ELECON

ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

INSTITUTO POLITÉCNICO DO PORTO

gecad

Knowledge Engineering and Decision Support Research Center

Distribution Networks Operation Using Decomposition Optimization Technique

by

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Outline

- Introduction
- Methodology for distribution networks operation using decompostion optimization technique
- Case study
- Conclusions

Introduction

The major challenge of an Electric Power Distribution System, after a good planning

Find a radial operating framework that minimize the system power losses

Keep the required reliability and satisfied the operating constraints

Are not easy to obtain:

- High exigency by the consumers
- Technical difficulties to control a significant number of variables in order to ensure the most efficient possible operation

Introduction

The increasing production through Distributed Generation

New reality in the distribution networks

This situation have many advantages, like increase network reliability

Reduction of power losses due to Joule effect

Deferring investments in new lines

Due to the unavailability of the primary source of energy

- Creates difficulties in operation

Introduction

Adequate reconfiguration of the distribution network

Promotes the improvement of technical and economic performance

- Reducing power losses

Whenever the settings of network is changed we are in the presence of so-called reconfiguration

Reconfiguration is performed by changing the status of switches

- This action may be manual or automatic and remotely

Introduction

Distribution networks are usually design in meshed and operated in radial topology

Restore the power supply to consumers located downstream of the fault as quickly as possible through cutting maneuvers, keeping the radiality condition of the distribution network.

In the developing countries it was estimated that distribution systems loss is between 5% and 13% of the total power generated

Benders decomposition

Difficulties related to solving nonlinear optimization problems with binary variables

Use of partitioning techniques such as the Benders decomposition

- Is a decomposition technique on two-levels, master and slave, which defines an iterative procedure between both levels in order to reach the joint optimal solution.

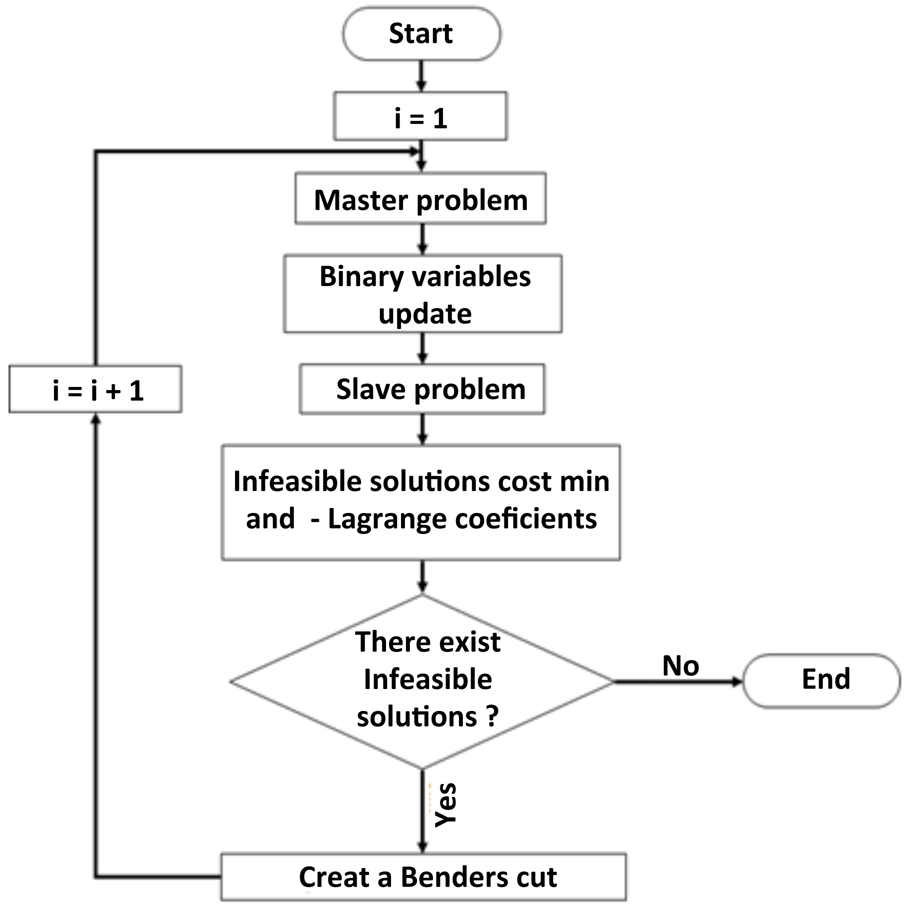
The master level represents the decision problem, which is defined as a mixed-integer programming (MIP) problem

