Power Dispatch in an Electrical Power System with Distributed Generators

[1]Lucian Ioan DULĂU, [2]Mihail ABRUDEAN
[1]PhD Student, [2]Professor, Department of Automation, Faculty of Automation and Computer Science
Technical University of Cluj-Napoca
Cluj-Napoca, Romania
[1]dulau.lucian@gmail.com, [2]Mihai.Abrudean@aut.utcuj.ro

[3]Dorin BICĂ
[3]Associate Professor, Department of Electrical and Computer Engineering, Faculty of Engineering
"Petru Maior" University of Tîrgu-Mureş
Tîrgu-Mureş, Romania
[3]dorin.bica@ing.upm.ro

***Abstract*—In this paper we present the power dispatch in a system with distributed generators. The simulation of the power dispatch is performed using the facilities of CitectSCADA software considering the loads profile, the availability of the generating units and the power losses. In order to cover the total load, the generating units are dispatched in ascending order of their power production costs, with the remark that if one of the distributed generation (DG) units is connected to the grid, then these DGs will be dispatched first due to the availability of their primary source. The analysis will be performed for the entire day.**

***Keywords*—power dispatch; dispatch order; base load; peak load; distributed generators**

I. INTRODUCTION

The "distributed generation" (DG) term refers to the production of electricity near the consumption place. The distributed generation resources are the combined heat and power or cogeneration (CHP) units and the renewable energy sources (RES).[1]

Distributed generation is characterized by some features which have not been present in traditional centralized systems. The power generated by the distributed generators (DGs) is relatively small and has variations dependent on the availability and variability of primary energy source. Also, their location in the network area is dependent on the presence of their primary energy source.[1]

DG can play an important role in: reducing the transmission losses, improving the power quality, improving the reliability of the grid, providing better voltage support and reducing the greenhouse and CO_2 emissions.[1]

The major obstacle for the distributed generation has been the high cost. However, the costs have decreased significantly over the past years.[1]

DGs can be used in an isolated way, supplying the consumer's local demand, or integrated into the grid supplying energy to the electric power system, or a combination of these.[1]

This paper is structured in 3 main sections.

In Section II is presented the test system data.

In Section III is presented the modeling of the power dispatch. The power dispatch will be performed according to the power price, in ascending order, with the observation that if the distributed generators are connected to the system they have priority access due to the availability of their primary energy source.

In Section IV are presented the power dispatch results for two cases:

- when the distributed generators are not connected to the system;
- when the distributed generators are connected to the system.

In Section V are reaffirmed the main concepts and benefits of DG, and are presented the conclusions which are supported by the results from the power dispatch analysis.

Other analyses were presented in [2-11] and were focused on the optimal design and dispatch of combined heat and power (CHP) systems ([2]), optimal dispatch in a medium-voltage microgrid (MG) with various types of distributed generation sources (DG) ([3]), optimal generation dispatch of the DG by artificial neural network ([4]), power dispatching of distributed wind-solar power generation hybrid system ([5]), dispatch for DG embedded distribution systems based on energy prices, weather forecasting and load forecasting ([6]), dispatch of DG in large-scale electrical power systems ([7-8]), optimization of power dispatch considering various electricity tariffs ([9]), methodology for the joint dispatch of demand response and distributed generation ([10]), and on the modeling and simulation of residential loads and distributed generators ([11]).

II. TEST SYSTEM DATA

The power dispatch will be performed for the entire day for the test system in Fig. 1, which comprises two distributed generators:

- a 3 MW small hydro generator at bus 4;
- a 2 MW photovoltaic power plant at bus 5.

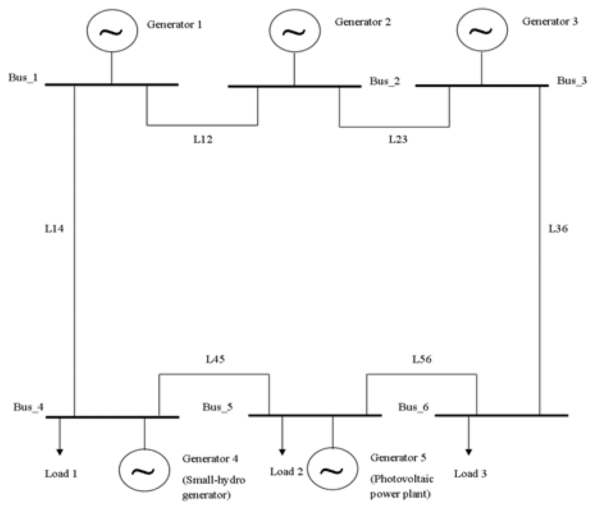

Fig. 1. Test system.

The data for each generating unit are presented in table I.

