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Chapter 2

Real-Time Reconfiguration of Distribution Network with Distributed Generation

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Additional information is available at the end of the chapter

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Abstract

This chapter shows a methodology to accomplish the real-time reconfiguration of distribution networks considering distributed generation in normal operating conditions. The availability of the wind power generation, solar photovoltaic power generation, and hydroelectric power generation is considered in the reconfiguration procedure. The real-time reconfiguration methodology is based on the branch-exchange technique and assumes that only remote-controlled switches are considered in the analysis. The multicriteria analysis, analytic hierarchy process (AHP) method, is used to determine the best switching sequence. The developed algorithms are integrated into a supervisory system, which allows real-time communication with the network equipment. The methodology is verified in a real network of a power utility in Brazil with different typical daily demand curves and distributed generation scenarios.

Keywords: distributed generation, distribution network, real-time reconfiguration, remote-controlled switches, smart grid

1. Introduction

The electric power system, especially the distribution system, is undergoing major changes in its current structure. This new concept of smarter grids, known as smart grids, is incorporating automation technologies and communication in real time to the grid, with more intelligent devices, distributed generators' connection and instant forward actions to electrical problems. These changes in the distribution system enable greater diversity in services related to energy, such as demand management, the use of distributed generation from renewable

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sources, connection of electric vehicles, and voltage maintenance after self-healing, among others.

In this sense, this chapter presents a new methodology and a software tool for real-time reconfiguration of distribution network considering distributed generation units the renewable sources. The work of [1, 2] indicates that this system has a good performance, applying smart grids concepts, from the information and functionality of remote-controlled equipment installed in the distribution test systems.

This chapter is divided into five sections. The second section presents the main concepts that guide the smart grids. Following is shown the distributed generation technologies to the application exposed in this work. The fourth section presents the reconfiguration methodology developed in real time. Then, the results and discussions are exposed considering a large real distribution system. Finally, the main conclusions are presented in the last section.

2. Smart grids concepts

The smart grids represent a new paradigm in the way power systems are designed and operated. They are characterized by the integration of well-established technologies and concepts that together seek to respond to the increased demand and requirements regarding quality and sustainability in the energy sector [3]. The resources available from technological advances in telecommunication and automation have brought benefits to the grid, especially: fast processing and information exchange between network devices, allowing real-time monitoring and control; cost and time reduction with maintenance teams; the possibility of creating more robust and reliable systems and less susceptible to human limitations; and the integration of network structures, such as distributed generation, stability control, and demand control.

However, the benefits of the technology are often economically viable only if the automated system is part of a larger whole, provided with a degree of intelligence. This applies, for example, for the automatic network restoration, in which the automatic operation of remotely controlled switches must be integrated with the detection and isolation of the fault systems, ensuring the restoration of the largest possible number of consumers. In this case, the system's intelligence can be represented by the response of computer programs that employ optimization techniques and support decision-making.

A general illustration of some features and elements of the smart grids is highlighted in **Figure 1**. From the bottom to the top, the figure shows the main interfaces between the power utility services and equipment, and the consumer and/or micro generator. The middle layer of the figure gives some examples of structures that can be related either to power utilities or to consumers. A brief discussion on the main concepts shown in the **Figure 1** is presented in this section.

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Figure 1. A general view of a smart grid.

2.1. Response demand

The demand response refers to the ability of management and control of power system loads. The primary goal of DR was to reduce peak consumption by turning off loads in higher power consumption schedules. Alternatively, consumption can be shifted to off-peak periods or even can be increased at certain periods, to maintain the stability of generation or to make the most of the available resources, such as energy from distributed generation [4].

The implementation of DR is done through electronic devices that communicate with the power utility and receive commands to turn off the loads connected to them, according to the request of the utility or to the energy rate variation. Previously, a priority study of the loads must be done to avoid interruptions that may harm important services to the consumer.

The demand response is one of the challenges of the energy market facing the smart grids. It can promote greater pressure to reduce prices and increase concern about the use of energy by consumers. From the utility's viewpoint, it may result in a change in load curves and reduction of the peak consumption, which implies lower need for investment in energy reserves. On the other hand, the biggest challenges are the consumers' behavior change, the need for compatible technology—such as advanced metering structures—and the efficiency of government agencies in regulating and supervising the process.

