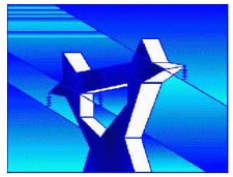

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Impact of Induction Motor Loads into Voltage Stability Margins of Large Systems – Rio Area Analysis

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Presentation Summary

- Introduction
- Motor Modeling in Power Flow Studies
- Illustrative Example
- Maximum Loadability Assessment – Rio Area
- Conclusions

Introduction

- Blackouts are result of voltage instability/collapse
- These events may occur due to exhaustion of the system reactive power reserves
- The analysis requires adequate methodologies and efficient software
  - Continuation Power Flow, analysis of P-V and Q-V curves

Motivation

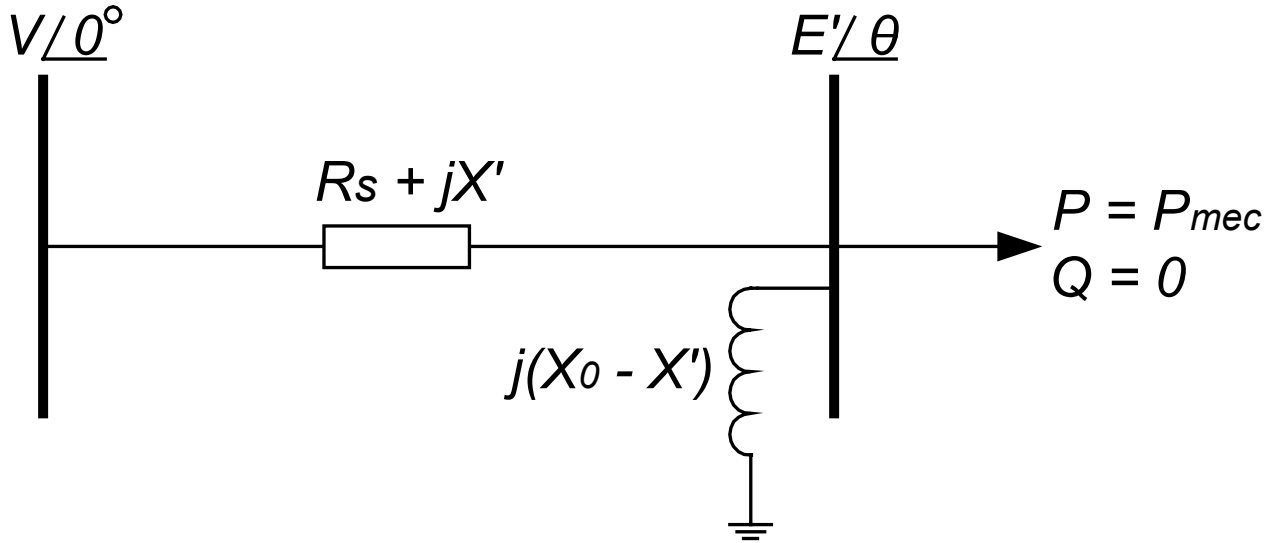
- Rio Area during hot summer days of ‘97
  - Air-conditioning systems highly used
  - Depressed voltage conditions despite active loading below the expected critical values
- Preliminary conclusions
  - Representing loads by constant-P and constant-I models was not adequate
  - Inductions motors should be better modeled

Motor Modeling in Power Flow Studies

- Implementation of aggregate induction motor models into a continuation power flow program
- Motor models – several types and typical parameters embedded in the program code
- User must specify the motor type and the content in each load bus
- Testing
  - Loadability studies of the Rio Area

Motor Modeling in Power Flow Studies

- Two-bus steady-state model for induction motors



- The mechanical torque is assumed independent of rotor speed
- For each motor, the electrical network is augmented by one bus with an additional shunt element and connected to the terminal bus by an additional impedance

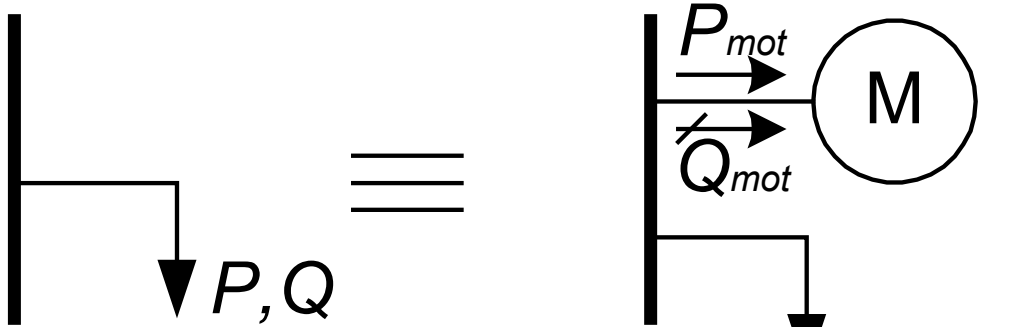
Motor Modeling in Power Flow Studies

- Bus Data indicate which motor type will be used and the percentage of load to be modeled as motors

Motor Type	*Motor Characteristics*
1	**Small Industrial I**
2	**Large Industrial**
3	**Mean values for 11 kVA motors**
4	**Small Industrial II**
5	**Commercial+Feeder**
6	**Aggregate residential**
7	**Single Phase**

Motor Modeling in Power Flow Studies

- MVA Base for each motor is a function of percentage of the load modeled as motor in that particular bus
- The power flow program calculates
  - Active and reactive power consumption
  - Internal voltage *E'*, angle θ, and rotor slip *s*
- The original load which is not modeled as motor is denoted as *P'* and *Q'*



