OPTIMUM REACTIVE POWER CALCULATION FOR REDUCING POWER SYSTEM OPERATION COST

S. Hassan, A. Majzoobi and A. Khodaei
University of Denver
USA

N. Abdullah, L. Zhang
ComEd
USA

Presented by: Mohsen Mahoor
University of Denver
USA

Outline

- Introduction
- Research Motivation
- Model Outline and Formulation
- Numerical Simulations
- Numerical Simulations Results
- Conclusion

Introduction

- Reactive power:
  - Plays a crucial role in power system stability and voltage control.
  - Essential ancillary service, supports the power system operation.
  - Can potentially minimize system real power losses and accordingly reduce total system operation cost.
- Various equipment/technics can be found in power systems to manage reactive power:
  - Capacitors banks
  - Flexible AC Transmission System (FACTS) devices
  - Static Voltage Compensators (SVC)
  - Various Volt/VAR control techniques
- Distributed energy resources (DERs) introduces another viable source for reactive power generation which is primarily integrated to distribution grids.

Research Motivation

- Existing literature: reactive power generation and control, primarily focus on voltage stability and reliability.
- The cost optimization problem through reactive power control is however an important topic which needs further investigation.
- In this paper, the optimal reactive power in all system is determined to minimize the system operation cost.
- A modified optimal power flow problem is defined and solved to find these optimum values, which is subject to all prevailing operational constraints.

Model Outline and Formulation

- The goal:

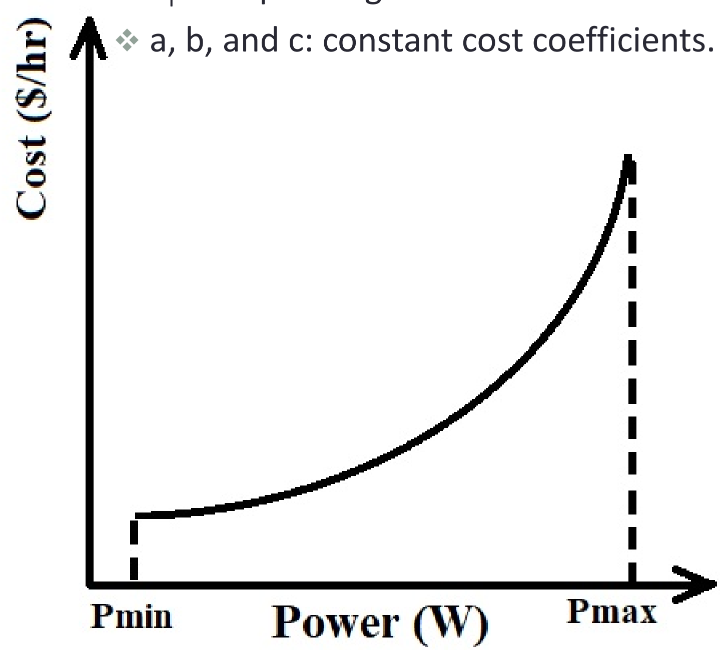
  Determine the optimal nodal reactive powers that guarantee a minimum total system operation cost.

- The nodal reactive powers are adjusted in a way that the cost of real power generation in the system is minimized.
- The objective function is defined as the sum of individual unit costs, each presented as a second order function of its real power generation

$$\min \sum_i \left(a_i P_i^2 + b_i P_i + c_i\right)$$

- P_i: real power generation of unit *i*
- a, b, and c: constant cost coefficients.

- The objective is subject to the operational constraints:
  - The limits of real and reactive power of synchronous generation units
  - Lines' real power flow and reactive power flow
  - Lines' real and reactive power capacities
  - Nodal real and reactive power balance equations

