OPTIMAL OPERATION OF DISTRIBUTION FEEDERS IN SMART GRIDS

Sumit Paudyal, Claudio A. Cañizares, and Kankar Bhattacharya
Department of Electrical and Computer Engineering
University of Waterloo, Ontario, Canada

OBJECTIVES

➢ Develop an optimal decision making tool for distribution system operations in Smart Grids.

➢ Incorporate unbalanced system operation in the model development.

➢ Propose a solution method for the optimization problem to facilitate practical implementations.

MODELING

Distribution Optimal Power Flow (DOPF) Model

➢ A generic three-phase optimization model.

➢ Objective Function:
- Minimize energy drawn from substation.
- Limit number of switching operations.

➢ Equality Constraints:
- Three-phase component models
  - o Conductors/cables.
  - o Switches.
  - o Transformers.
  - o Load Tap Changers (LTCs).
  - o Loads and Capacitors.
  - o Switched Capacitors (SCs).
- Network Equations.

➢ Inequality Constraints: Operating limits such as,
- Voltage limit (as per ANSI).
- Feeder current limits.

SOLUTION METHOD

➢ Nature of the Problem:
- Proposed DOPF model is an MINLP problem.
- LTC positions are discrete (-16 to +16).
- Capacitor blocks in SCs are discrete (1, 2, 3 ..).
- Associated with large number of variables even for a small distribution system.
- Number of variables increase for 24-hour optimization problem.

➢ Converting MINLP to NLP problem:
- Commercially available solvers (BARON, DICOPT) did not perform well in terms of solution time and convergence characteristics.
- A quadratic penalty function is used.
- Integer solution to NLP problem is obtained.
- Integer solution may lie outside feasible space.

➢ Proposed Local Search:
- In order to make sure that the obtained optimal solution lie in feasible space.
- Search was carried out in the neighbourhood of the obtained solution (integer variables).
- The search space is still huge due to the large number of integer variables and 24-hour optimization problem.
- An hourly local search procedure is employed which reduces the search space substantially.

CASE STUDIES

IEEE 13-node Test Feeder

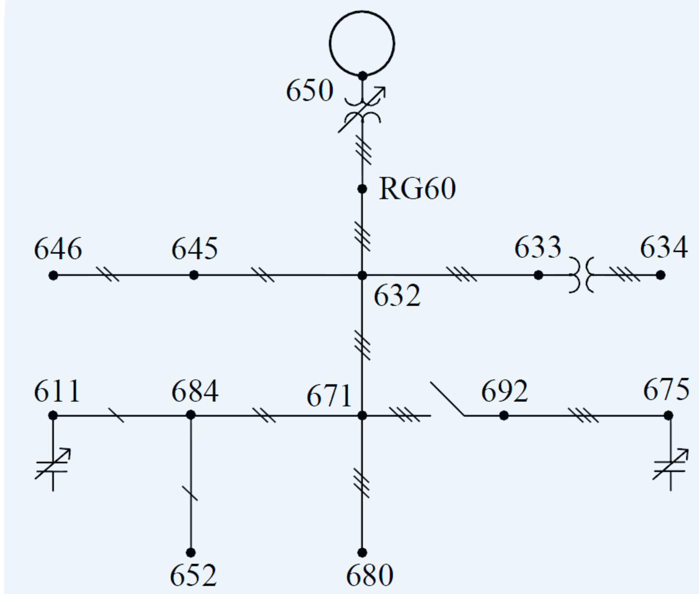

Fig 2: Feeder Line Diagram.