The slave level deals with the operation problem, being a nonlinear OPF

This method allows us to appropriately treat the nonconvexity associated with binary variables and to divide the global problem into two smaller problems which are easier to solve.

Benders decomposition

Benders decomposition



Mathmatical formulation

Master problem

$$\min = \sum_{k \in \Phi_i} C_k \cdot \left(S_k\right)^2 + \alpha^*$$

<u>Subject to:</u>

- Benders cuts

$$\alpha^* = INF^{m-1} + \tau^{m-1} \cdot \left(a_i - A_i^{m-1}\right) + \mu^{m-1} \cdot \left(x_k - X_k^{m-1}\right)$$

- First Kirchhoff law

$$\sum_{t \in {}_i^{IN}} S_{it} - \sum_{l \in {}_i^{OUT}} S_{il} = L_i$$

- Generation limits

$$Sgen_i^{\min} \le Sgen_i \le Sgen_i^{\max}$$

Mathmatical formulation

- Radialy condition

$$\sum_{l \in_{i}^{IN}} X_l \leq 1$$

- Thermal limits of lines/cables

$$S_k \leq S_k^{\max}$$

- Only one direction of power flow should exist

$$X_{il} + X_{li} \leq 1$$

Mathmatical formulation

Slave problem

- Minimize the infeasibility

$$\min F = \sum INF$$

$$INF = \sum_{i=1}^{N} \left(P_i^{\inf} + Q_i^{\inf} \right) + \sum_{k=1}^{NE} \left| S_k^{\inf} \right|$$

