MAXIMISING PENETRATION OF ACTIVE POWER BY DISTRIBUTED GENERATION ON A REAL SYSTEM

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Contents

Introduction

- Energy security and environmental: renewable sources (RS)
- Brazil Electricity: hydraulic - others RS – auctions of biomass and wind energy
- Self-energy producers, from sugar cane bagasse.
- Distributed Generation (DG): Technical and economic impacts in distribution networks (DN)
- Multiple accesses – individual contributions
- Particle Swarm Optimization (PSO)

The Optimization Problem

- Active power injections – unity power factor at the Point of Common Coupling
- No additional onus to Distribution Company: global losses with DG limited (base case)
- From the Utility's point of view, unit production costs of the different producers are not relevant.
- Optimum: highest total active power delivered by the set of auto-producers, without violating operational limits of the distribution network.

Problem Formulation

- Partial objective functions
  - DG:

$$f_{dg} = \sum_{i=1}^{n} (1 - P_{gi} / P_{nom,\ gi}) \qquad (1)$$

  - Losses:

$$f_{losses} = \frac{(Losses - Losses_{CB})^2}{Losses_{CB}} \qquad (2)$$

  - Voltage:

$$f_V = \sum_{i=1}^{n} (V_i - V_{ref})^2 / Vref \qquad (3)$$

n: Number of buses;
P_{gi}: Generated active power at the bus i;
$P_{nom,\ gi}$: Rated active power of DG at bus I;
Losses – Losses calculated at each iteration of the whole algorithm;
$Losses_{BC}$ – Losses of the base case;
Vi – Voltages of the bus i calculated at each iteration of the algorithm;
Vref – Reference voltage (equals the average of limit values).

Problem Formulation

- Global objective function, including penalty function:

$$F_{ob} = f_{dg} + f_{losses} + f_v + f_{penalty} \qquad (4)$$

- Penalty function: losses, voltage and current violations:

$$f_{penalty} = a.p_{losses} + b.p_{Vmax} + c.p_{Vmin} + d.p_{Imax} \qquad (5)$$

Problem Formulation

- $f_{penalty}$:

$$p_{losses} = \frac{Losses - Losses_{CB}}{Losses_{CB}} \quad (6)$$

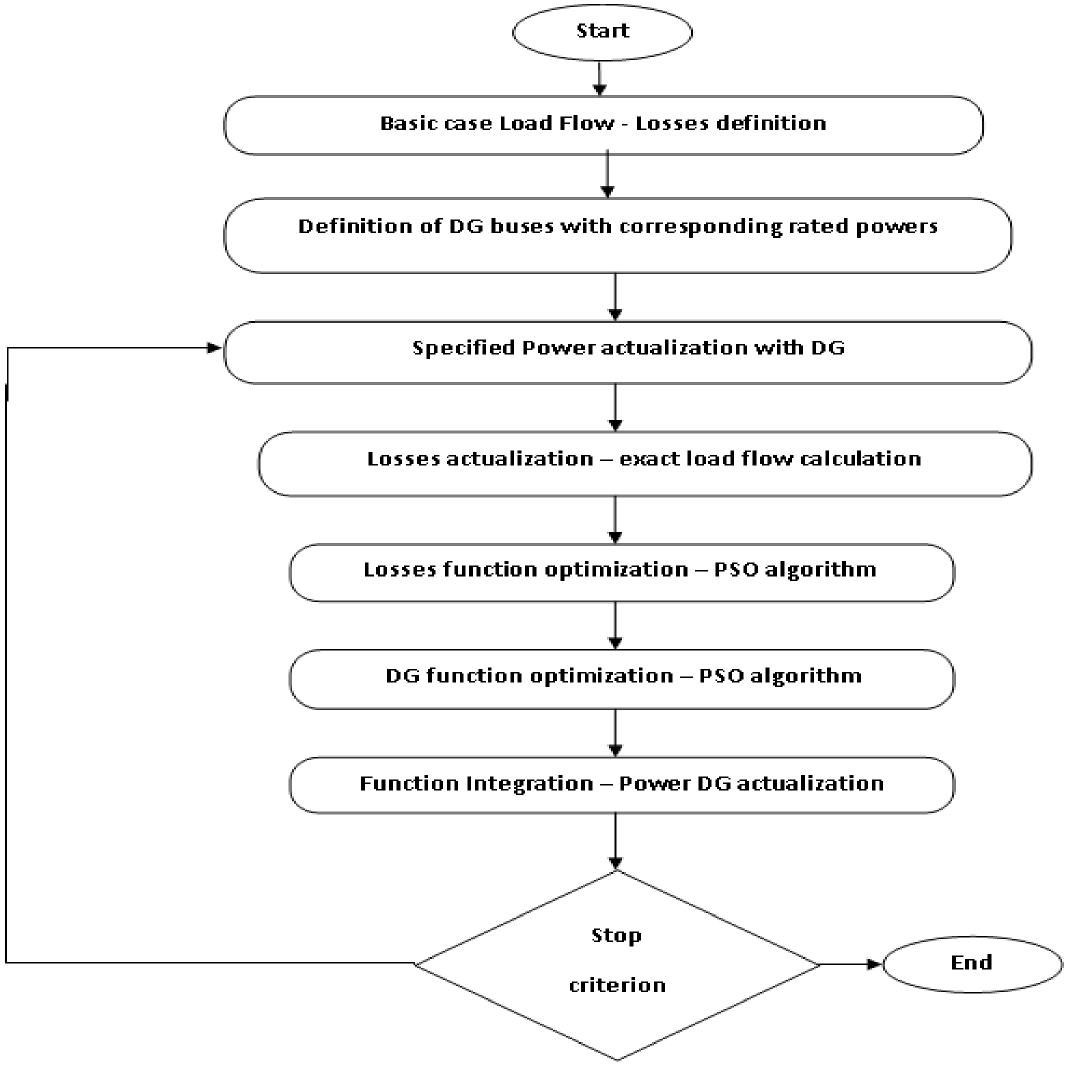
$$p_{Vmax} = \frac{\sum_{i=1}^{n}(V_i - V_{max})}{V_{max}} \quad (7)$$