2.2. Advanced metering infrastructures (AMIs)

Advanced metering infrastructure comprises all the elements needed for the measurement and communication between consumers and suppliers. The communication in this case is

bidirectional and allows, for example, that a power utility sends to the consumer the real-time energy pricing. Integration with demand response devices allows load management according to the change in the price or according to the need of the power utility.

The advanced metering infrastructure consists of electronic meters, communication networks, and a data management system (MDMS, meter data management system), which is responsible for storing and managing the large amount of data from the power meters and establish interface between the data collected and other features of the network, such as the billing system and maintenance teams, for example.

The advantages of AMIs include the possibility of monitoring the energy billing in real time by the consumer, fast detection of measurement failures and non-technical losses, and the creation of consumer profiles for demand response programs and fast response to energy restoration systems. AMIs also allow the creation of more accurate consumer databases for profiles and demand estimation studies and provide real-time measurements that help in decision-making regarding the system operation. The technological challenges of AMIs include the need for standardization of communication and interfaces between devices, and security issues to ensure that only authorized devices could access the network information [5].

2.3. Smart meters

The smart meter may be considered as an evolution of the automatic electronic power meter. The main feature of smart meters is the two-way communication, which makes it possible to receive real-time power utility commands.

The standard of communication varies depending on the smart meter application project. In some countries, for example, power meters communicate through wire with a data concentrator and the data concentrator communicates with a central by a wireless network. Many smart meters, however, have wireless communication capability directly to the operation center.

Communication can be considered the biggest challenge of deploying smart meters. A wide variety of protocols and possible ways of communication is used, and there is no universal standardization of power meters. Possible arrangements of networks include the use of cellular networks, satellite communications, radio frequency, Wi-Fi, power line communication, directly to a central or a data concentrator, or in cascade mode communicating through a mesh network. The main protocols used are defined by ANSI C12.18 standard in the United States, and IEC 61107/62056 in Europe. Regardless of the type of communication, the discussion about the project to be adopted involves cost, safety, and health.

Some common features in smart meters include possibility of remote connection and shutdown of the energy point, grid failure warning, fraud warning, real-time monitoring of energy bill, and demand control. In some projects, smart meters also have the ability to communicate with user internal devices. For example, in a residence, the smart meter can receive or send information to and from appliances, air-conditioning units. This concept is based on the home area network and enables the timely management of user loads.

2.4. Plug-in electric vehicles

The smart grids led to concerns about changes in consumer load profiles, and the prospect of increased plug-in hybrid electric vehicles (PHEV) connected to the power system is one of the most discussed points [6]. Electric vehicles are characterized by substituting fully or partially (in case of hybrid vehicles) the traditional internal combustion motor by electric motors for vehicle propulsion. Electric motors are typically powered by batteries; and if the batteries are recharged through the electric distribution network, the vehicles are called plug-in.

The impact of PHEVs in power systems is significant, and several studies highlight the need for planning of battery recharges, to avoid concentration of PHEVs overloading the system, and solutions based on the use of the vehicle to inject energy into the network during peak periods (vehicle-to-grid).

The smart grids shall be prepared to absorb this new type of demand. Some aggravating quality factors in power systems can be cited: power imbalances (in case of single-phase chargers), harmonics, and increased voltage drops and losses, particularly in feeders with large extensions. Furthermore, the capacity of distributions transformers may be easily extrapolated if a large amount of PHEVs is loaded simultaneously.

2.5. Small-scale distributed generation

Distributed generation (DG) normally employs renewable energy sources, mainly wind and photovoltaic, due to difficulties of building small conventional power plants, such as hydro and thermal coal, close to consumption centers.

In residences, photovoltaic energy has the advantages of cost and modularity to install in roofs —in the power range up to 10 kW. **Figure 2** shows a typical arrangement of a photovoltaic microgeneration connected to the grid, which includes a set of batteries for energy storage, power electronics circuits (charge control and inverters), and a bidirectional power meter.

Figure 2. Small-scale generation connected to the grid.

To take advantage of DG, smart grids have to include advanced mechanisms of generation estimation, short- and long-term ability to quickly regulate power and energy storage, and

management of distributed resources in conjunction with the demand response [7]. The main technical issues involved are related to power quality, stability, and protection, due to the intermittent characteristic of the primary sources.