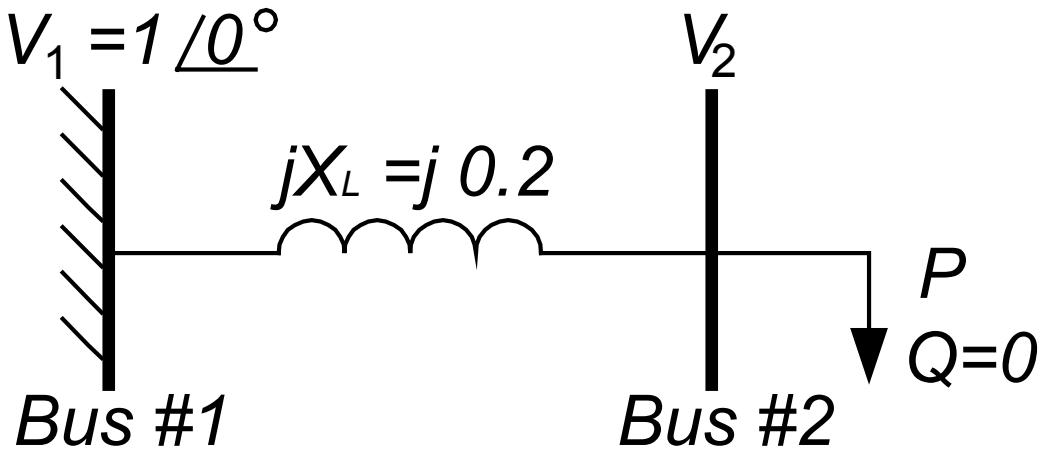
$$P = P_{mot} + P'$$
$$Q = Q_{mot} + Q'$$

Motor Modeling in Power Flow Studies

- Methodology for continuation power flow studies
  - Motor load is increased by increasing the MVA motor base
  - This procedure is equivalent to increasing the number of motors in the system

Illustrative Example

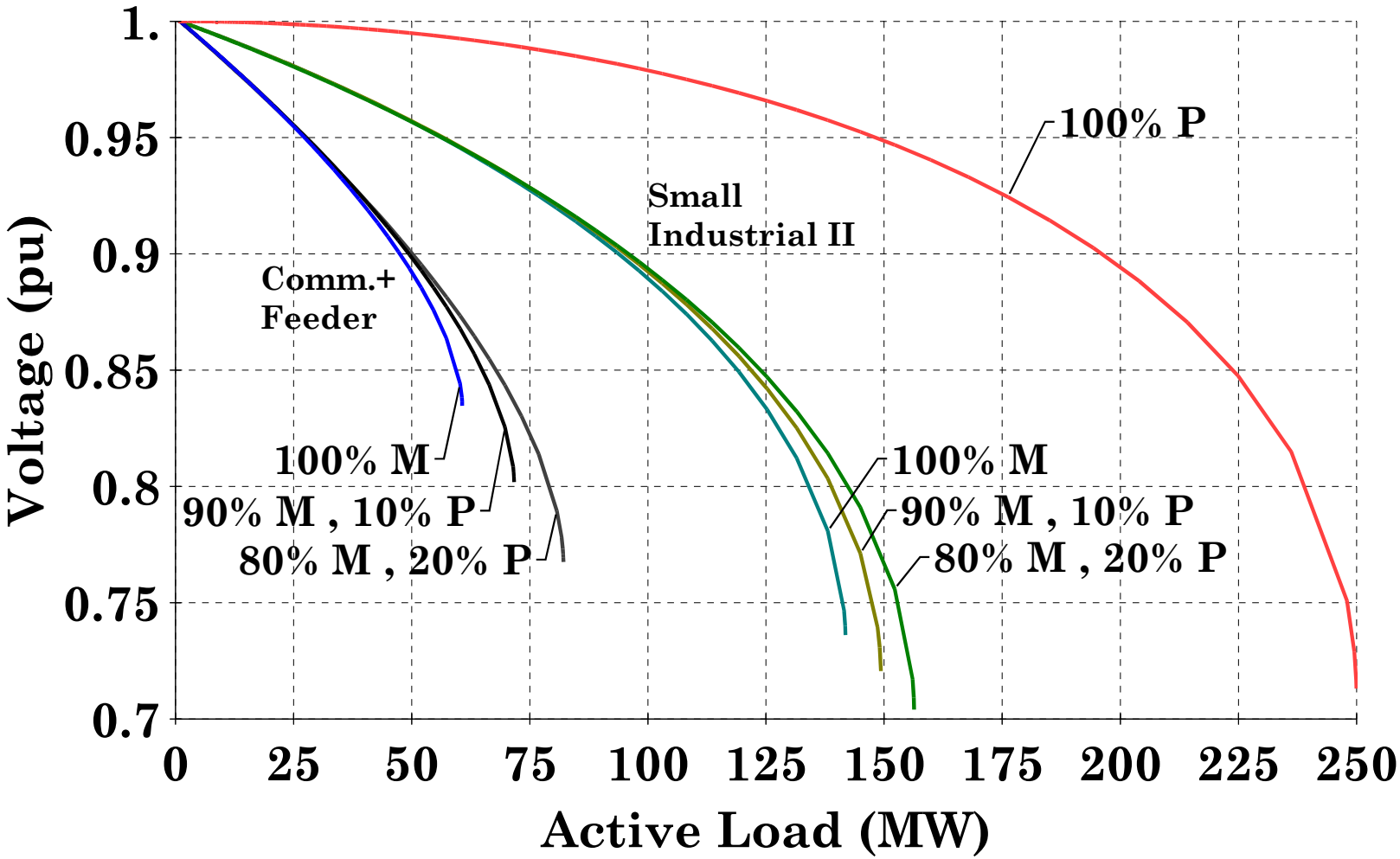
- Test System



- Continuation Power Flow
  - Used to obtain maximum loadability for different models of the load at bus #2

