Three-phase Distribution OPF in Smart Grids: Optimality versus Computational Burden

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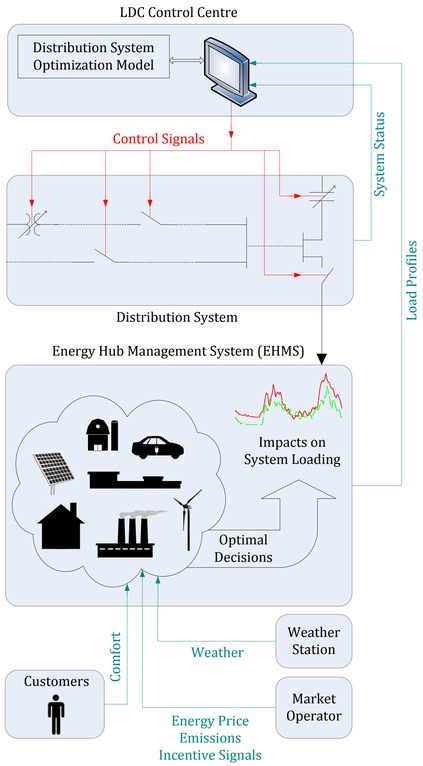
Objectives

- Implement a Genetic Algorithm (GA) based solution method for three-phase Distribution Optimal Power Flow (DOPF).
- Compare its optimality and computational burden with respect to the heuristic solution method proposed in S. Paudyal, C. Cañizares, K. Bhattacharya, "Optimal Operation of Distribution Feeders in Smart Grids," IEEE Trans. Industrial Electronics, to be published.

Overall Concept

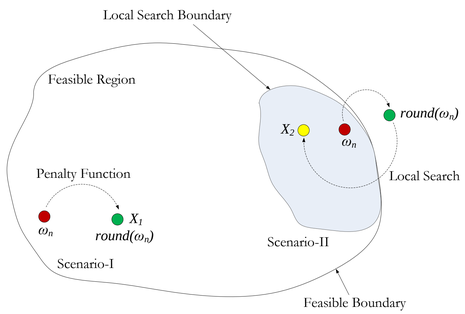


Mathematical Modeling

Three-phase Distribution Optimal Power Flow (DOPF) Model

- A generic MINLP optimization model.
- Objective Function:
  - Minimize energy drawn from substation.
  - Limit number of switching operations.
- Equality Constraints:
  - Three-phase component models.
  - Network equations.
- Inequality Constraints: Operating limits such as,
  - Voltage limit (as per ANSI).
  - Feeder current limits, transformer capacity limits.

Heuristic Solution Method



- MINLP is converted to NLP by using a "Quadratic Penalty Function".
- An hourly search procedure is employed to ensure the integer solution lie inside the feasible space.

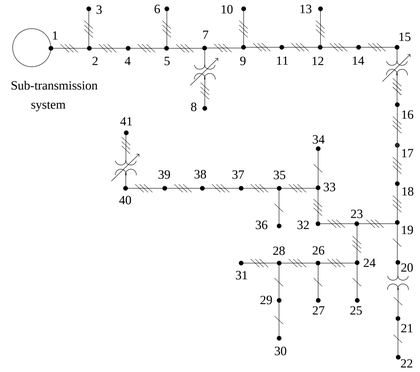
GA-Based Solution Method

begin
define *X*, *F*
choose *G*, *S*, *CR*, *MR*
choose individuals of *S*
solve three-phase DLF for individuals in *S*
evaluate *F* for individuals in *S*
repeat
  rank individuals of *S* based on *F*
  repeat
    create a pool of individuals, based on *CR*, for mating
    choose parents based on two random numbers
    apply cross-over operator to reproduce offspring
    apply mutation operator to offspring based on *MR*
    solve three-phase DLF for offspring
    evaluate *F* for offspring
    discard unfit offspring
  until *S* number of offspring are reproduced
  choose best *S* fit individuals among parents and offspring
until generation *G* is reached
end

CR: Cross-over rate
F: Fitness Function
G: Generations
MR: Mutation rate
S: Population Size
X: Chromosomes

Case Studies

Hydro One Distribution Feeder



Case	α	Heuristic Solution Method				GA-based Solution Method					% Difference in Objective Function
		Energy (MWhr)	No. of Switchings	Objective Function	Solution Time	Generation	Energy (MWhr)	No. of Switchings	Objective Function	Solution Time	
1	1	286.98	46	286.98	10m5s	1	293.80	123	293.80	5m7s	2.38
						25	291.26	164	291.26	1h8m54s	1.49
						50	291.03	147	291.03	2h37m51s	1.41
						100	283.63	139	290.63	5h17m29s	-1.17
2	0.6	293.79	42	193.08	9m4s	1	292.39	136	229.83	5m38s	19.04
						25	292.39	136	229.83	1h21m50s	19.04
						50	292.03	114	220.82	2h42m22s	14.37
						100	292.19	42	192.11	5h34m14s	-0.50
3	0	293.99	32	32.00	7m9s	1	292.39	136	136.00	5m50s	325.00
						25	293.39	128	128.00	1h27m41s	300.00
						50	292.84	57	57.00	2h46m10s	78.13
						100	295.67	30	30.00	5h55m57s	-6.25

Conclusions

- GA-based solution method yields global optimal solutions to the DOPF problems but at extensive computational burden.
- The heuristic solution method yields solutions reasonably close to optimal solutions at significantly reduced computational burden, which renders the method suitable for real-time applications.

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