بسم الله الرحمن الرحيم

MONA MAGHRABY

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

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شبكة المعلومات الجامعية

التوثيق الإلكتروني والميكروفيلم

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

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MONA MAGHRABY

Effect of Different Distributed Generation Technologies on the Performance of the Electrical Distribution Networks

By Nancy Gamal ElDin Mohamed Azazy

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electrical Power and Machines Engineering

Effect of Different Distributed Generation Technologies on the Performance of the Electrical Distribution Networks

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electrical Power and Machines Engineering)

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Examiners' Committee

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Thesis Abstract

The penetration of renewable energy resources in power system as a distribution generations (DGs) is increasing due to the continuous increase in the electric energy demands and the fluctuations of fossil fuel prices which makes many economic challenges including shortages in the electricity and water resources. To overcome these challenges, The Egyptian government is making obvious efforts to increase the investments in oil and gas sectors while seeking diversity in Egypt's non-conventional sources of energy because it's better than the conventional sources from the economical side and the environmental point of view, since they have a minimum environmental impact, higher efficiency, better performance and low cost. One of the most important non-conventional source of energy is the geothermal energy which is considered a clean, free and renewable energy that is used worldwide in generating electrical energy without a need to burn fuel.

A Controlled electrical and mechanical design of a Dynamic Geothermal power plant model for low temperature geothermal plant is presented in this thesis using Simulink model and Matlab software which represents the whole power plant starting from the geothermal temperature of the production well ending with the electrical power output from the used synchronous generator and the output variation with the different geothermal temperatures. The model includes all the mechanical equations and energy conversion equations related to the organic Rankine cycle, enthalpy curves and the organic fluid used in the mechanical part of the plant and it's effect on the generated electrical power. On the other hand, the model shows clearly the variation and unstable response of the electrical power output energy signals at different geothermal temperatures (72°C-130°C) as found in Egypt's promising geothermal regions (ex. Hammam Pheroan hot spring). A PID controller based on Genetic Algorithm is used to control the steam governor of the turbine to overcome of variation and unstable electrical power output at different temperatures so as to be able to be integrated as a Generation unite in a power system. The geothermal generation unite was used as a Distribution Generations (DG's) unites integrated to IEEE 33 Bus system. The IEEE 33 bus system's electrical performance was studied before and after adding Geothermal DG's unites from the point of view of the system power quality and the voltage profile. An optimization tool in the MATLAB Genetic

Algorithm is used to obtain the optimum number, size and locations of the Geothermal DG's unites integrated in the IEEE 33 bus system to enhance the voltage profile and the power quality of the system with objective function of least power losses and enhanced voltage profile. A clear comparison is displayed using the voltage profile with and without the DG'S units shows the great improvement in the voltage profile and power quality after adding Geothermal DG's unites. The results of this research will helps strongly the governmental and private sectors working on geothermal energy in Egypt to specify the best locations of the geothermal power plants to be integrated in at the national grid and predict easily the quantity of the electric power energy can be generated from the geothermal power plant according to it's geothermal temperature.

The second part of this research presents a comparison between two optimization tools; Grey wolf optimizer (GWO) and Genetic Algorithm (GA) to obtain the optimal size, number and locations of the DGs. In this thesis the distribution radial networks used to apply the GWO and GA on IEEE33 bus and IEEE69 bus systems. The comparison showed the greatness and more successful results of the GWO than that of the GA from the point of view of accuracy and better results (better voltage profile and power quality).

Key words:

Renewable energy, geothermal, Geothermal model, PID Controller, Genetic Algorithm, PID based on Genetic Algorithm PID-GA, Power Quality, Voltage Profile, Grey Wolf Optimizer (GWO), Distribution Generation (DG), Voltage profile, Power Losses, Genetic Algorithm (GA), heuristic algorithm, Metaheuristics.