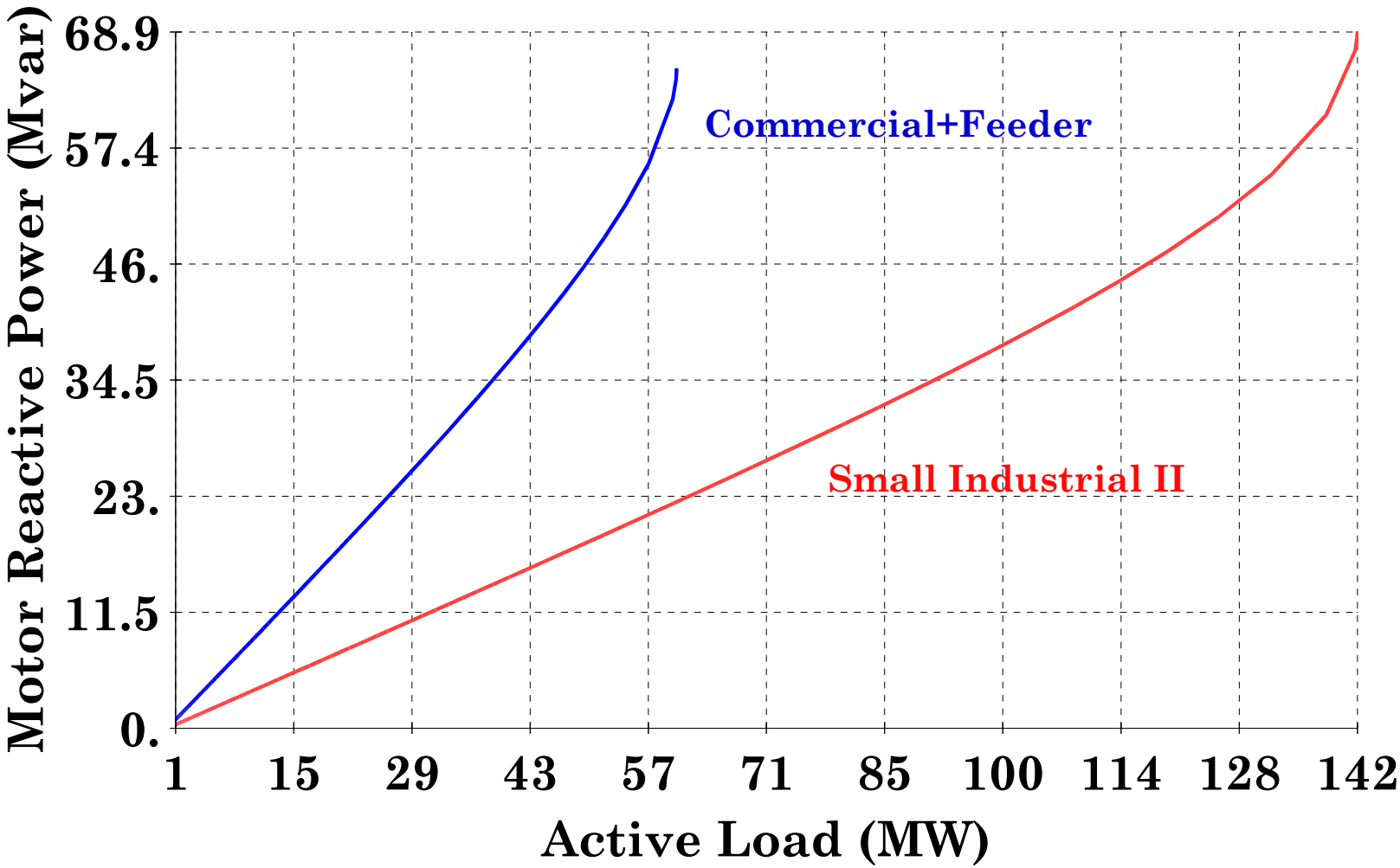
Illustrative Example

- PxV Curves for different load models at bus #2



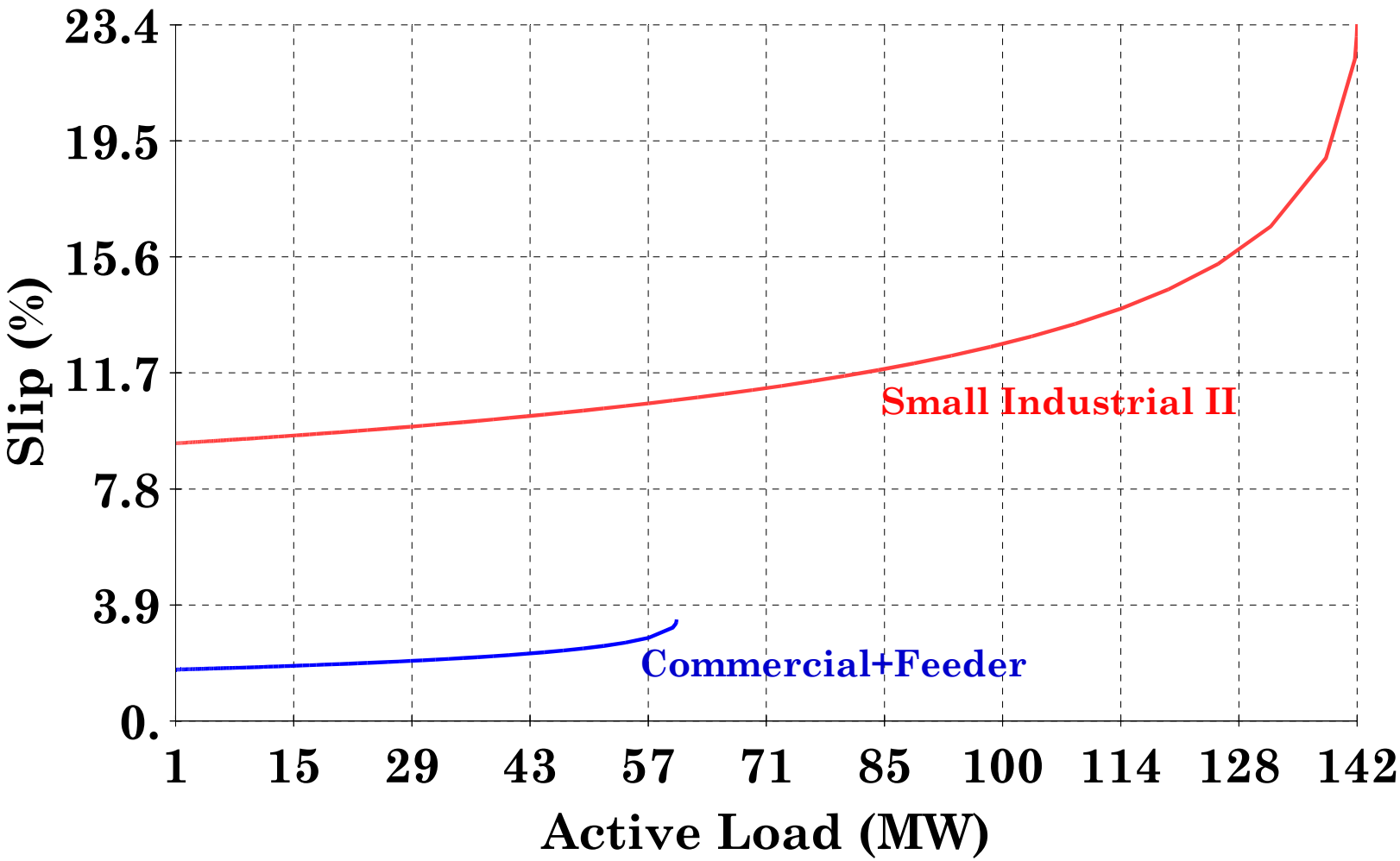
Illustrative Example

- Reactive Power Consumption at bus #2



Illustrative Example

- Rotor Slip Curves: two set of induction motor parameters



Maximum Loadability Assessment - Rio Area

