

Optimal Usage of Transmission Capacity with FACTS Devices In the Presence of Wind Generation

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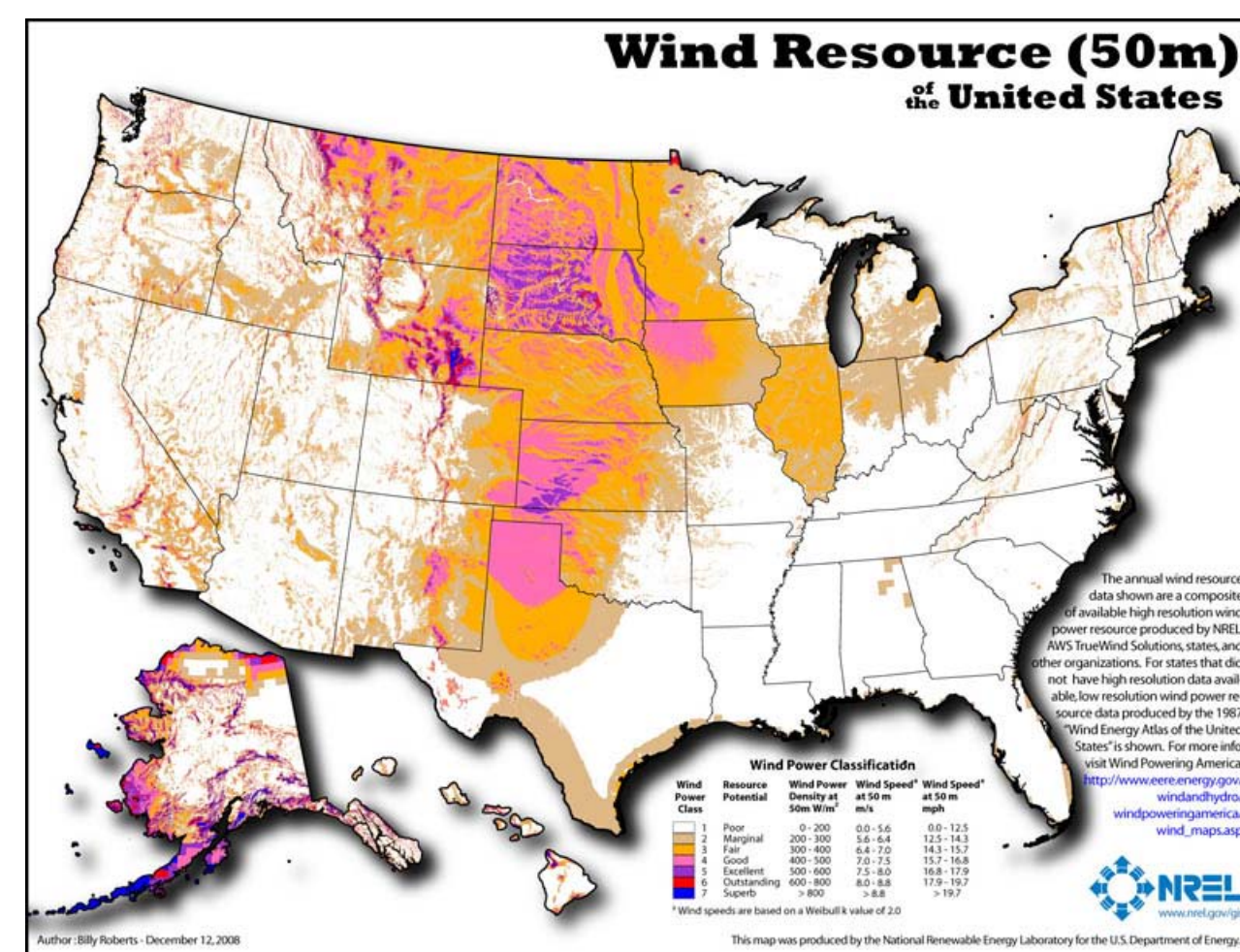
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Motivation

Accelerated Integration of Wind Energy Resources

Challenges



Class	Potential	Density (W/m ²)	Wind Speed (m/s)
1	Poor	0-200	0.0-5.6
2	Marginal	200-300	5.6-6.4
3	Fair	300-400	6.4-7.0
4	Good	400-500	7.0-7.5
5	Excellent	500-600	7.5-8.0
6	Outstanding	600-800	8.0-8.8
7	Superb	>800	>8.8

- Areas with high availability of wind \neq demand centers
- Variable power output of the wind generators

Potentials of FACTS Devices

- Redirect the network flows and regulate nodal voltages
- Allow better usage of the current transmission facilities
- Able to deal with the rapid fluctuations of the wind generation