2.6. Automation and information technology

A high level of automation and information technology (IT) is expected in a smart grid. The network infrastructure must support data management of electronic meters (MDMS), monitoring and control of network status (overload, reactive power control, etc.), load and distributed generation management, charging of PHEVs, among other features. Information systems should communicate with each other at different levels of implementation, such as power regulation strategies, billing, maintenance management, consumer and network databases, geographic information systems (GIS), among others. Interoperability between standards and communication protocols plays a critical role in the advancement of smart grids. An important reference guide is published by the National Institute of Standards and Technology (NIST) [8].

At the operation center, the supervisory systems (SCADA) perform the interface between the technical team (operator, planner, supervisor, etc.) and the network devices. At the distribution network, some automation features may include automatic adjustment of protection devices, automatic regulation of voltage levels, control of capacitor banks and transformers' taps, control of distributed generation, self-reconfiguration, in addition to the automatic management of loads and consumption measurements. Furthermore, the automation requires the employment of remote-controlled equipment (switches, reclosers, circuit breakers, etc.), and digital controllers and intelligent electronic devices (IEDs).

With the advancement of the smart grids, the profile of the load curves of distribution feeders will be subject to a different dynamic behavior. Some features, such as increased use of distributed generation, demand response, and charging of electric vehicles, will require a fast network response for new generation and load scenarios. The automatic reconfiguration in real time will help to improve the network performance and to promote more efficient use of the smart grids resources.

3. Distributed generation technologies

The concept of distributed generation refers to the use of small generators directly connected to the distribution network or the local network of consumers. Among the current generation sources stand out wind power, photovoltaic, hydroelectric, and diesel. Thermal power plants and biomass have also been employed in DG, but on a smaller scale.

3.1. Wind power

The wind power harnessing is obtained from the kinetic energy conversion of the air masses through translational movement in rotational kinetic energy, using a wind turbine or wind

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generator for electricity generation. **Figure 3** illustrates the typical components of a wind turbine: rotor, nacelle, generator, sensors, among others.

The rotor is responsible for transforming the kinetic energy of wind in mechanical energy of rotation. The turbine blades are fixed in the rotor, which in turn is connected to a hub interconnected to the generator through a gearbox. The mechanisms to allow operation of the generator are located in the nacelle, for example, the turning control, the brake system, the wind sensors, among others.

3.1.1. Determination of wind power

Only part of the extracted wind power can be used to generate electricity. The amount of energy that can be converted into electricity is obtained by the power coefficient of the wind turbine C_p, which is the ratio between the possible power to be extracted from the wind and the total amount of power contained therein [9, 10]. Equation (1) defines the effective output power of a wind turbine (kg m/s) (where 1 kg m/s is 9.81 W):

$$P_t = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot v^3 \tag{1}$$

where ρ is the specific air density (kg/m^3), A is the cross-sectional area (m^2) swept by the propeller blades or the turbine blades, e v is the wind speed (m/s).

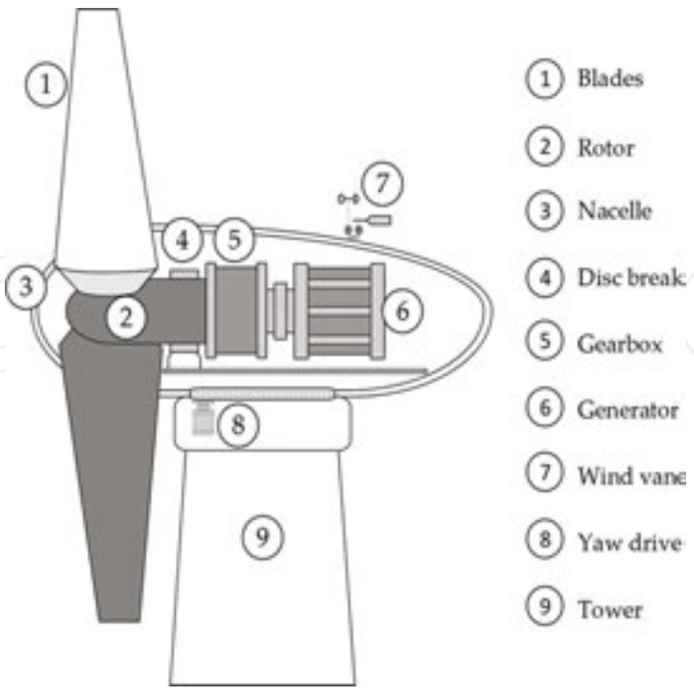


Figure 3. Schematic of a wind turbine generating power.