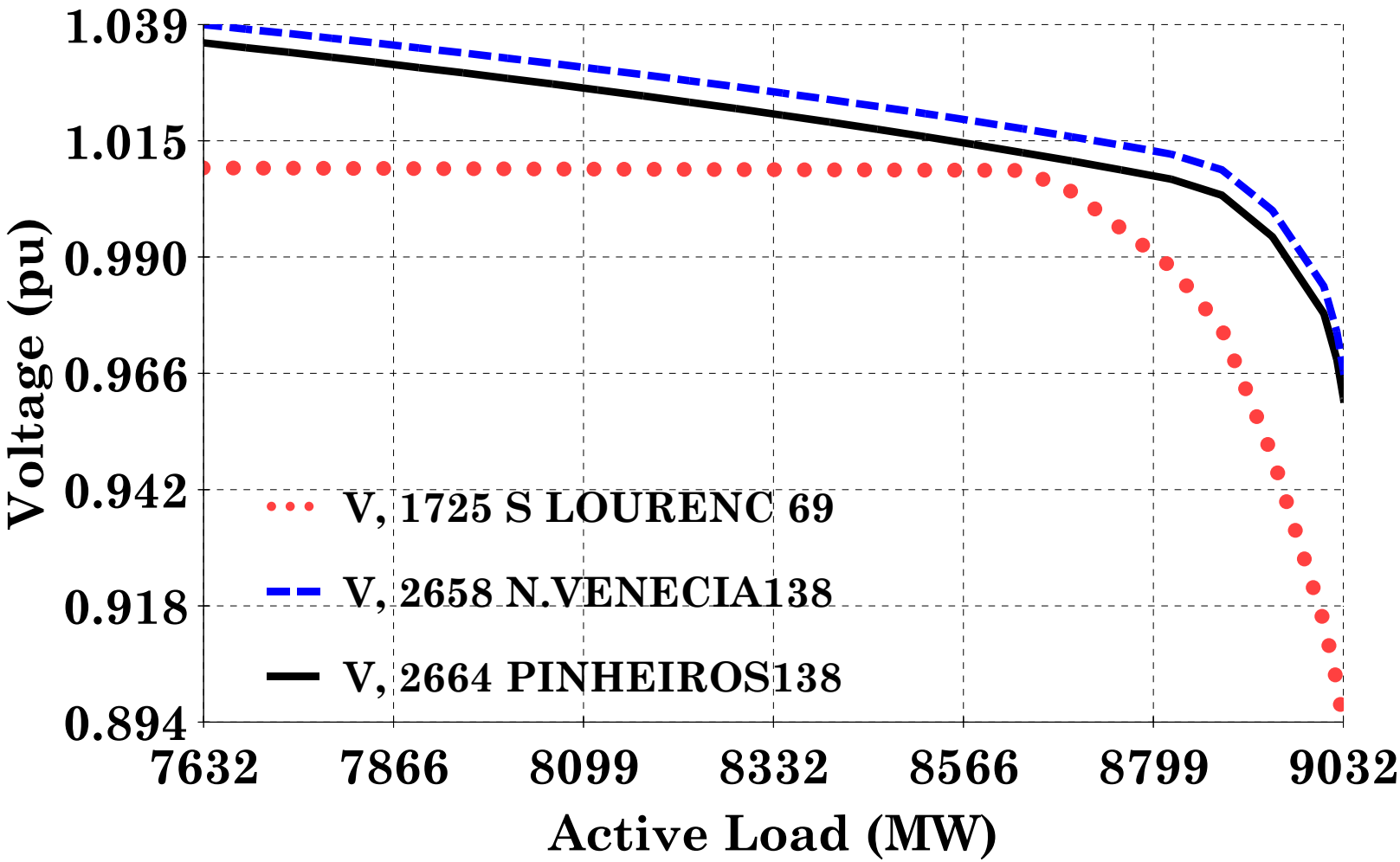
- Rio Area – 3 utilities: LIGHT, CERJ and ESCELSA
  - 288 buses
  - 200 load buses (7632 MW)
  - 149 buses with load modeled as induction motor (5733 MW)
    - Industrial: 2227 MW – Comercial: 3506 MW
  - Operation point refers to a heavy load condition for the Rio Area on a summer day