Chapter 1
Introduction

Chapter 1: Introduction

The increasing demand for clean non-conventional energy sources to be used instead of fossil fuel sources leads to a rapid increase in integration of distribution generation DG in power systems [1]. Ackermann et al. have given definition of DG as: "DG is an electric power generation source connected directly to the distribution network or on the customer side of the meter." [4]. Due to this rapid increase in the penetration of DG in power systems, it has an impact on the system operation and performance [2],[20]. Distribution generation can be used for different sources of energy such as biomass-based generators, combustion turbines, thermal solar power, photovoltaic [21] systems, fuel cells, wind turbines, micro turbines, engines/generators sets and Geothermal systems. One of the most important non-conventional sources of energy is the geothermal energy which can be used as a DG in the power system in the form of geothermal power plant. The location of the Geothermal power plant project is determined by steam field site, rather than by the location of the electrical power demand [5]. Integration of a new DG (Geothermal generation) unit will impact strongly the operational performance of the existing electrical power network. These strong impacts must be taken in consideration during the preliminary planning stage of any Geothermal power plant project.

1.1 Traditional Power Systems

Most of the power systems generate electricity must have the following conditions [1],[2],[3]:

- The electricity generation process in the large generation power plants is always located close to the primary energy source at the same time far away from the consumers centers.
- Electric power it transmitted to the customers through large distribution networks which includes high voltage (HV), medium voltage (MV) and low voltage(LV) networks.
- The distribution networks of this system operate in a radial form such that the power flows in only one direction from upper voltage levels down towards lower voltage levels (customers) along the radial feeders.
- The generation process here has three stages before delivering the power to the customer; i.e. generation, transmission and distribution.

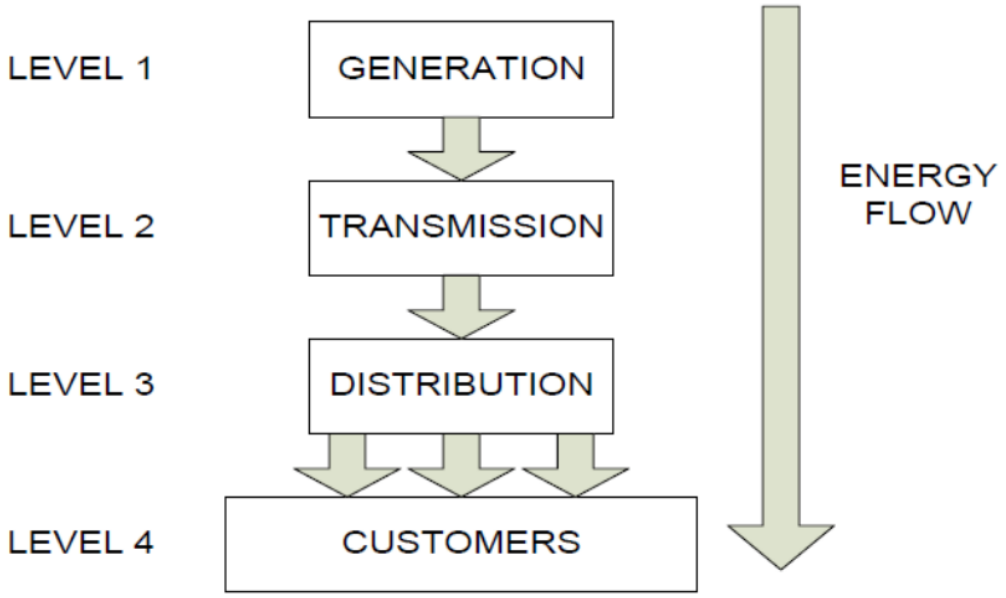

Figure 1 Traditional power generation of the electrical energy supply

In the first stage of generation the electric energy is generated in large power plants located far from populated areas and also away from loads to take in consideration the economic effects related to the size of the power plant and the environmental impact of the power plants.
The second stage of generation needs support of different types of devices such as transformers, underground cables and overhead transmission lines.
The third or the last stage is the distribution stage which link the whole power plant with the final customers. This stage is considered the most important stage as that the power quality of the received power by the customers depends on the reliability of this distribution stage [3].

Since the rapid increase in the electric energy demands, there is a must to develop and increase the sources of generation to meet the load demands. Therefore we can reach this goal by adding new energy sources "Distribution Generation" (DG) in level 1 (see figure 1.1) while there will be less addition in the transmission and distribution systems.

1.2 New power systems with Distribution generation:

these days, the continuous increase and evolution in the electrical markets, technological development and different environmental laws and rules demanding new specs and properties in the electric power generation system[3].

New unconventional resources allow electric power energy to be generated in small scale such that small power plants can be used in electric energy generation. On the other hand, the revolution in the renewable sources in order to decrease the bad effects of the electrical power generation on the environment demands development of the traditional electric power systems techniques.