Proposed Solution

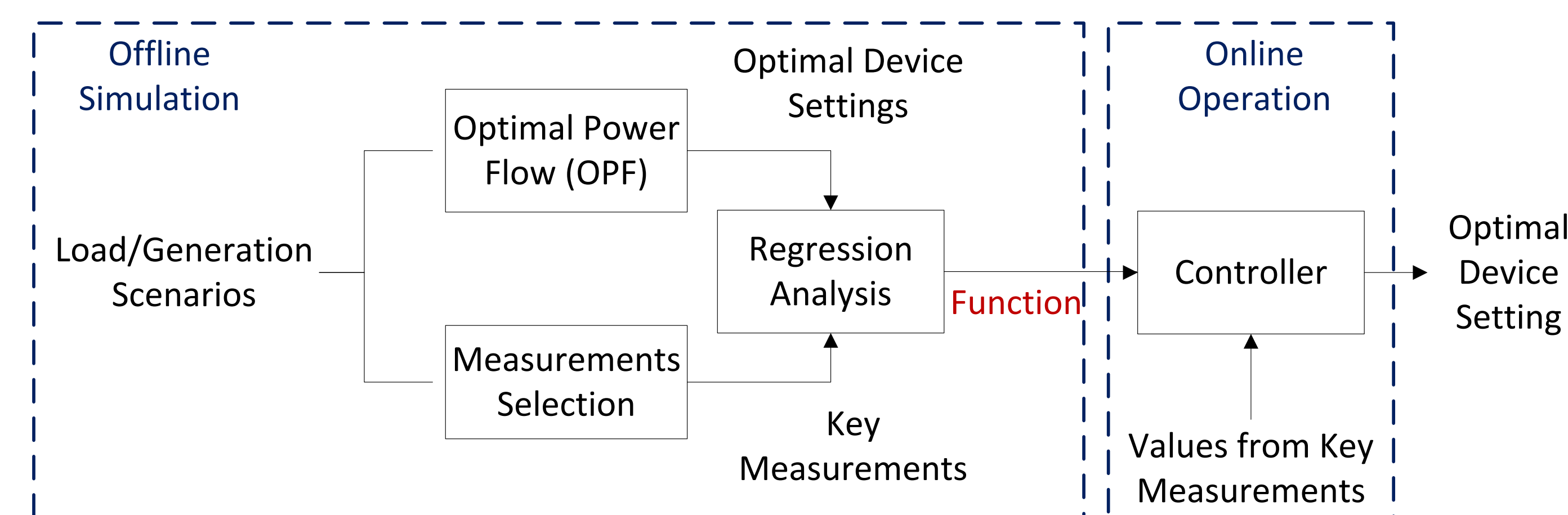
- Use FACTS devices to render the system more flexible

A Two-stage Approach

Objective

- Develop a scheme which determines the optimal steady-state settings of the FACTS devices with respect to certain objectives only using a limited amount of information

Proposed Method – A Two-stage Approach



Offline Simulation

- Solve OPF for various generation and load scenarios
- Determine function: **optimal setting = f(key measurements)**

Online Decision Making

- Evaluate the locally stored function
- No online OPF calculations needed

Offline Simulation

Optimization Problem Formulation

Control variable

- Setting of the FACTS devices $X_{TCSC,n}$

Objective function

- Maximizing the minimum value of the capacity margin

$$\max (\min (P_{margin,ij})), \text{ where } P_{margin,ij} = \frac{F_{ij}^{\max} - |P_{ij}|}{F_{ij}^{\max}}$$

Constraints

- Power flow equations $P_{G,i} - P_{L,i} - \sum_j P_{ij} = 0, Q_{G,i} - Q_{L,i} - \sum_j Q_{ij} = 0$
- Limits of the device settings $-0.9X_{Line,n} \leq X_{TCSC,n} \leq 0.4X_{Line,n}$

Determining Key Measurements

- Active power flow and current magnitude of each line
- Voltage angle at each bus
- Current setting of the FACTS device

Regression Analysis

- Polynomial fitting - a sparse solution for the coefficients wanted
- Formulate a L_0 -norm regularization problem
- **Orthogonal Matching Pursuit (OMP)**
 - A subset of important coefficients is identified
 - The optimal tradeoff between the fitting accuracy and the number of measurements used is achieved