Maximum Loadability Assessment - Rio Area

- Other assumptions made in continuation power flow analysis:
  - Industrial motor load remains constant
  - Only commercial motor load is increased
  - Commercial and industrial load is initially modeled as constant P and Q, with fixed power factor
  - The PxV curves
    - Most critical buses belong to ESCELSA (distribution utility)

Maximum Loadability Assessment - Rio Area

- Constant P and Q load model

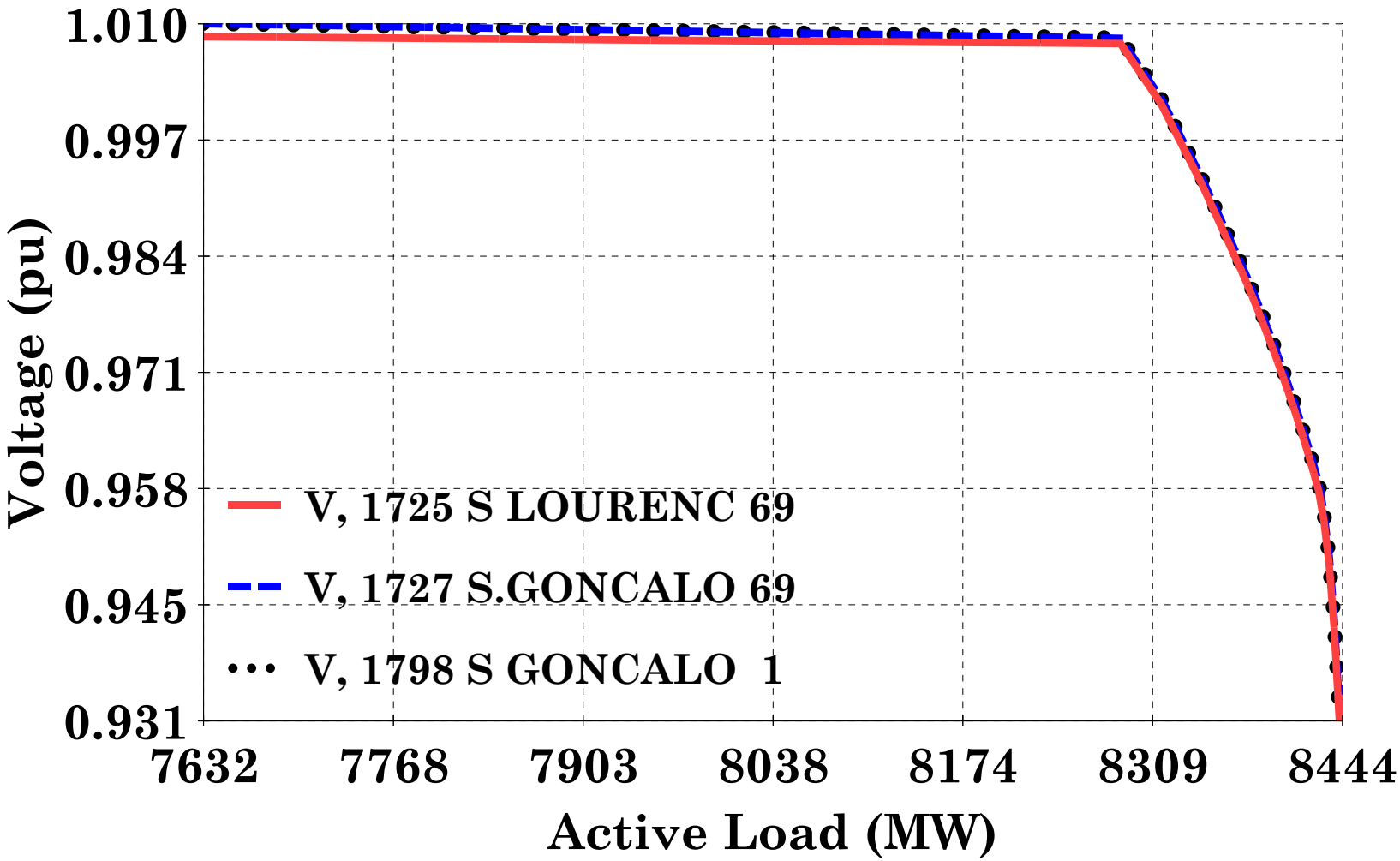


Maximum Loadability Assessment - Rio Area

- Two cases were investigated where the Commercial induction motor load was modeled as:
  - Commercial+Feeder (Type 5)
  - Small Industrial (Type 4)
- The Industrial induction motor load was modeled as Large Industrial (Type 2)
  - This load remains fixed at the base case value