$$p_{Vmin} = \frac{\sum_{i=1}^{n}(V_{min} - V_i)}{V_{min}} \quad (8)$$

$$p_{Imax} = \frac{\sum_{j=1}^{b}(I_j - I_{max})}{I_{max}} \quad (9)$$

Were:
- *Losses:* losses, for each particle at each iteration;
- $Losses_{CB}$: losses of base case;
-V : voltage calculated from node *i* for each particle at each iteration;
-V_{max} and V_{min}: maximal and minimal acceptable voltages for node *i*;
-I: current calculated from branch *j* for each particle at each iteration;
- *b*: number of branches;
- I_{max}: thermal limit for branch *j*.

Proposed Algorithm



Particle Swarm Optimization

- A set of vectors (particles) with DG injections is the population to representing possible solutions
- Each vector is specified by a position (*x*) and a velocity (*v*) in each iteration *k*:

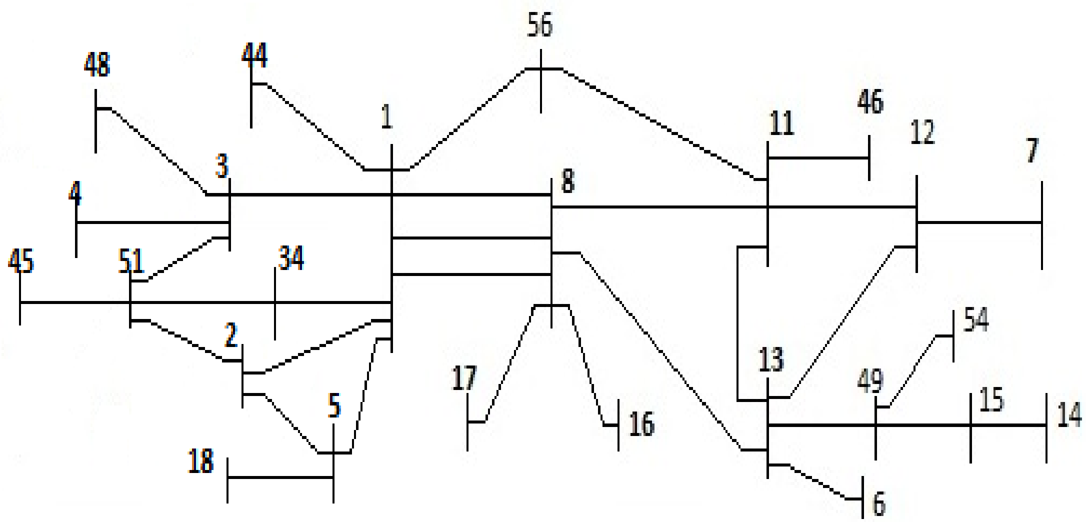
$$v_j^{k+1} = w * v_j^{k} + c_1 * r_1\left(pbest_j^k - x_j^k\right) + c_2 * r_2\left(gbest^k - x_j^k\right)$$

$$x_j^{k+1} = x_j^k + v_j^{k+1}$$

- *pbest:* best particle tested by the *Fob* at actual iteration
- *gbest:* best particle tested by the *Fob* for all iterations already performed
- When *Fob* is minimized, gbest is the solution