TABLE I. GENERATORS DATA

Type	Installed power (MW)
Generator 1 (G1) -Thermoelectric power plant	70
Generator 2 (G2) -Hydroelectric power plant	46
Generator 3 (G3) –Hydroelectric power plant	62
Generator 4 (G4) – Small hydro	3
Generator 5 (G5) –Photovoltaic power plant	2

The power demand for the first load is 50 MW, 60 MW for the second load, respectively 44 MW for the third load.

The power demand for the entire day is presented in Fig. 2. Also, the distributed generators output for the entire day is presented in Fig. 3.

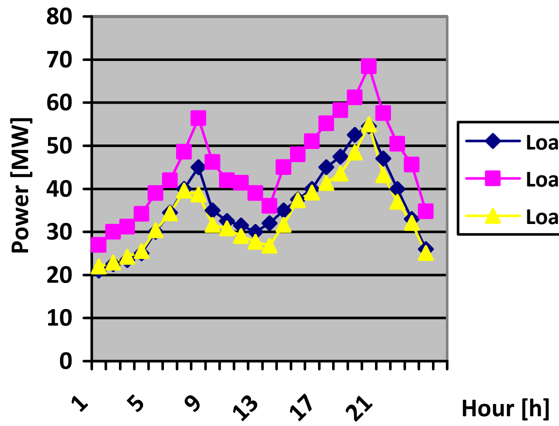

Fig. 2. Power demand for the entire day.

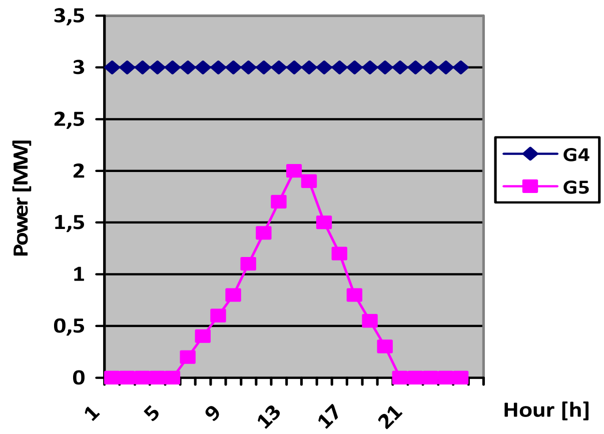

Fig. 3. Distributed generators output for the entire day.

The Romanian National Energy Regulatory Authority (ANRE) set the average prices for the production of electric energy from different sources that are presented in table II.[12]

TABLE II. AVERAGE PRICES FOR THE PRODUCTION OF ELECTRIC ENERGY FROM DIFFERENT SOURCES [12]

Energy type	Average price [lei/MWh]
Nuclear energy	142
Hydroelectric energy	125
Thermoelectric energy	190
Producers beneficiaries of the bonus support scheme type that produce electricity from high efficiency cogeneration	189
Producers with dispatchable energy units	189

III. MODELING OF POWER DISPATCH

The power dispatch simulation is performed using the CitectSCADA software [13], which can be used to create applications or projects, configure dynamic graphics, create alarms and trends, and then run those projects like a real system.

The simulation will take in consideration the power demand (Fig. 2).

The SCADA simulation interface (Fig. 4) contains the following components:

- 5 generators, each with a slide bar and a numerical object (####) that illustrates the power output;
- 2 meters, which are illustrating the total generated power and the total load;
- 2 charts, which are illustrating the total generated power and the total load;
- 3 loads (AC consumers), with a slide bar and a numerical object that illustrates the power consumption;

- a numerical object that illustrates the hour of the simulation;
- a Cicode Object (f(x)) which controls the system.

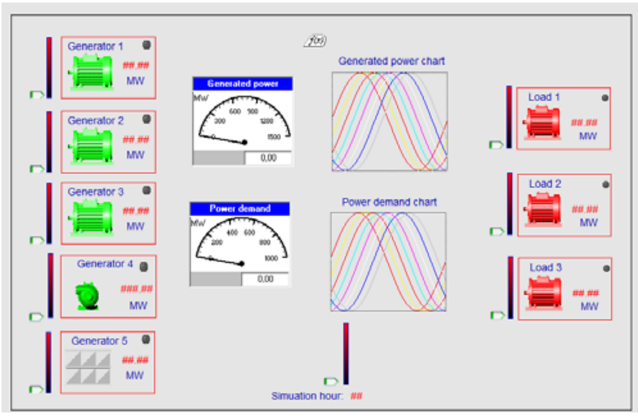

Fig. 4. SCADA simulation interface.

The power dispatched by the generating units is according the power demand (Fig. 5).

Fig. 5. Dispatch interdependency.