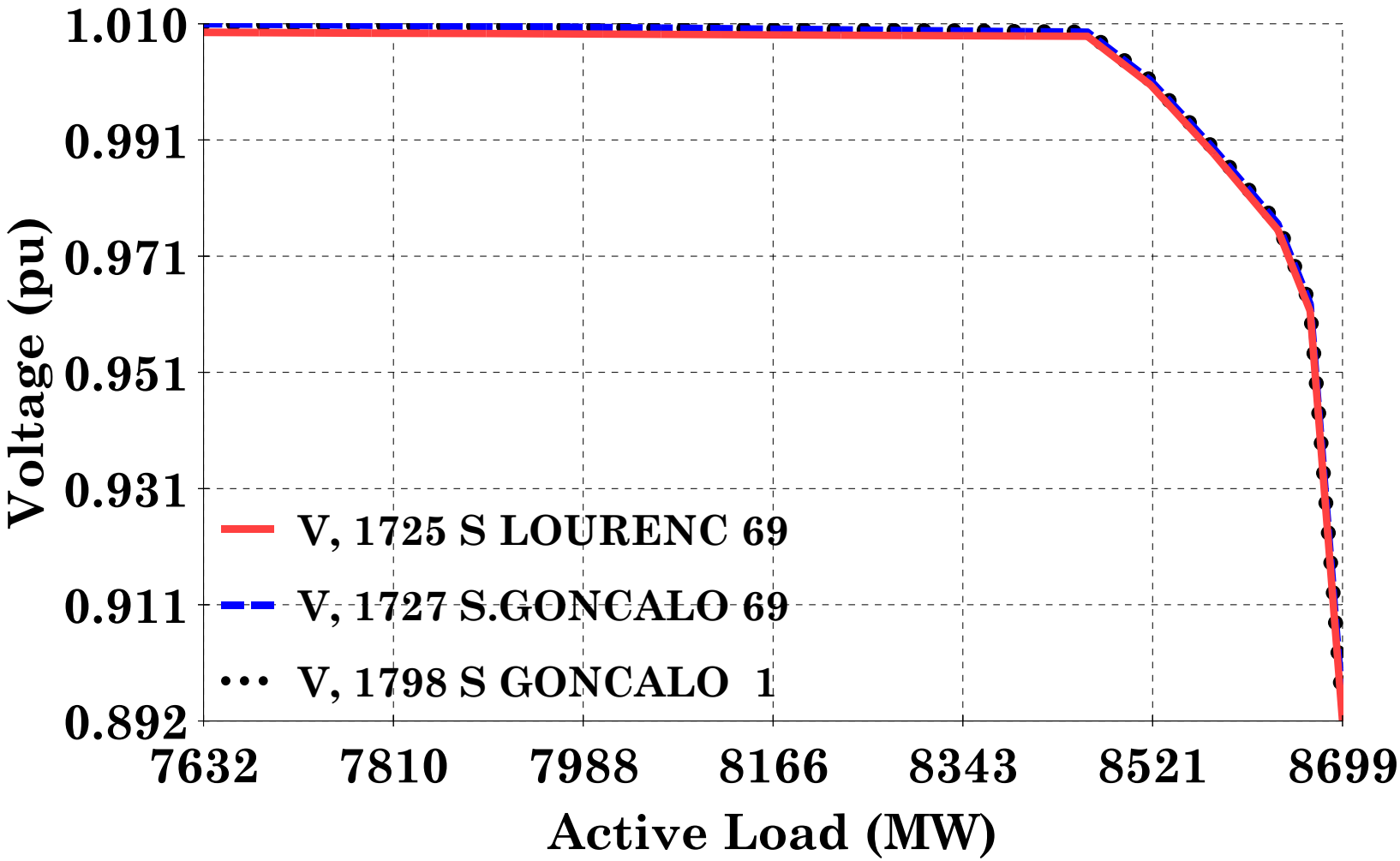
Maximum Loadability Assessment - Rio Area