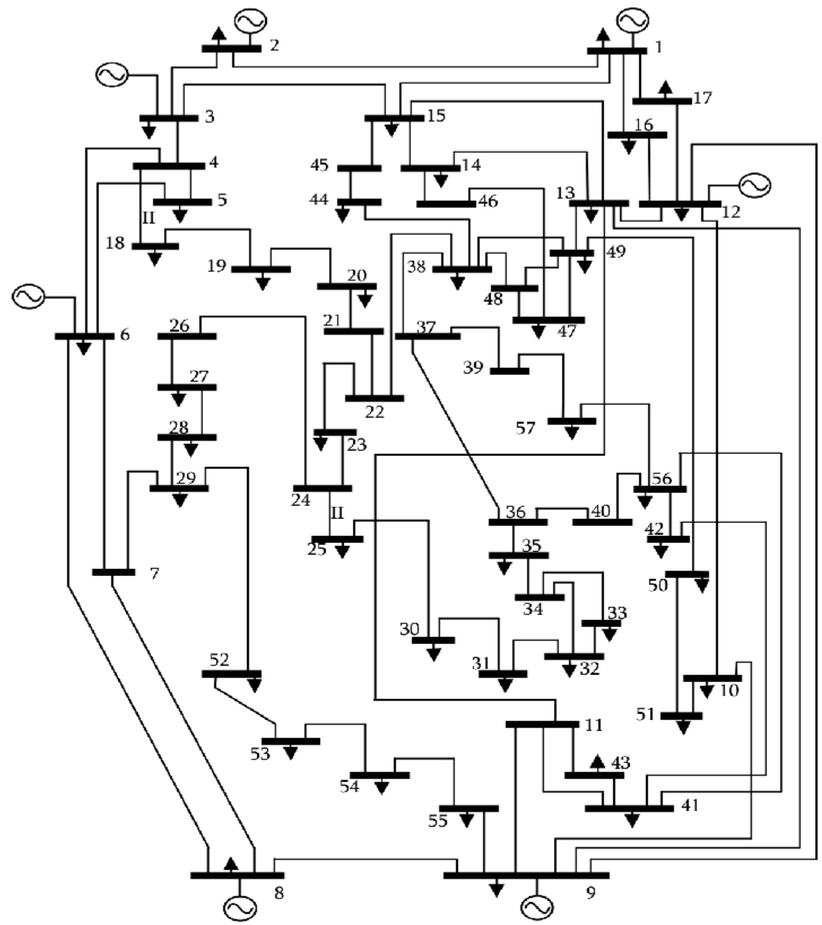


Model Outline and Formulation (cont'd)

- To consider the role of microgrids and DERs in reactive power generation/consumption, a new variables is defined and added to the reactive power balance constraint:
  - Nodal reactive power injection + power injected/withdrawn through the lines = reactive power load - ***local reactive power generation***
- As this is a free variable in the optimal power flow problem, it will reach an optimal value that minimizes the objective function.
- This new variable represents the amount of reactive power that DERs and microgrids contribute to each node.
- The available microgrids in the system generate much reactive power and can contribute locally.
- Microgrids can provide the reactive power to the utility grids as an ancillary service.

Numerical Simulations

- The proposed model is formulated in MATPOWER and applied to the IEEE 57-bus standard test system.
- This system consists of seven generators and fifty PQ buses.
- The reactive power is initially considered to be fixed and equal to the values provided by the input data.
- To minimize the total operation cost, the reactive power at each bus, individually, is considered to be variable and the optimal reactive power is calculated accordingly.