- Active and reactive power flow equation

$$Pgen_i + P_i^{\inf} - Lp_i - P_i(v, \delta) = 0$$

$$Qgen_i + Q_i^{\inf} - Lq_i - Q_i(v, \delta) + Qcap_j = 0$$

- Generation limits

$$Pgen_i^{\min} \le Pgen_i \le Pgen_i^{\max}$$

$$Qgen_i^{\min} \le Qgen_i \le Qgen_i^{\max}$$

Mathmatical formulation

- Reactive power output by shunt capacitors

$$B_{ja} \cdot A(a) \cdot V_j^2$$

- Capacity limits of distribution lines/cables

$$S_k(v,\delta) - S_k^{\inf} \le S_k^{\max}$$

- Bus voltage magnitude limits

$$V_i^{\min} \le V_i \le V_i^{\max}$$

- Bus angle limits

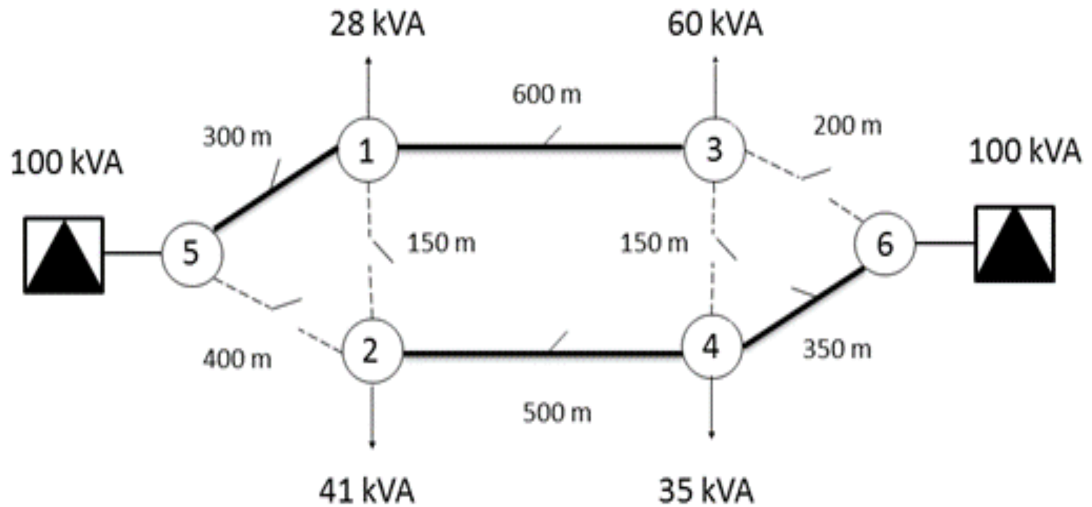