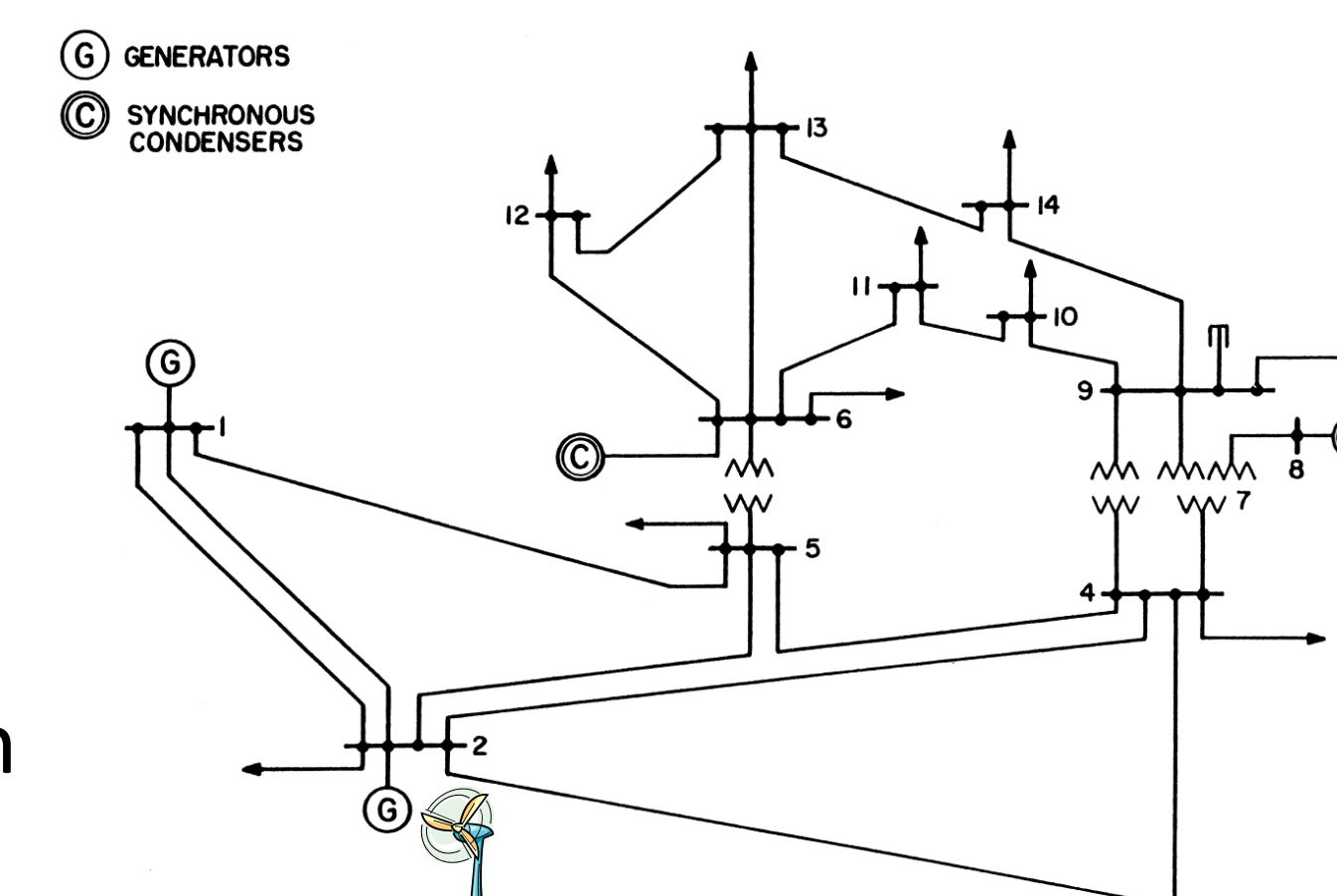
System Setup

System Setup

- IEEE 14-bus system
- Wind generator at Bus 2
- Load center on north side

Simulations