In the new schemes of power systems, the generation process is not only in level 1.although some of the loads are supplied from the main generation units while at the same time other loads are

supplied from the distributed generation which leads to a great benefit that the produced electric energy is closer to the loads and customers.

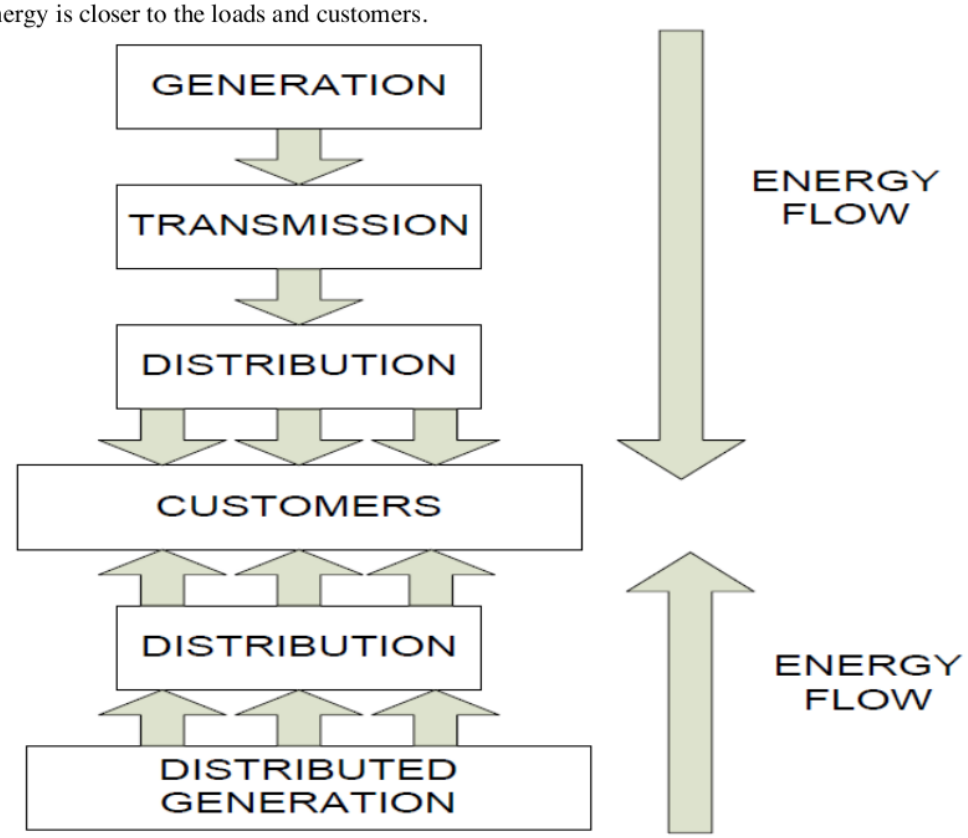

Figure 2 New schemes of electric power generation systems

1.3 Distribution Generation (DG):

In large power systems which contains large number of distribution generation units with different technologies at either LV or MV to fulfill the demands of the loads of different customers. The generators of the DG's units (such as thermal, geothermal, nuclear…) are smaller in size than the ordinary conventional generating units.

1.4 Advantages and disadvantage of DG's

DG's Advantages

- Connecting DG's in power systems increase the reliability of the power system, on the other hand according to the location of the DG's units from the loads they may decrease the losses in the distribution and transmission of the electric energy.

- Installation of DG's enhance the voltage profile, power quality and voltage stability[4],[5].
- Installation of DG's take less time than conventional units which increase the opportunities of investments in the countries which encourage using renewable energy sources and green energy which enhances the Economy and national security of the country.
- Most of the DG's technologies such as Geothermal, wind energy and photovoltaic…. are friendly with the environment since they produce green energy, have no pollution and contributes in decreasing the greenhouse gases.

DG's Disadvantages

- Most of DG units are connected to the grid via power electronic converters that inject harmonics, fluctuations and unbalance in the system voltage.
- DG's cause over-voltage and bad power factor.
- Some DG's technologies such as wind and photovoltaic cause sometimes fluctuations due to the variation of the output power generated.
- DG'S might cause an increase in the loses according to the used DG's technology, network configuration and the penetration level due power injection done by the DG.
- The protection system devices' (such as relays) settings should be changed in case in connection of DG's and must program it to return to their original settings in case of disconnecting the DG's.