3.2. Photovoltaic power

Photovoltaic generation uses semiconductor elements capable to generate electricity from the direct conversion of solar energy in electrical energy through solar cells (photovoltaic). Although it can be straightforward, this conversion process depends on the characteristics of each semiconductor and quality of the materials employed in manufacturing technology.

One of the key aspects for the photovoltaic systems implementation is the knowledge of local solar radiation characteristics. These data may be obtained through the meteorological data base information. Solar radiation and temperature are the major variables that affect the generated power of the photovoltaic cells. To illustrate these effects, characteristic curves were obtained with the PV module parameters (245 W KD245GH) of the Kyocera manufacturer [11]. **Figure 4a** shows the *I–V* curves as a function of solar radiation. As can be seen, the solar radiation modifies the available power by changing the output current of a photovoltaic module. Besides to the solar radiation, the operating temperature of the cells also influences the amount of generated power, since the output voltage of the photovoltaic cell is changed depending on the ambient temperature. **Figure 4b** shows the *I–V* characteristic curve considering the temperature variation.

Figure 4. (a) Current and (b) voltage characteristics for the KD245GH module.

3.2.1. Determination of the solar photovoltaic power

The photovoltaic systems' behavior is usually characterized by measuring the voltage and current curves (*I–V* curves) of the PV modules from standard test conditions (STC). These conditions establish the reference values for the radiation (L) 1000 W/m^2, temperature (T) 25°C, and air mass (AM) 1.5.

However, STC conditions rarely occur in real operating conditions. Consequently, the estimation of the PV modules behavior requires extrapolation from the standpoint of real operating conditions.

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Currently, there is no standard methodology for assessing the electricity production of PV modules. There are typically two methods of assessing the amount of maximum power that modules produce numerical methods and algebraic methods [12, 13]. The numerical procedures are used to calculate the instantaneous power peak of the curve *I–V* in specific conditions, such as STC. Since the algebraic procedures use data regression analysis using historical data and can be used for any operating condition, they are more suitable for real data applications.

The method of Osterwald is one of the algebraic methods most commonly used because of the simplicity. It allows calculating the output power of a photovoltaic system for any amount of irradiation and cell temperature. Equation (2) shows the method of Osterwald [14]:

$$P_{Máx} = P_{STC} \cdot \frac{G_i}{G_{STC}} \cdot \left[1 - \gamma \cdot (T_i - T_{STC})\right] \tag{2}$$

where P_{STC} is the maximum power generated by the module (Watts), usually being the rated power of the manufacturer datasheet. G_{STC} is the overall radiation to the condition of the STC; G_i and T_i is the overall radiation; and air temperature condition T_{STC} is measured and the temperature for STC condition. Knowing that the STC conditions are given in restricted conditions, it is necessary to apply a power factor correction for temperature, which is represented by γ and corresponds to the value of the interval -0.005 to -0.003°C^{-1}.

3.3. Hydroelectric generation

The energy generation through the hydraulic potential for exploitation in a river can be characterized in different ways: When there is a concentrated unevenness in a waterfall, featuring a natural advantage, through a barrage with small unevenness, or through diversion of river from its natural course. The water is conducted through canals, tunnels, or penstocks and transformed into kinetic energy by spinning of turbine blades; this motion produces electrical power from the drive shaft of a generator.

Small hydro power (SHP) currently accounts for a fast and efficient way to promote the expansion of supply of electricity. This type of project enables better compliance with the consumers' requirement of small urban centers and rural areas, complementing the power supply performed by the conventional system.

Regarding operating philosophies, SHPs have great flexibility, having two main forms of reservoirs regularization: the river or storage, with daily regulation reservoir, and the dispatched power depends on the physical characteristics and techniques and also the central philosophy of the undertaking that holds.

3.3.1. Power extracted from a hydraulic turbine

The estimated output power for a hydraulic turbine can be obtained in relation to the height of the available downfall and of the flow of the hydraulic turbine, considered constant. Generally, the turbines models of Pelton, Francis, Kaplan, and Bulb are used for small hydro

projects. The choice considering one or other model is defined according to the height of fall characteristics, water flow, and rotation of the turbine generator set.