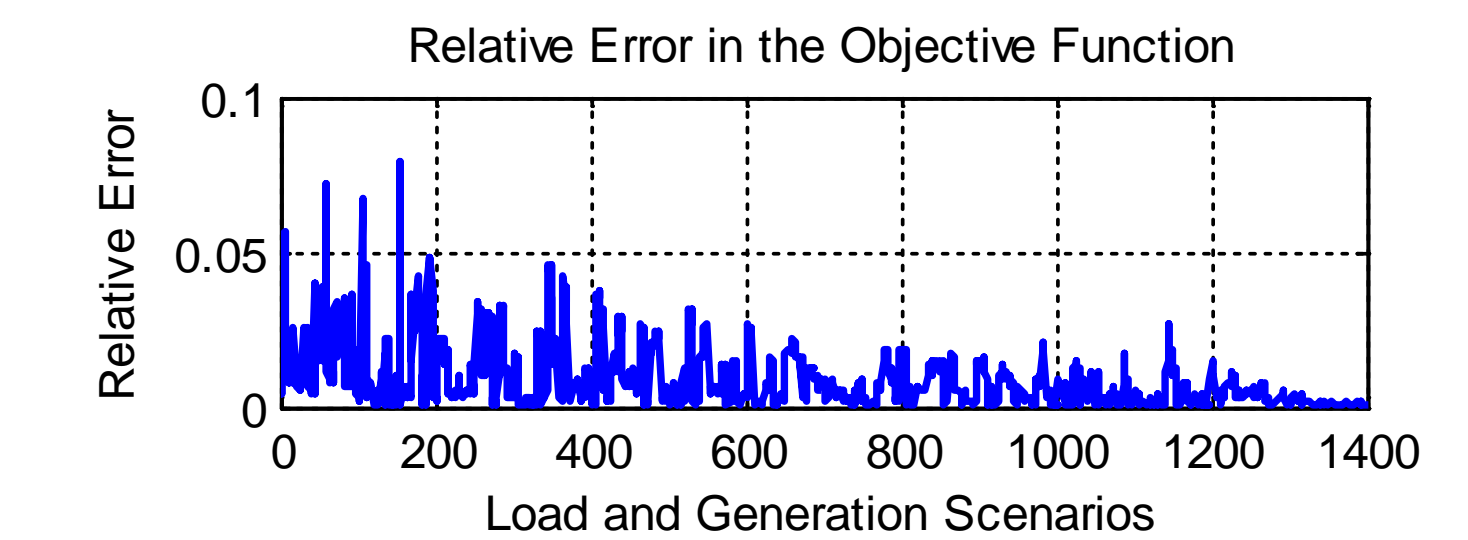
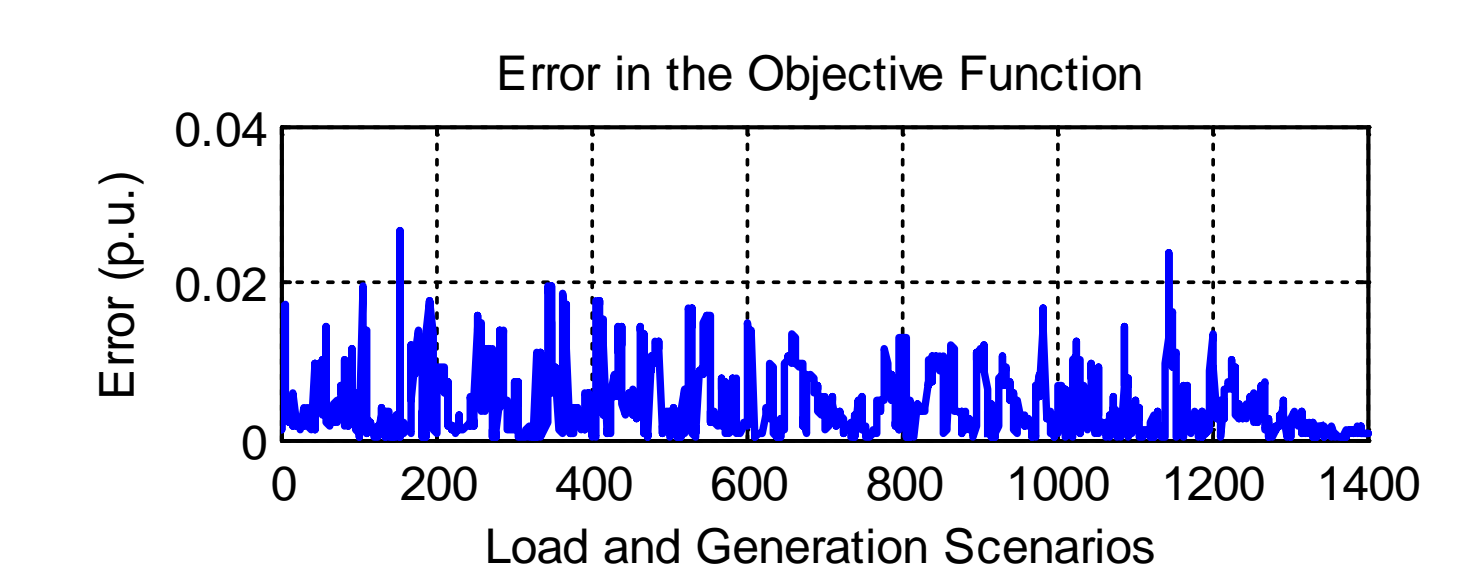
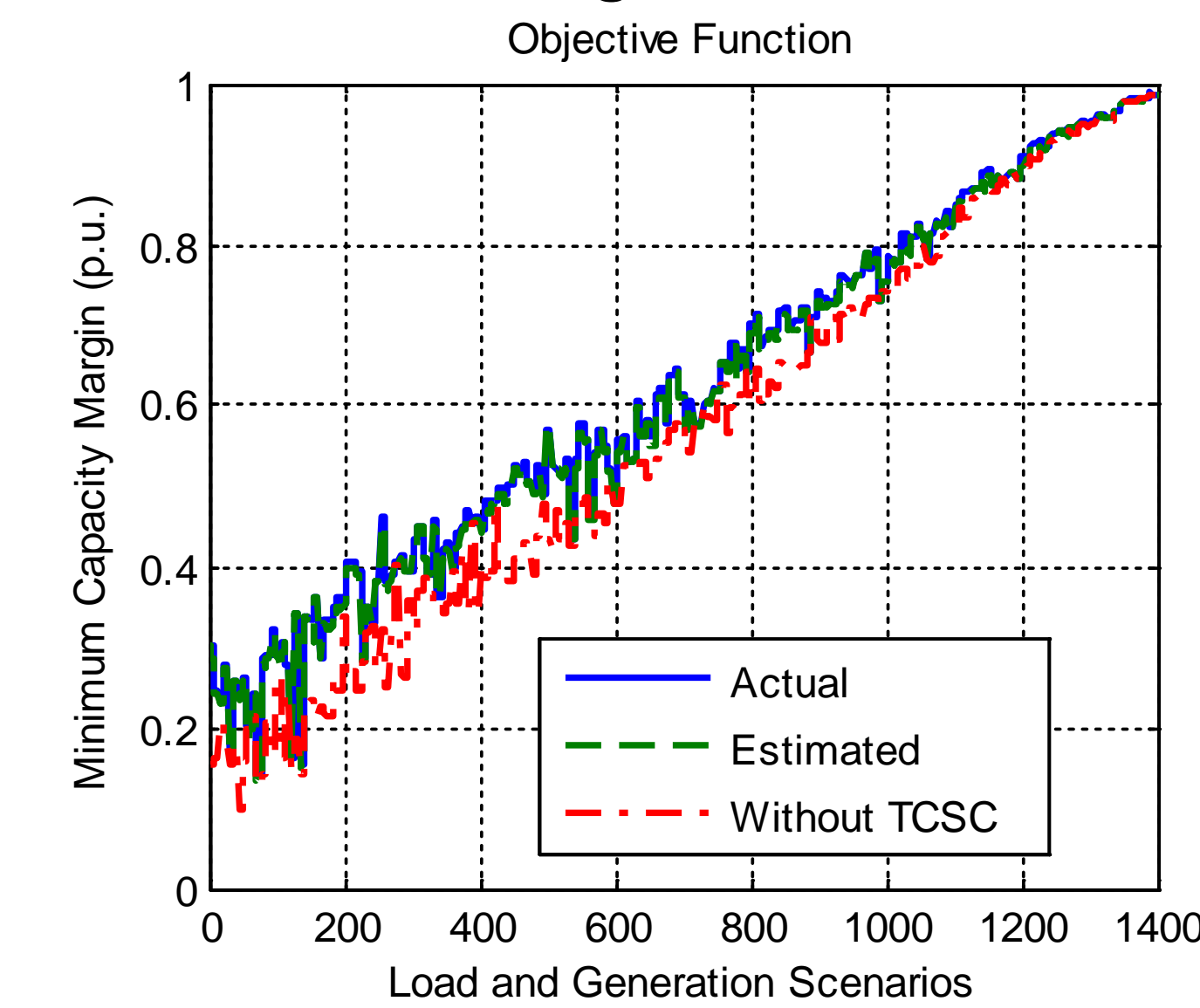
- 1000 different load/generation scenarios
 - 800 scenarios for training
 - 200 scenarios for testing
- One TCSC in the system – TCSC in Line 1-2
- Two TCSCs in the system – TCSC₁ in Line 1-2 and TCSC₂ in Line 2-5