Results of Simulation

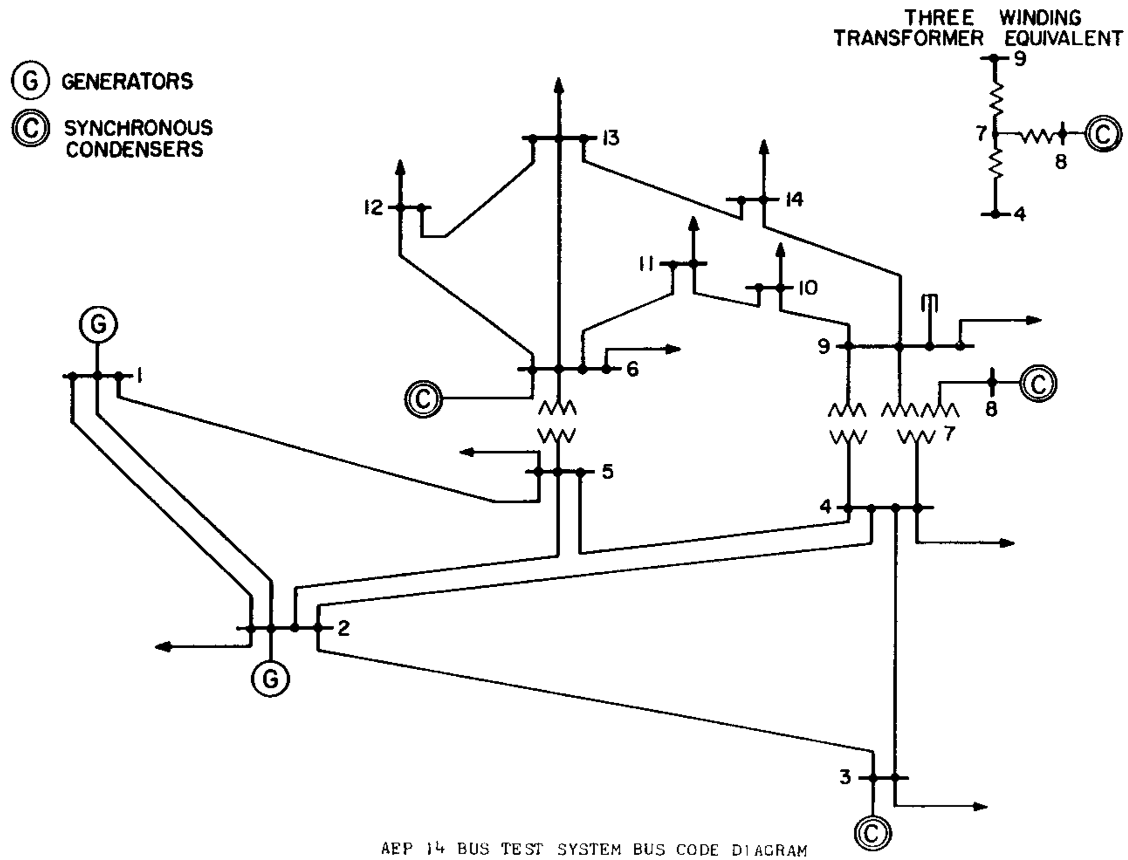
Network A: 25 nodes, 42 branches, weakly meshed, total supply of 457 MW.



HV distribution system 69 kV – R. G. do Norte, Brazil.

Results of Simulation

Network B: IEEE 14 bus test system



Results of Simulation

Table 1: Maximal penetration of DG for Network A
DG7-70 MW and DG56-105 MW (rated)

Simulations	1	2	3	med
iterations	7	9	8	8
Percentage of DG (DG/DG rated)				
DG7	66,5 %	68,1 %	67,9 %	67,5 %
DG56	100,0 %	99,6 %	100,0 %	99,9 %
Relative losses to base case	97,8 %	99,8 %	99,7 %	99,1 %

Table 2: Maximal penetration of DG Network A
DG7-70MW and DG18-105MW (rated)

Simulations	1	2	3	med
iterations	9	8	9	9
Percentage of DG (DG/DG rated)				
DG7	58,5 %	61,3 %	61,4 %	60,4 %
DG18	58,4 %	58,7 %	58,7 %	58,6 %
Relative losses to base case	97,1 %	99,1 %	99,9 %	98,7 %

Results of Simulation

Table 3: Maximal penetration of GD
Network B
DG3-20MW and DG4-30MW (rated)

Simulations	1	2	3	med
iterations	4	5	5	5
Percentage of DG (DG/DG rated)				
DG3	82,1 %	80,0 %	85,5 %	82,6 %
DG4	57,9 %	54,2 %	51,8 %	54,6 %
Relative losses to base case	71,6 %	72,6 %	72,2 %	72,1 %

Conclusions

- This study provides a methodology to specify the maximal absorption capacity of generators in previously defined nodes of a system. It can be used in studies of planning of the operation and expansion of the grid, as well as a reference to other studies.

- Metaheuristic algorithms may produce different results at each simulation. However, the methodology embedded in the PSO proposal presents small errors between the various simulation's repetitions.

Thank you for attention