In general terms, the power of a turbine can be expressed as the sum of the three forms of energy of Bernoulli's theorem [9], as represented in Eq. (3).

$$\frac{v^2}{2g} + \frac{p}{\rho g} + h = \frac{P}{\rho g Q} \tag{3}$$

where v is the flow velocity (m/s), g represents the gravitational constant (m/s), p is the water pressure (N/m^2) at a height h of water (m) with ρ density (kg/m^3) and a water flow Q (m^3/s).

The output power of the turbine shaft in a hydroelectric system can be obtained through **Eq. (4)** [15].

$$P_e = \rho \cdot g \cdot Q \cdot H_{liq} \cdot \eta_T \tag{4}$$

where ρ represents the specific mass of water (1000 kg/m^3), g is the gravity acceleration (9.81 m/s^2), Q is the flow rate (m^3/s) of the turbine at a drop height H_{liq} (m) with an efficiency of η_T, which depend on the chosen hydraulic turbine model.

4. Automatic reconfiguration of distribution network in real time

4.1. Problem formulation

The reconfiguration of the distribution network is considered an optimization problem in that search, among the various solutions (topologies) possible, the solution that leads to better performance, considering the ultimate goal of reconfiguration and observing the network constraints. One factor that increases the complexity of the problem is the high number of switching devices in a real network, which results in a lot of different possible configurations to be analyzed.

In general, it may be impractical to test all possible combinations and perform, for each of the calculations needed—such as power flow and reliability indicators—in order to identify the setting that results in the best performance. To solve the problem, optimization methods that reduce the search space of the optimal solution are used.

Another problem is that the optimal solution found meets a given situation of power generation and consumption, which typically varies over a period. The load variation during the day, for example, can modify the parameters for which the topology is optimized, resulting in a new optimum configuration. At this point, the solution for the reconfiguration of the network must come from at least two premises:

http://dx.doi.org/10.5772/62632

a. The network must be flexible to allow the reconfiguration, whenever observed the need; and

b. It is necessary to establish a cost–benefit relationship to determine the necessity and the effectiveness of the reconfiguration;

The diagram in **Figure 5** shows the architecture employed in this work to meet these premises. The SCADA program is the main interface between the real-time reconfiguration program developed and the equipment in distribution network.

The first premise is to facilitate the implementation of the reconfiguration, so there is an effective gain with the network topology change. The use of remote-controlled equipment such as switches and reclosers is a solution that meets this premise on two aspects: The reconfiguration can be automated without the need to displacement teams to operate the equipment, and immediate, or can be performed at the time wherein determining its need.

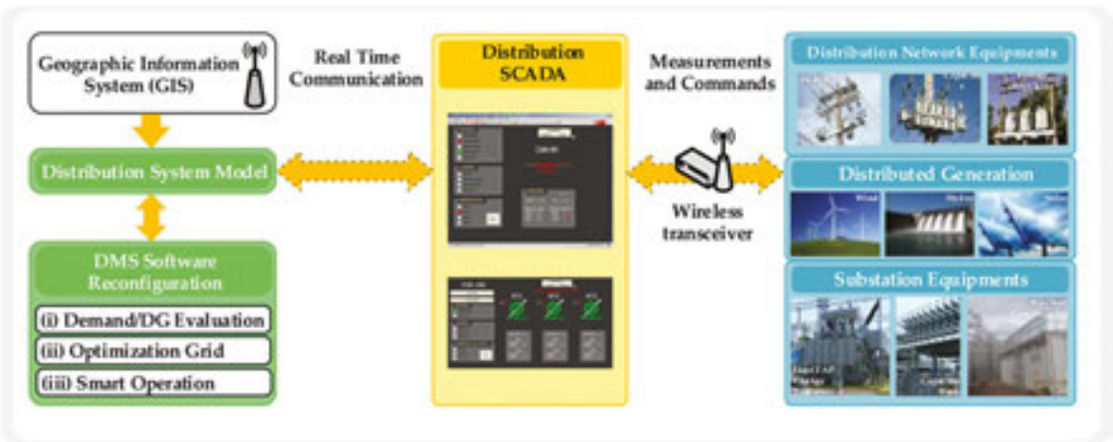


Figure 5. Architecture of the developed system.