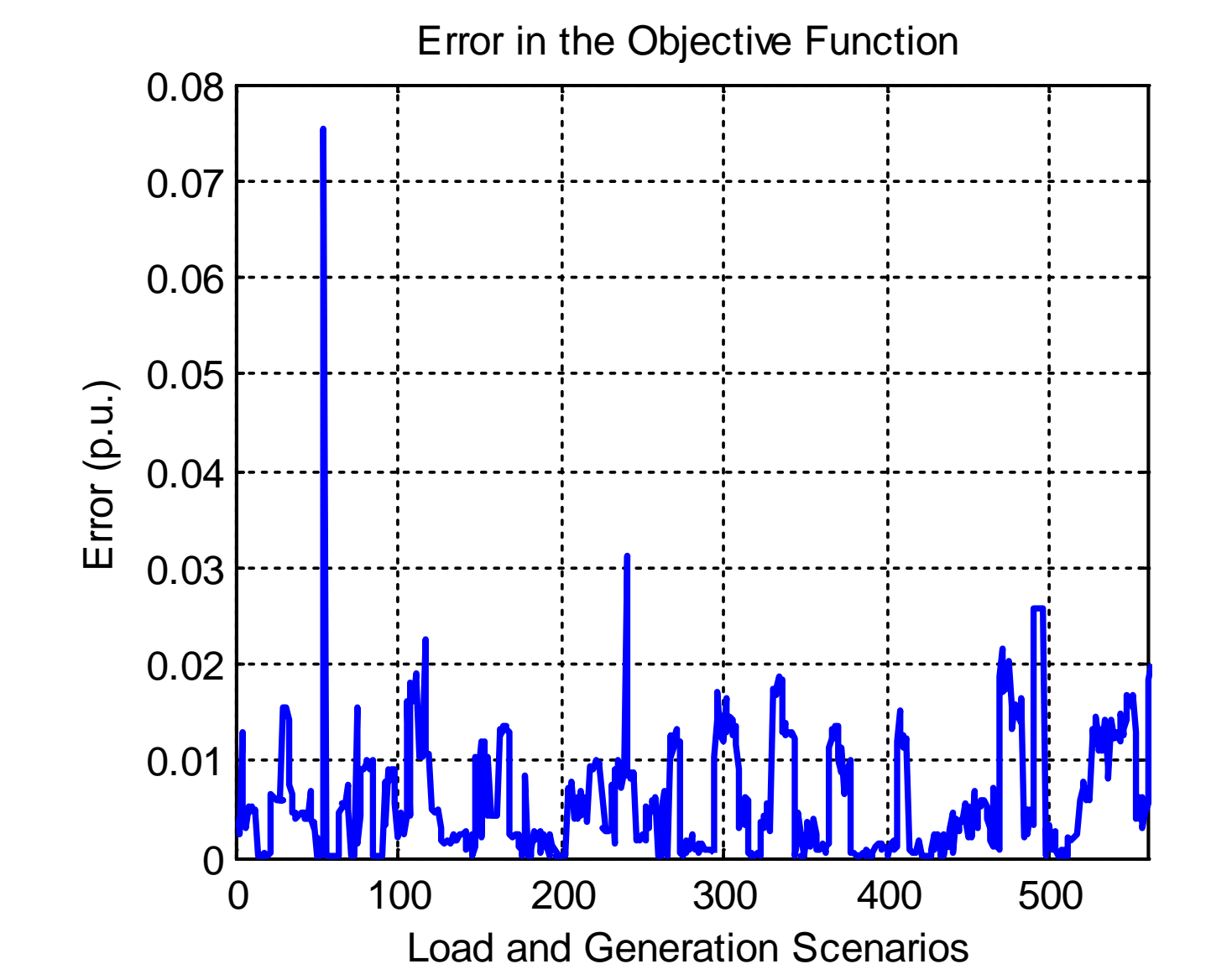
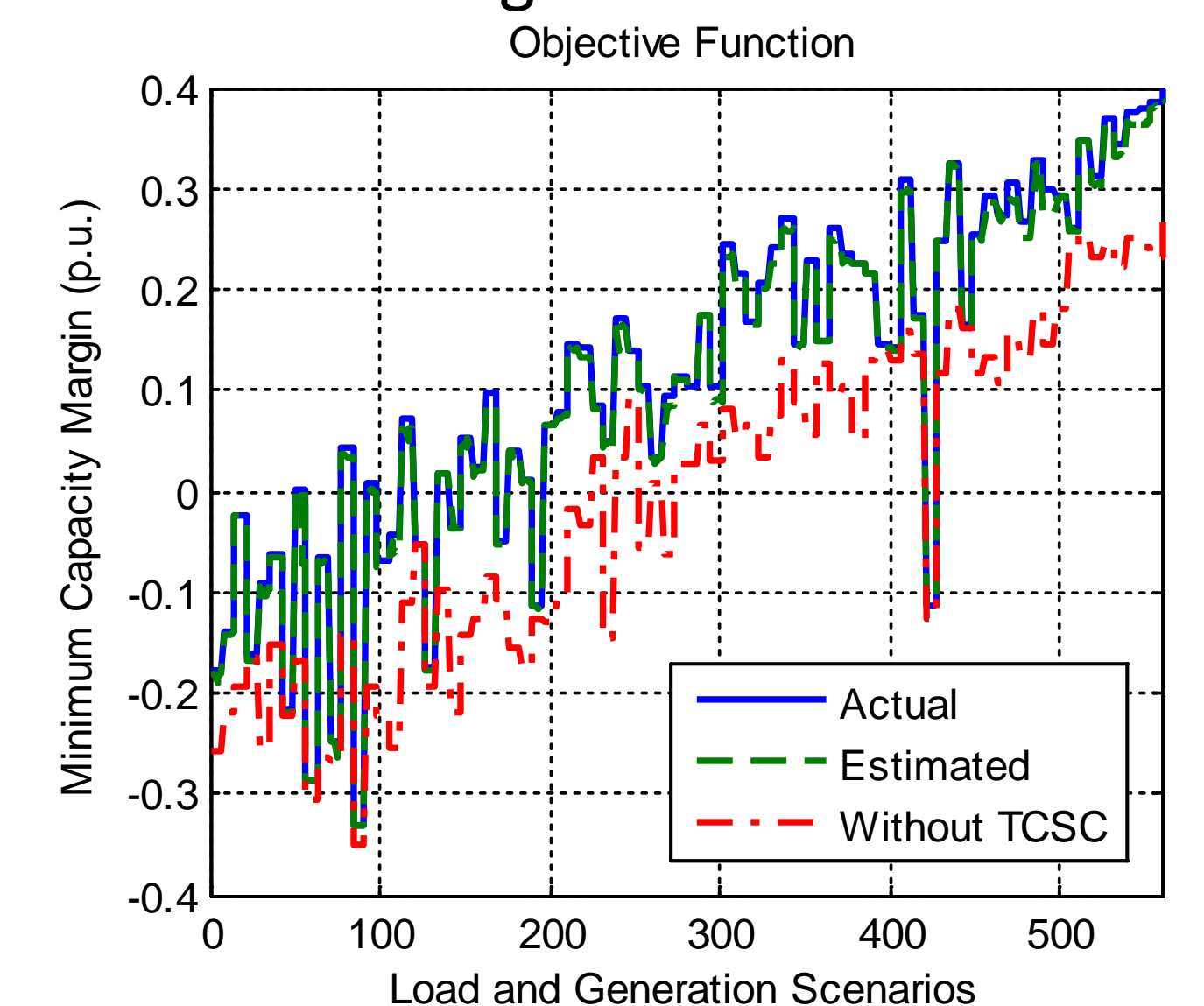
Simulation Results