- Commercial induction motor modeled as Comm.+Feeder



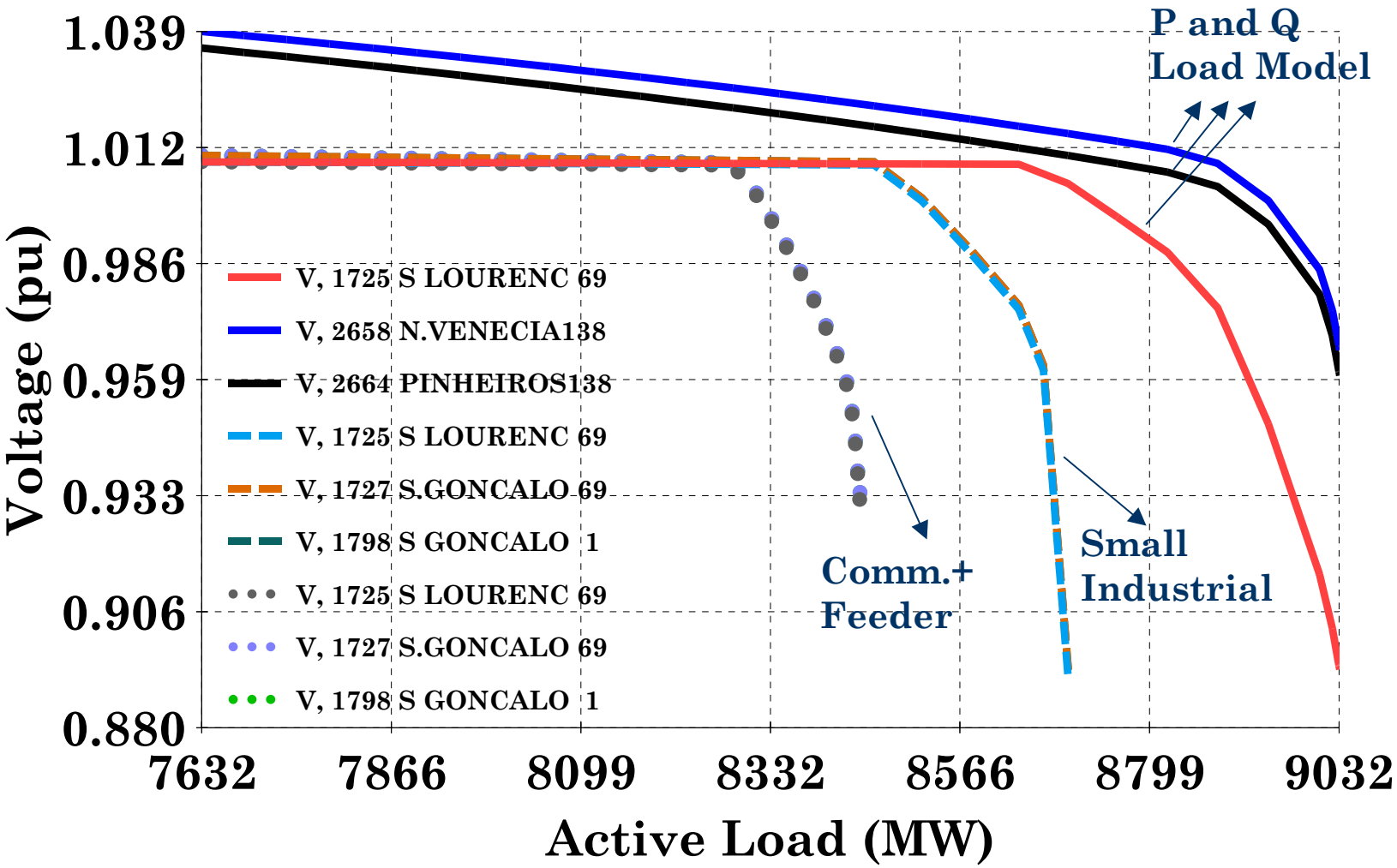
Maximum Loadability Assessment - Rio Area

- Commercial induction motor modeled as Small Industrial



Maximum Loadability Assessment - Rio Area

- Maximum loadability for 3 different load models



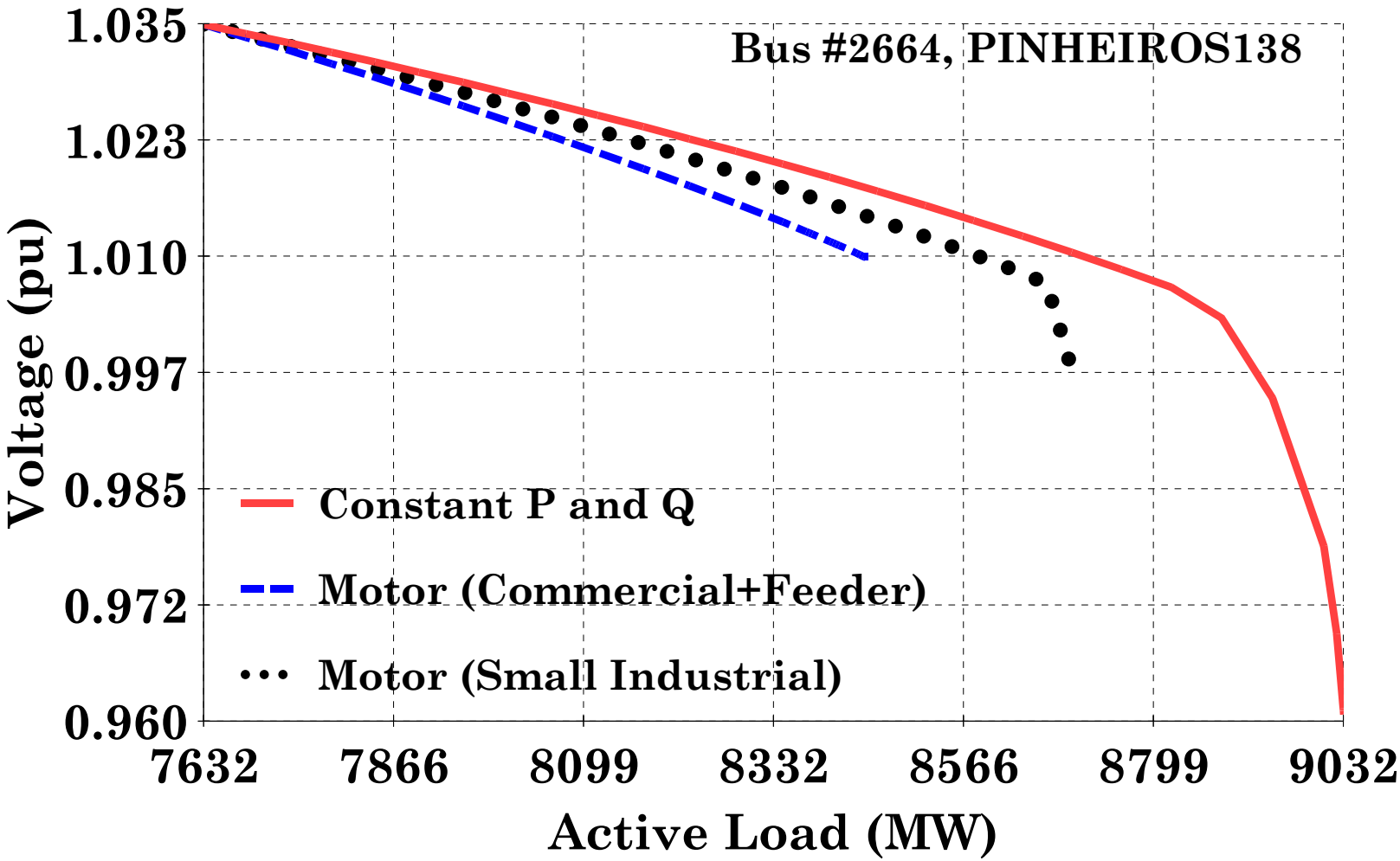
Maximum Loadability Assessment - Rio Area