The second premise aims to limit the wear of the switching equipment. One solution is to establish relevant levels change in the network (e.g., demand) and parameters utilized as the aim of reconfiguration (e.g., energy losses), and conditioning reset only to cases in which the alteration levels exceed the reference values.

4.1.1. Demand rate evaluation and profile of distributed generation

In order to obtain a good discretization of the demand curve and generation curve to avoid frequent reconfigurations in the network, it is employed a set of six demand rates. The rates are constructed from the average of historical data (typical daily demand curve). The representative demand for one entire period is the maximum value observed in it and the case of generation curve it is used the average output power.

Figure 6 exemplifies the discretization of typical curves; **Figure 6a** shows the demand curves of an industrial feeder; and **Figure 6b** shows a wind turbine generation curve.

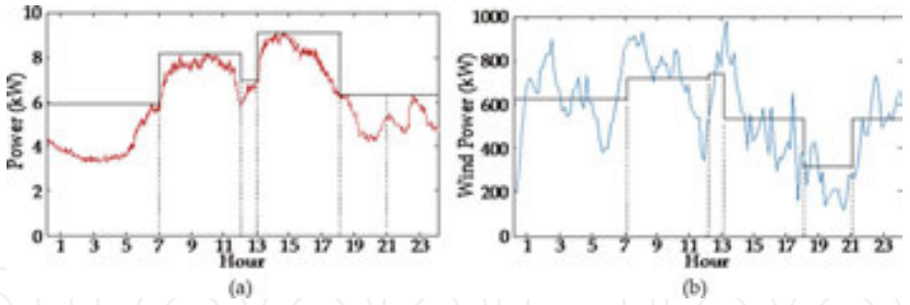


Figure 6. Discretization of typical curves of (a) an industrial feeder, (b) a wind turbine.

4.1.2. Objective functions and constraints

The first stage of the optimization process is to define the objective function (FO) and constraints of the problem. The OF includes the minimization of network indicators:

i. Expected loss of energy in the primary network (*ELosses*);

ii. Expected index of interruption frequency in the system (*ESAIFI*); and

iii. Expected value of energy not supplied (*EENS*).

These three indicators can identify each of the alternatives, and reconfiguration is shown in **Eq. (5)**.

$$OF = \min \left(ELosses_i^* .w_1 + ESAIFI_i^* .w_2 + EENS_i^* .w_3 \right) \tag{5}$$

Subject to:

$$\begin{aligned} |I_i| &\le I_{i\max} \\ V_{j\min} &\le V_j \le V_{j\max} \\ P_{\min} &\le P_{DG_n} \le P_{\max} \end{aligned} \tag{6}$$

where i corresponds to the period of analysis: 1...6; $w_1 ... w_3$ are weights of the criteria in multicriteria method; I_i is current equipment or driver; V_j is operating voltage in permanent state; P_{DGn} is active and reactive power limits provided by the distributed generator, the minimum power equations P_{min}, and maximum power P_{max} presented in Section 3, depend on the DG technology considered.

4.1.3. Optimization technique for selecting configurations

Several optimization methods are proposed to solve the reconfiguration problem of distribution networks. The search techniques can be classified into different categories: heuristics, meta-heuristics, expert systems, and mathematical programming [16]. Following is detailed

http://dx.doi.org/10.5772/62632

one of heuristic search techniques, and considerations are then presented to illustrate a reconfiguration of application example using this technique in a real network model. The heuristic search technique, also known as branch exchange, is based on a local search, where the algorithm looks for a new solution from neighboring configurations in each iteration.

In power systems, the method is premised on the radial configuration of the network. This method consists in carrying out successive changes in network configuration (e.g., opening a switch and closing another), so that each search tree node represents a possible solution of the problem. If the objective function indicators decrease, there is a new solution, and the algorithm continues the search process until no further improvement occurs. The technique can best be understood in two stages:

i. Step A: Analysis of interconnections between feeders in situations where there are not distributed generators connected to the distribution network [17] and

ii. Step B: Analysis of interconnections in situations where there are distributed generators connected to the distribution network [1, 2].

Figure 7 illustrates the flow chart includes the Stage A and Stage B of heuristic search technique for reconfiguration of distribution networks.



Figure 7. Flowchart from step A and step B of heuristic search technique for reconfiguration of distribution networks.