One – TCSC – Case

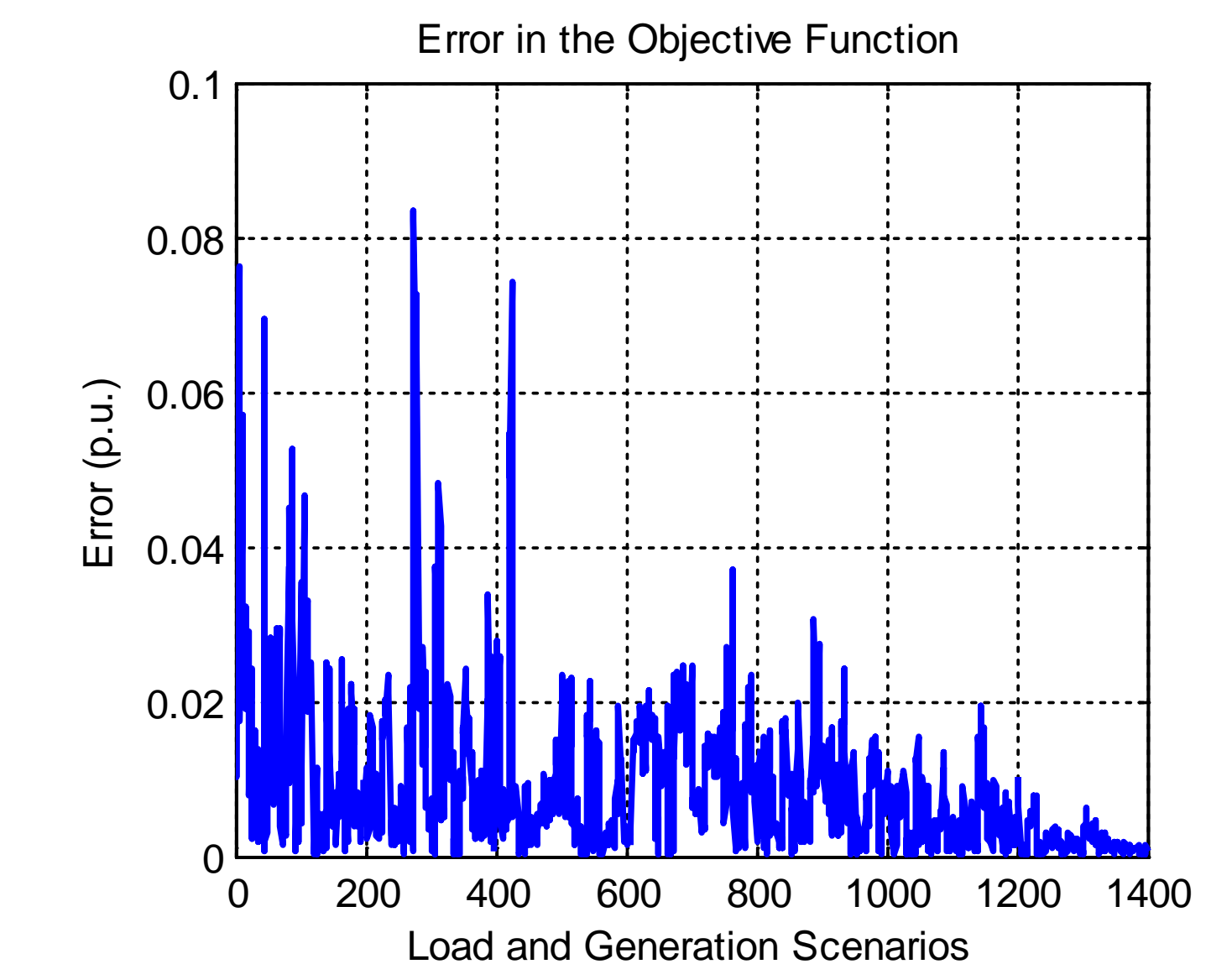
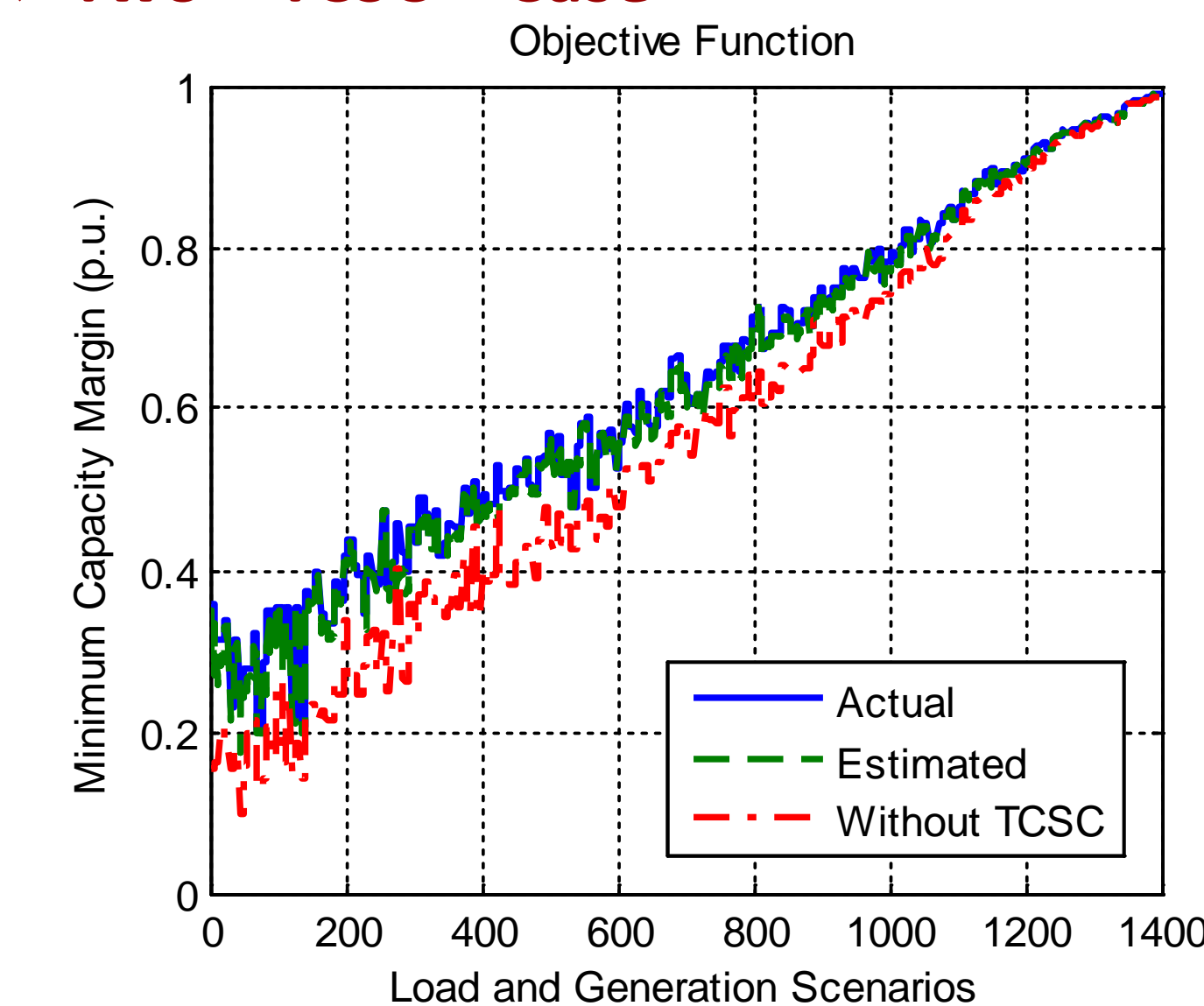
- No overloading



- Overloading



Two – TCSC – Case



Conclusions and Future Work

Conclusions

- Usage of regression analysis provides solution to determine close-to-optimal settings of the FACTS devices
- Proposed approach provides fast online operation without solving OPF

Future Work

- Further investigation with larger system