- Maximum loadability for 3 different load models

Load Model	*Rio Area Active Load*		
	Initial Load (MW)	*Induction Motor (MW)*	*Maximum Loadability (MW)*
Constant P and Q	**7632**	**-**	**9032**
Induction Motor 4	**7632**	**5733**	**8699**
Induction Motor 5	**7632**	**5733**	**8444**

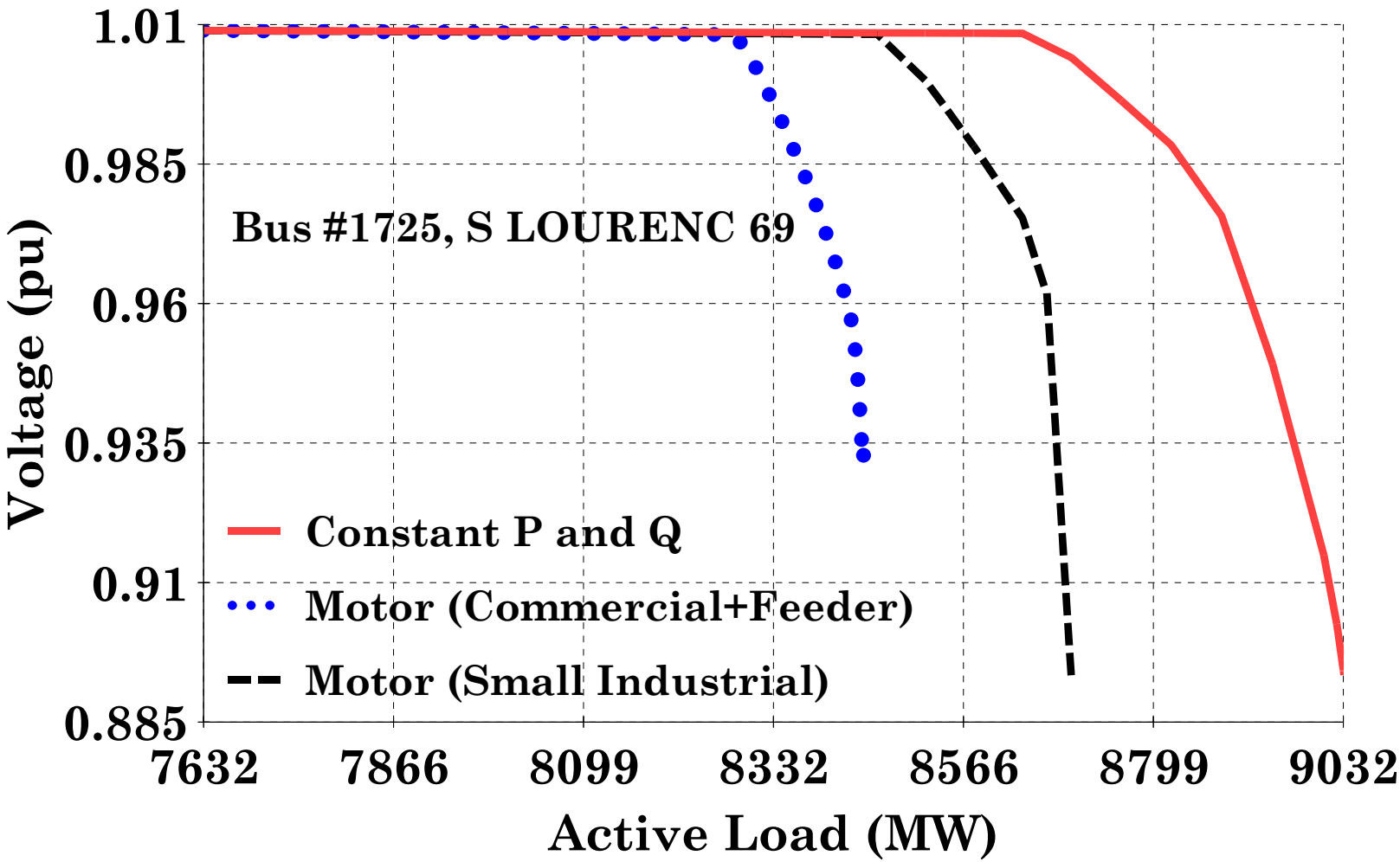
Maximum Loadability Assessment - Rio Area

- PxV Curves of “Pinheiros-138 kV” for 3 scenarios



Maximum Loadability Assessment - Rio Area

- PxV Curves of S. Lourenco - 69 kV for 3 scenarios



Conclusions

- Modeling the load as induction motors
  - Allows better analysis of system behavior
  - Ability to reveal voltage stability problems
  - Finding the cost-effective level of modeling for subtransmission and distribution networks is not an easy task
- The results are coherant to observed system behavior in Rio Area and would not be obtained if only constant-P and constant-I load models were utilized