In order to cover the power demand, the generating units are dispatched in ascending order of their power production costs, with the remark that if the distributed generation (DG) units are connected to the system, then these DGs will be dispatched first due to the availability of their primary source.

The simulation takes in consideration if the generated power covers the power demand. If it does, then the excess power is exported. If the load is higher than the generated power, then the remaining required power is supplied by the reserve generator (G1).

Considering the prices from table II and the fact that the DGs will be dispatched first due to the availability of their primary source, the dispatch order is presented in table III.

TABLE III. DISPATCH ORDER

Generator	Priority
Generator 1 (G1)	5th
Generator 2 (G2)	4th
Generator 3 (G3)	3rd
Generator 4 (G4)	1st
Generator 5 (G5)	2nd

IV. Power Dispatch Results

The power dispatch results for two cases are presented in Fig. 6 (without distributed generators) and Fig. 7 (with distributed generators).

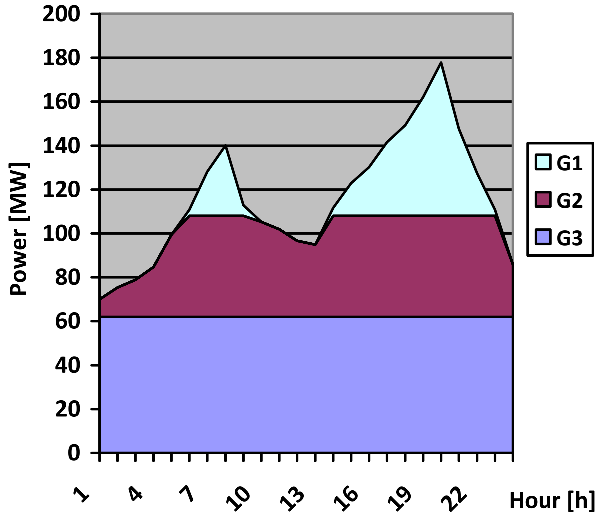

Fig. 6. Power dispatch results (without distributed generators).

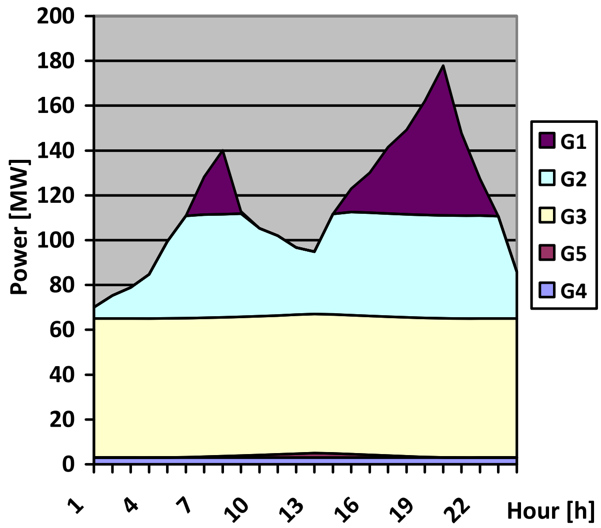

Fig. 7. Power dispatch results (with distributed generators).

V. Conclusions

Distributed generation (DG) refers to the production of electricity near or at the consumption place. The distributed generation resources are the combined heat and power or cogeneration (CHP) units and the renewable energy sources (RES).

DG has a significant role in reducing the transmission losses, improving the reliability of the grid, improving the power quality, providing better voltage support and reducing the CO_2 and greenhouse emissions.

The power generated by the distributed generators (DGs) is relatively small and has variations dependent on the availability and variability of primary energy source. Also, their location in the network area is dependent on the presence of their primary energy source. These DGs can be used to supply energy for an isolated consumer, or they can be integrated into the grid supplying energy to the electric power system, or a combination of these.

The major obstacle for distributed generation was the high cost of power produced by the DGs. However, these costs have decreased significantly over the past years.

The power dispatch analysis emphasis that in order to cover the base load four generators had to be dispatched (G4, G5, G3 and G2). The power dispatched by G3 was maxim during the entire day.

The power dispatched by G2 at base load was dependent on the situation of the DGs (if they were connected or not to the system). If the DGs were not connected to the system, then the power dispatched by G2 was higher. If the DGs were connected to the system, then the power dispatched by G2 was lower.

As a particular case, at 6:00, 14:00 and 23:00, when the DGs were connected to the system, the power dispatched by the reserve generator G1 was 0, in comparison with the situation when the DGs were not connected to the system when the reserve generator G1 had to be dispatched in order to cover the power demand.

At peak load all the generators had to be dispatched in order to cover the total power demand. If the DGs were not connected to the system, then the power dispatched by the reserve generator G1 was higher. If the DGs were connected to the system, then the power dispatched by G1 was lower.

ACKNOWLEDGMENT

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