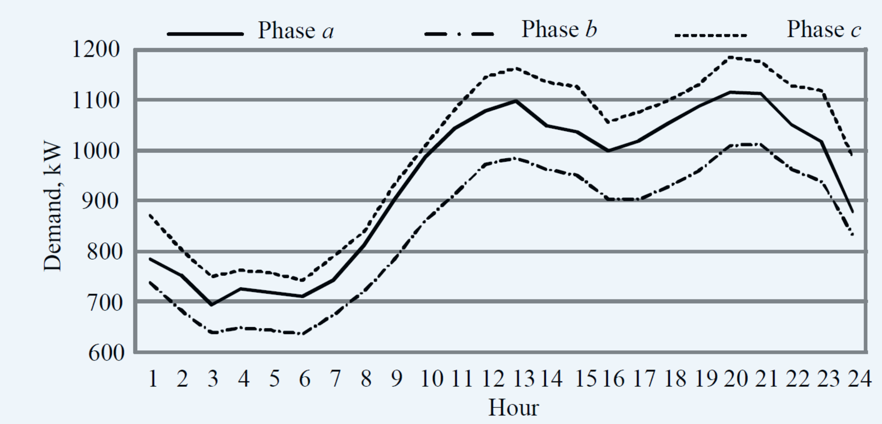

Fig 3: Load Profile.

Table I: Simulation Results in IEEE 13-node Test Feeder.

Case	α	Number of switching operations				Energy from substation (Mwh)	Energy loss (Mwh)	% Reduction in energy from substation	% Reduction in number of switching operations
		Tap_1	Cap_1	Cap_2	Total				
1	—	10	8	14	32	67.684	2.129	—	—
2	1.0	8	16	6	30	62.886	1.986	7.09	6.25
3	0.2	16	2	2	20	67.081	2.125	0.89	37.5
4	0.0	12	0	0	12	67.730	2.138	-0.07	62.5

Hydro One Distribution Feeder

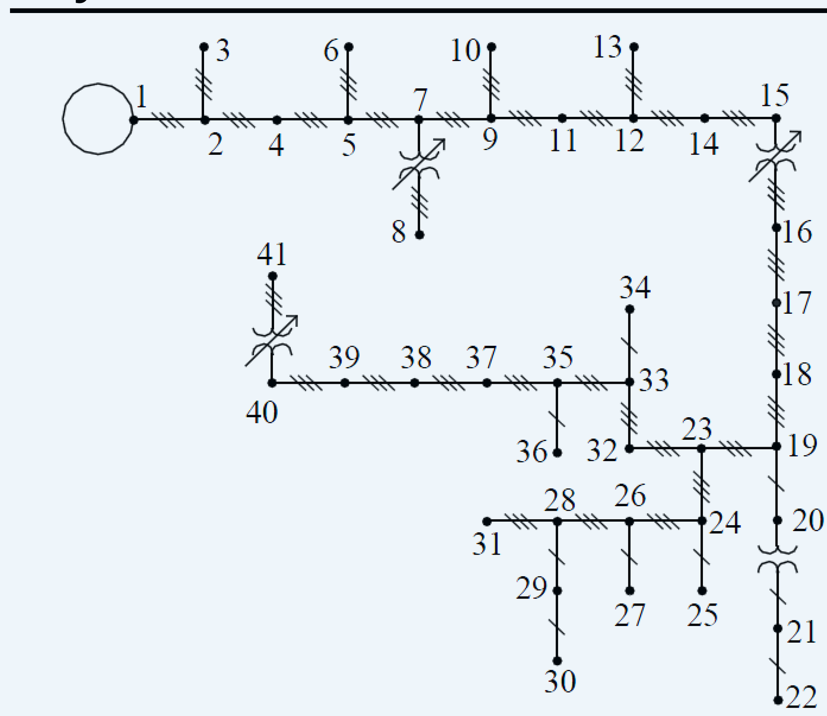
Fig 4: Feeder Line Diagram.

Table II: Simulation Results in Hydro One Distribution Feeder.

Case	α	Number of switching operations				Energy from substation (Mwh)	Energy loss (Mwh)	% Reduction in energy from substation	% Reduction in number of switching operations
		Tap_1	Tap_2	Tap_3	Total				
1	—	12	14	50	76	291.619	6.090	—	—
2	1	28	6	12	46	286.976	6.058	1.59	39.47
3	0.6	10	12	20	42	293.793	6.264	-0.75	44.73
4	0	4	14	14	32	293.987	6.265	-0.81	57.89

CONCLUSIONS

➢ The generic DOPF model, developed as an integral part of a Smart Grid, will help to optimize distribution operation.

➢ The proposed solution method yields suboptimal solutions, but reduces computational burden so that it can be used in real-time applications.