$$-\pi \le \delta_i \le \pi$$

- Transformer taps limits

$$tap^{\min} \le tap \le tap^{\max}$$

Case study

6 buses distribution network



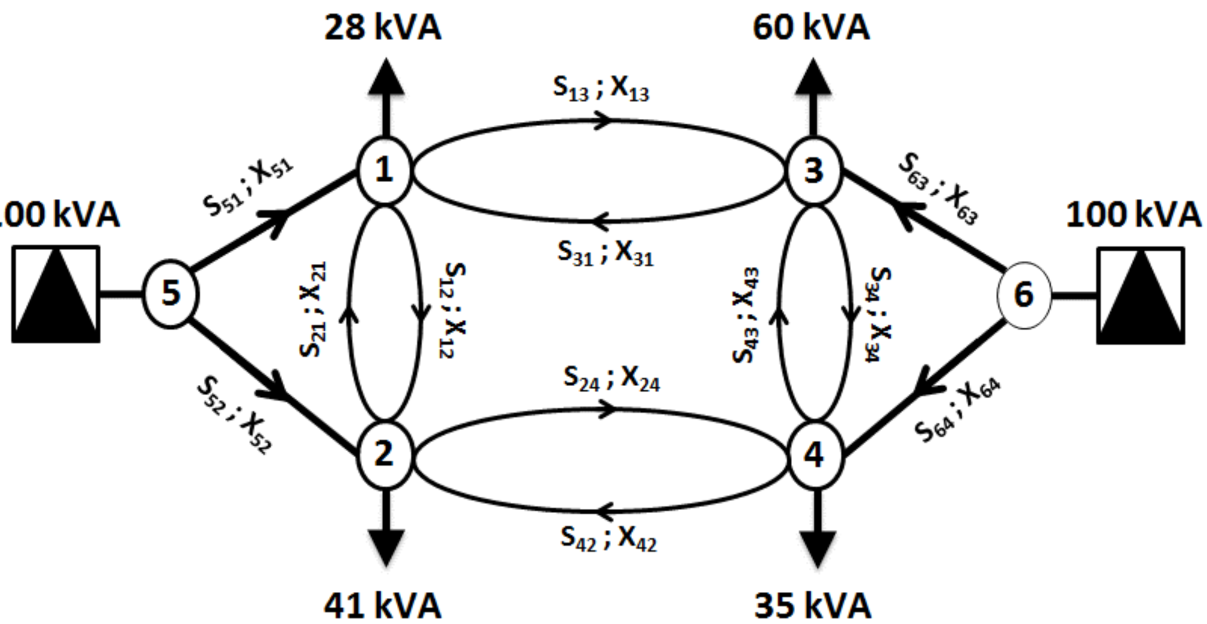
Case study

6 buses distribution network power losses before reconfiguration

Branch	Losses (kVA)
5-1	1.690
1-3	3.890
4-2	2.220
6-4	1.700
Total	9.500

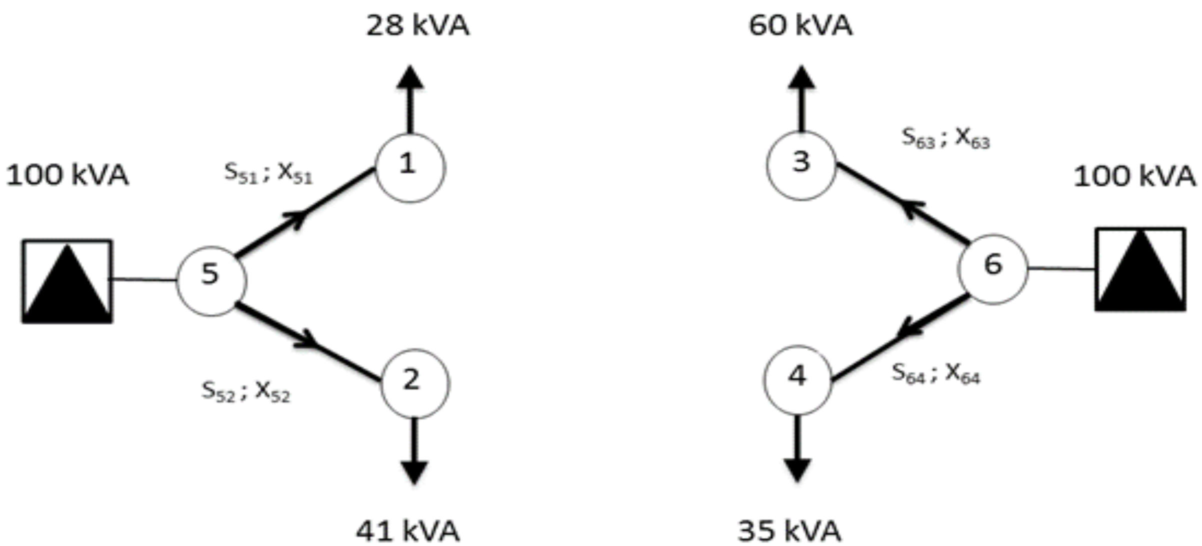
Case study

Possible ways for 6 buses distribution network



Case study

6 buses distribution network topology after reconfiguration



Case study

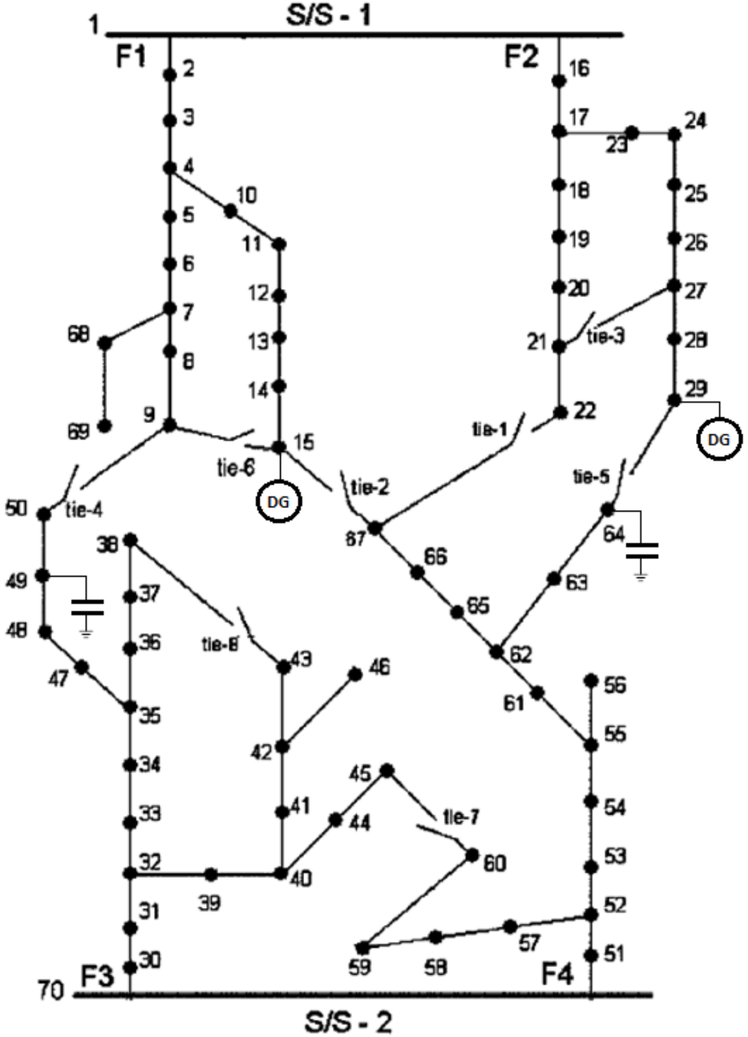
6 buses distribution network power losses