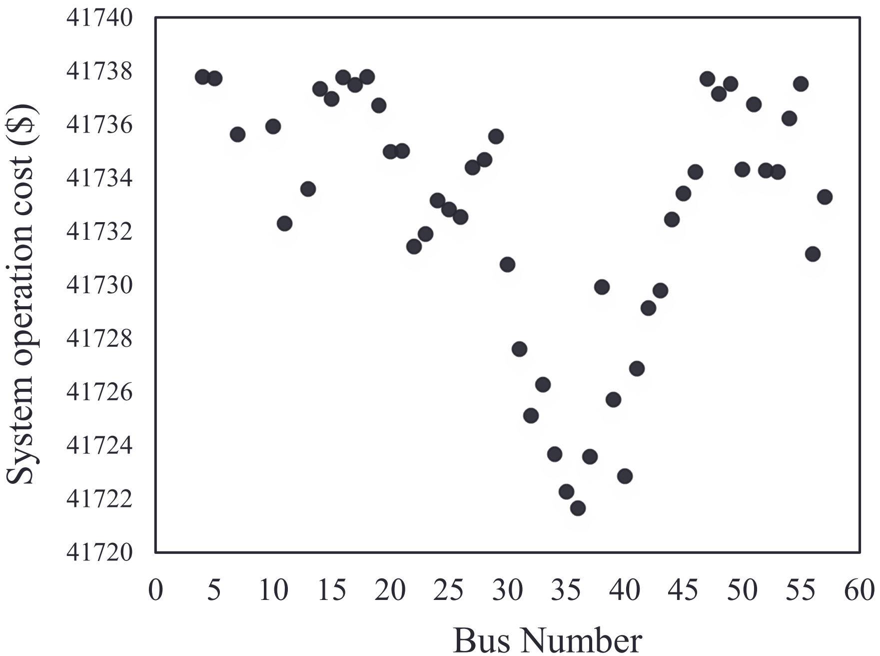
Numerical Simulations Results

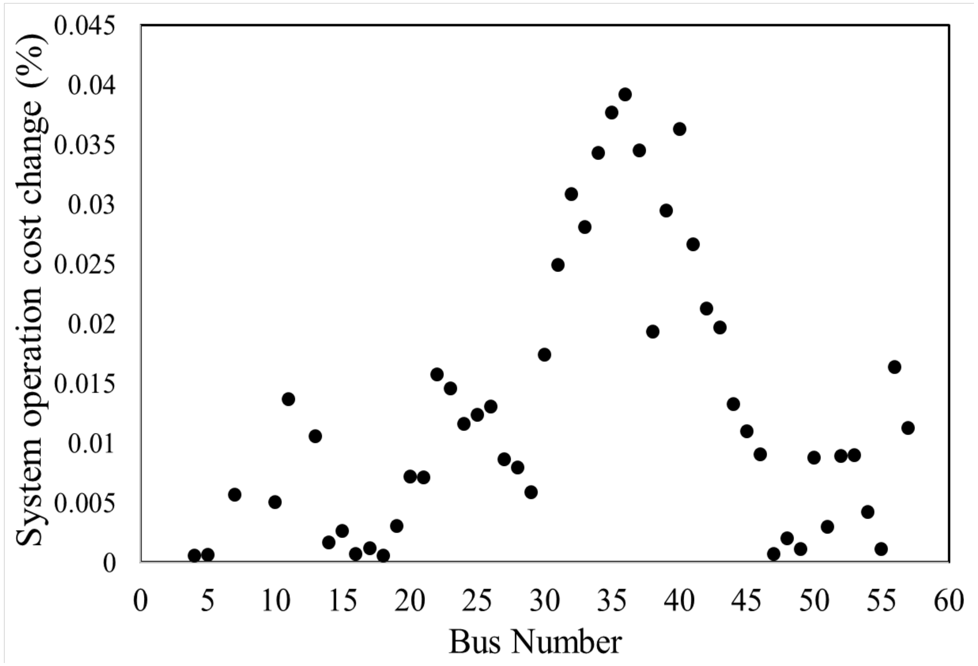
- The results of the optimal reactive power in each bus:

Load bus number	Basic reactive power (MVAR)	Optimum reactive power (MVAR)
4	0	1.77
5	4	2.47
7	0	55.21
16	3	1.13
18	9.8	-5.58
21	0	-4.41
23	2.1	-0.46
25	3.2	0.85
27	0.5	177
29	2.6	-49.34
31	2.90	3.00
33	1.90	1.90
36	0	0.08
40	0	40
42	4.4	4.82
51	5.3	-78.26
52	2.2	-1.68
54	1.4	1.66
57	2	0.27

Numerical Simulations Results (cont'd)

- System operation cost and system operation cost changes **(decrease)**:





- Some buses have a large effect on the system operation cost, while others have a relatively smaller effect, showing the criticality of some buses over others in impacting the system operation cost.
- Buses 35, 36, and 40 share the highest effect on the total system operation cost.
- It would be logical to focus only on a handful of buses in the system for reactive power generation.

Numerical Simulations Results (cont'd)

Test system	Base case (without applying optimization)	Q=0 in all load buses (unity power factor)	After applying optimization
IEEE 57-Bus System	$41,738	$41,724 (0.033%)	$41,721.7 (0.04%)

- Having unity power factor at all buses does not necessarily lead to the minimum system operation cost.
- A unity power factor in all buses reduces the cost by around 0.033% while this reduction for the optimum reactive power case is 0.04%.
- This may seem as a small percentage, however considering the extremely large operation cost of practical systems, this reduction can lead to significant savings.

Conclusion

- Reactive power is an important factor in reducing system losses.
- A nodal reactive power variable was added to the optimal power flow problem, and the critical buses which showed the highest effect on decreasing the system operation cost were determined.
- The required reactive power adjustments were considered to be supplied by available DERs and microgrids.
- The unity power factor at all buses does not necessarily minimize system operation cost, but the combination of positive and negative reactive powers at various buses in the system would help achieve this objective.

Thank you

Mohsen.Mahoor@du.edu