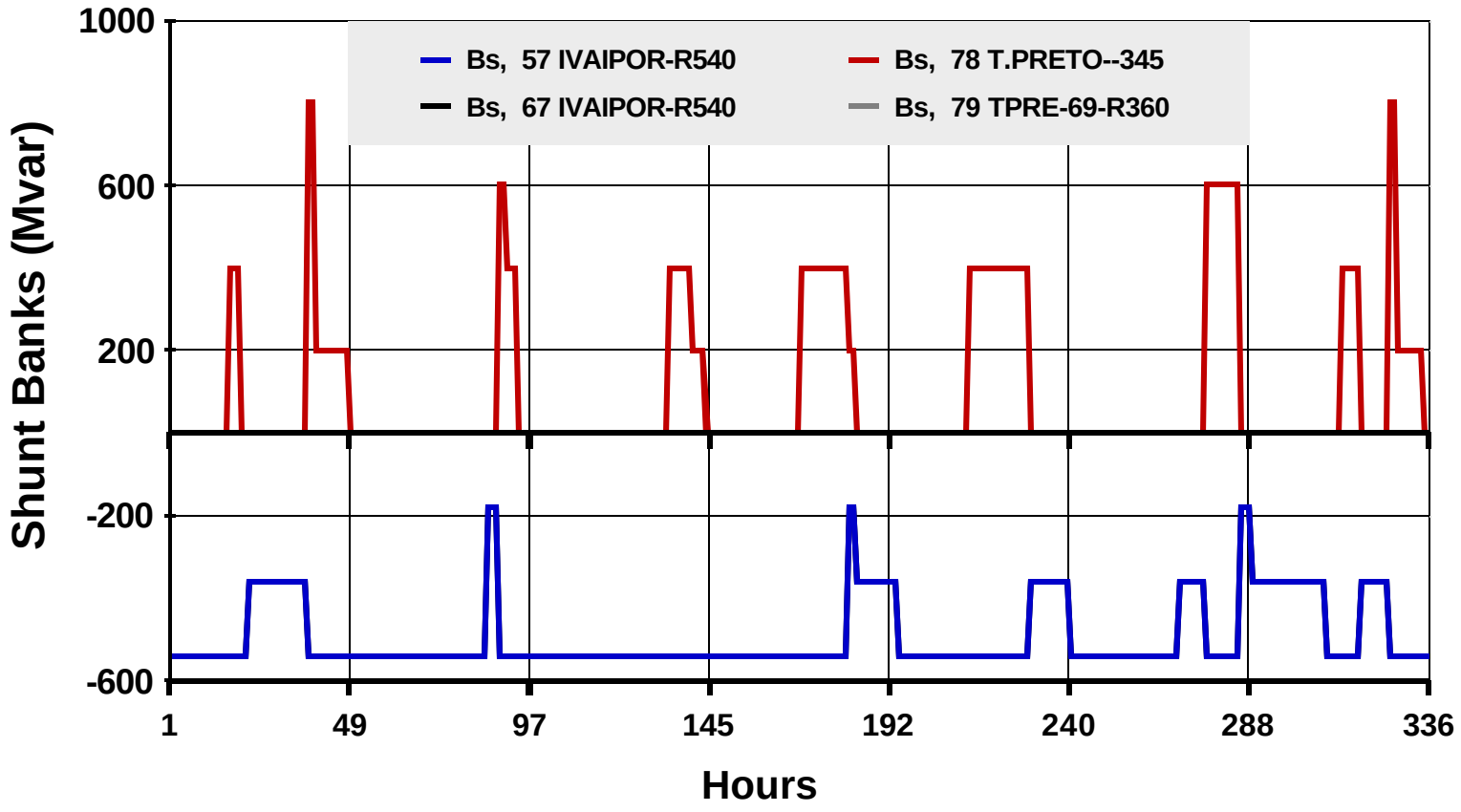
Large Scale System

Voltage Profile for major 138 kV Buses



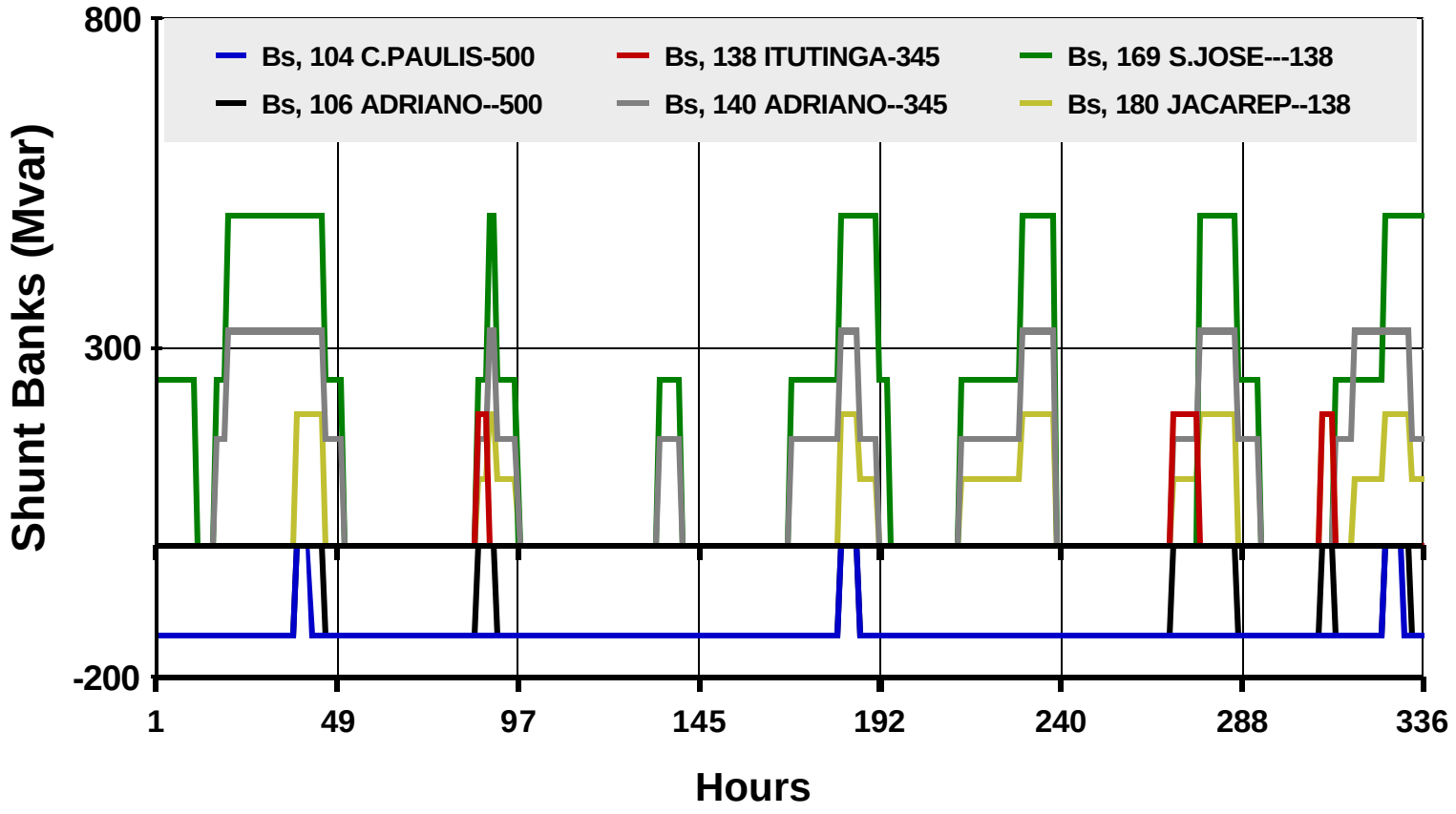
Large Scale System

Shunt Switching – 765 kV Transmission System



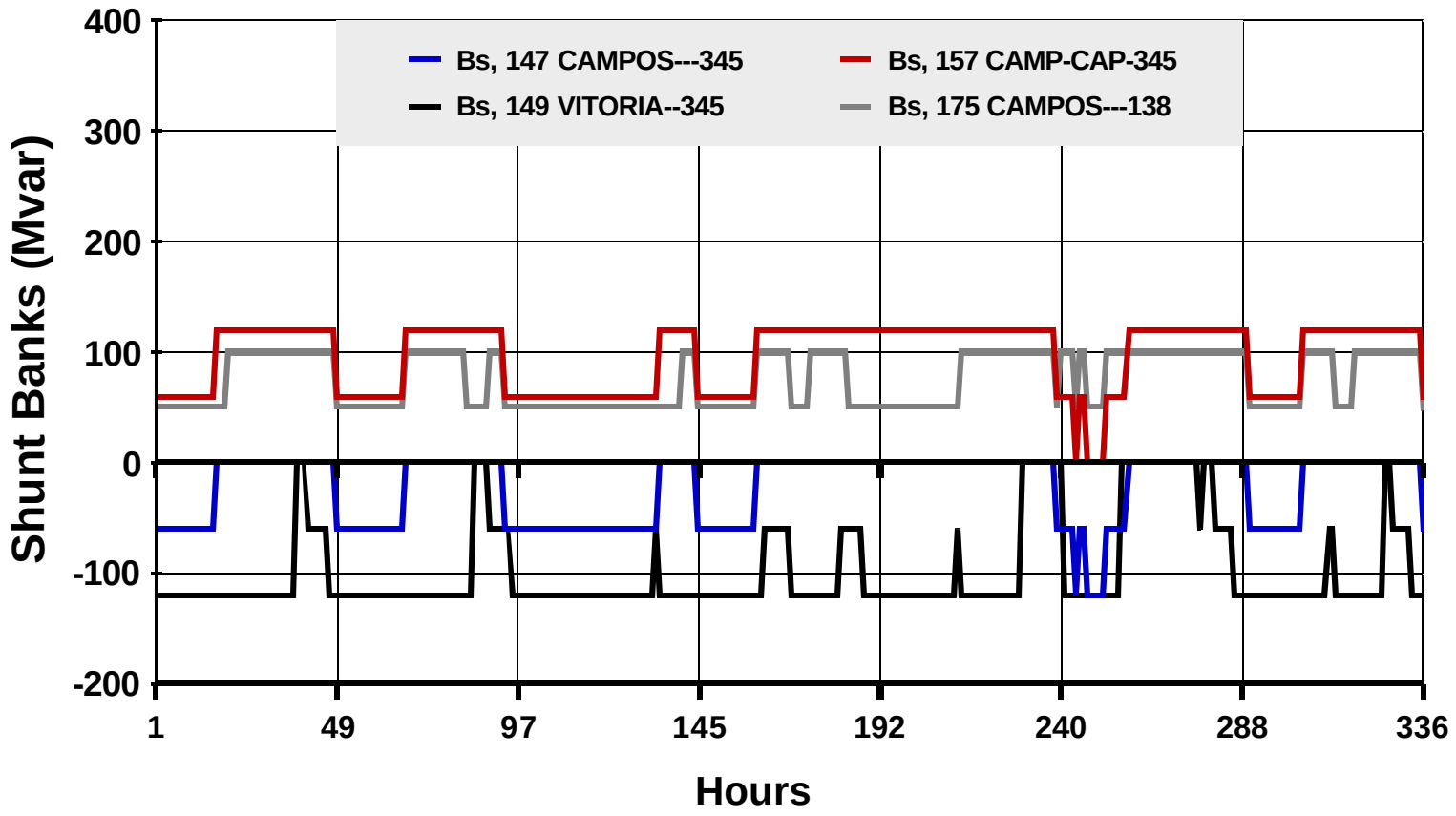
Large Scale System

Shunt Switching – Rio Area



Large Scale System

Shunt Switching – Espírito Santo Area



Conclusions

- Critical settings of control devices
  - ✓ Better voltage regulation
  - ✓ Control devices hierarchy
- Robust convergence
  - ✓ Full Newton representation
- Automatic switching of capacitor/reator banks
  - ✓ More realistic representation of the system
- Better adjustment of base case
  - ✓ Different scenarios
- Representation of large shunt banks