Branch	Before reconfiguration	After reconfiguration
	Losses (kVA)	Losses (kVA)
5-1	1.690	0.337
1-3	3.890	-
2-4	2.220	-
4-6	1.700	0.622
5-2	-	0.986
6-3	-	1.043
Total	9.500	2.987
Reduction	-	69%

Case study

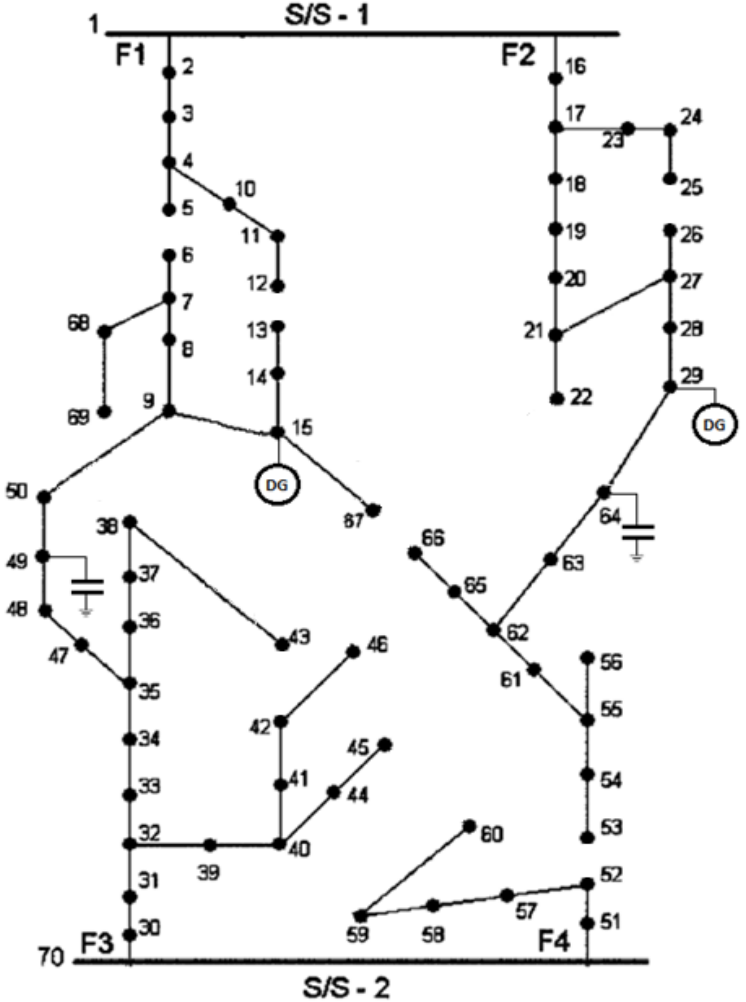
70 buses distribution network

Power losses = 341.427 KVA



Case study

- **Losses =** 235.167 kVA
- **Reduction =** 31%
- Buses 12, 29 and 53 have the worst voltage level (0.955 p.u.)
- 32.447 seconds



Conslusions

- A new and efficient methodology for optimal reconfiguration of distribution networks integrated with an OPF has been presented
- The main advantage of the proposed method is the capability of representing a large number of system components and aspects, including complete AC network constraints, distributed generation, capacitor banks, transformer taps, etc
- A novel variant of the generalized Benders decomposition algorithm was applied for solving the problem
- The model needs very low execution time for solving the whole problem, so it is also suitable for applications in real time

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Thank you!