4.1.4. Decision-making method of multicriteria

The reconfiguration of the distribution network can involve optimization criteria that result in conflicting solutions. For example, considering the minimization of losses and increased reliability, a network topology can represent the optimal solution that meets the first criterion is, however, not represent the optimum solution to the second criterion.

A usual method of multicriteria analysis-based decision-making is the analytic hierarchy process (AHP) proposed by Saaty [18]. In AHP, the degree of preference of one over another objective is quantified through a table of the method suggested by the author, and the relationship between alternatives is represented by a matrix. A detailed description of AHP calculation methodology used in this work is presented in [17], which obtained as results for the indicators of the OF: w_1 (*ELosses)* = 0.64; w_2 (*ESAIFI*) = 0.26 and w_3 (*EENS*) = 0.10.

5. Experimental analysis

The proposed methodology was verified through several tests on the concession area of a power utility of Brazil. The real distribution network model presented in **Figure 8** is used as a case study, and this network has the following:

- Two substations with voltage 69/13.8 kV;
- Five feeders: FD-101; FD-102; and FD 103 connected from the Substation A; and FD-104 and FD-105 connected from the Substation B;
- 15 tie-switches remote-controlled (TS) in normally open state, named and numbered as TS-1 to TS-15;
- 143 remote-controlled switches (S) in normally closed state[1];
- Solar photovoltaic plant of 500 kW, located between the S11 and S12 switches;
- Wind power plant of 1600 kW, located between the TS-10 and S39 switches;
- Hydroelectric power plant (SHP) of 1000 kW, located between the TS-15 and S61 switches.

The original configuration of this system is shown in **Figure 8**, where it is important to highlight the interconnection switches and the distributed generation plants.

5.1. System evaluation

The analysis is done considering the expected maximum values of demand feeders and the average availability of active power generation by source of DG during the period corresponding to each of the six levels, as shown in **Figure 9**. For the developed methodology exemplification, only the results of level 5 are detailed (18h00–20h59).

[1] The manual switches which are not part of the tests are omitted in the representation of the network.

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Figure 8. Network distribution with DG.

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Figure 9. Demand evaluation and generation.

5.2. System optimization

The reconfiguration algorithm is applied considering the individual analysis of each switch interconnection shown in **Figure 8**. The individual analysis of the tie-switches leads to the results shown in **Figure 10**. Only the cases where the objective functions analyzed presented positive evolution are shown.

The results of objective function in **Eq. (5)** are sorted from lowest to highest value to give the best switching sequence. These results of the objective function represent the individual changes made in the network and its effects, as can be seen in **Figure 10a** for energy losses, **Figure 10b** for ESAIFI and **Figure 10c** for EENS.

These sorted results represent one switching sequence that should be performed by reapplying the branch exchange according to the defined order. The best configuration achieved with one tie-switch is preserved as the initial configuration to the following tie-switch to be tested. The final result of the network optimization to the analyzed rate demand is shown in **Figure 11**.

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Figure 10. Results for the individual analysis of tie-switches. (a) Energy losses. (b) ESAIFI. (c) EENS.

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Figure 11. Final results of reconfiguration analysis.

The final result of the optimization of the network to the rate demand analyzed is shown in **Figure 12** which shows the loads distribution between the analyzed feeders; **Figure 12a** shows the original configuration; and **Figure 12b** shows the network configuration after changes. All procedures of the main software were successfully performed to give the best network topology that improves the FO indicators.

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Figure 12. Load distribution between the distribution network feeders: (a) original configuration and (b) after changes reconfiguration.

6. Conclusion

In this chapter, a novel methodology for real-time reconfiguration of power distribution networks considering distributed generation units was presented. The main advantages of the

proposed system are automatic change of the network topology based on load rate analysis, modelling, and DG profile from distinct generation sources; multicriteria decision-making is given by the AHP method to choose the switching sequence and, finally, the computational analysis, the supervisory control, and the data acquisition of remote-controlled switches are integrated to perform the real-time reconfiguration. The switching is performed automatically, in the sequence determined by the software. Additionally, case studies are performed with real data from a power utility in Brazil, with the use of different operational scenarios that guarantee a real evaluation of the developed software performance. The results included in this chapter shown the feasibility of the proposed methodology, which assure the use of this system to other real networks with DG.

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