1.5 Geothermal energy

Geo: earth Thermal: heat

2

•From the Greek "geo" meaning "earth" and "therm" meaning "heat".

•Harnessing the thermal energy (heat) flowing upward through the crust.

Electrical energy resources are growing faster these day and everyday there's new technologies used in generating electric energy through unconventional sources such as Geothermal energy which transmits the thermal (heat) energy in the earth into electric energy using turbines.

Nowadays Using DG's with different technologies became essential to fulfill the continuous increase in the loads and customers.

Geothermal energy [7],[8],[9]is considered a free, clean source of energy ,it is green energy which generates electric energy without burring any fuel which is a great advantage that allows us to get electric energy free and on the other hand has no harmful gases which participates strongly in reducing greenhouse gases.

1.5.1 Basics of Geothermal Power Plant

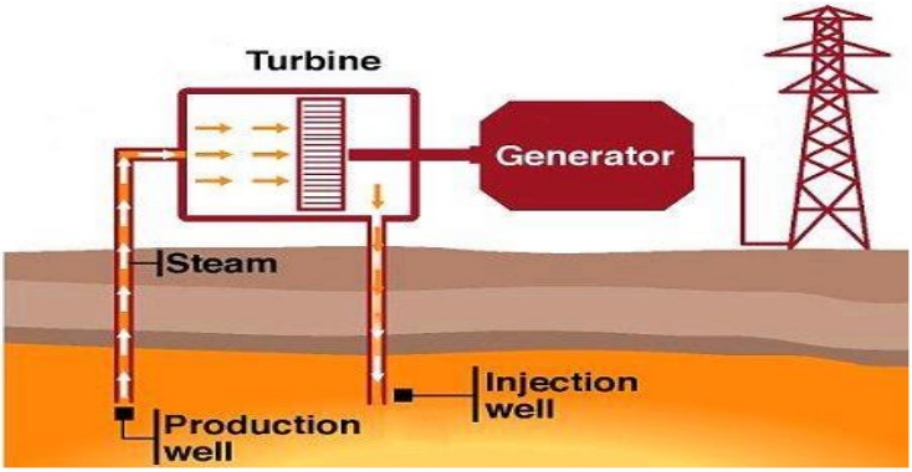

Figure 3 Geothermal power plant main components

it was mandatory to study the Geothermal model as DG unit since it has impacts on the existing power system[7],[8],[9]: fault currents ratings, the increase in the real and reactive power, transient stability, system losses and voltage regulation [5]. There are three geothermal power plant technologies being used to convert hydrothermal fluids to electricity: dry steam, flash steam and binary cycle. The type of conversion used (selected in development) depends on the state of the fluid (steam or water), its temperature and temperature gradient of the earth layers in the location of the Geothermal power plant. Since the Binary cycle is widely used worldwide due to it's flexibility in generating electrical power energy at low geothermal temperatures such as in the promising areas Egypt along the coasts of the Gulf of Suez (Hammam pheroan's surface temperature 71℃ and Hammam Mousa 48℃). while both dry steam and flash steam need high geothermal temperatures which isn't always available especially in Egypt's hot springs [6].

Like all steam turbine generators, the force of steam is used to spin the trubine blades which spin the generator, prducing electricity. But with geothermal energy, No fuels are burned.

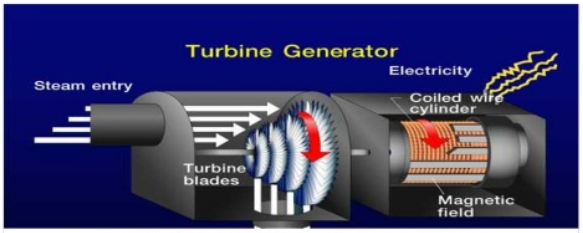

Figure 4 Geothermal turbine generator

1.5.2 Benefits of Geothermal energy

- **Clean**
- **Sustainable (Renewable)** **almost unlimited amount of heat** generated by the Earth's core.
- **Cost of energy:** the resource used (heat) is free of charge. Moreover, geothermal power doesn't require fuel to operate, therefore is not subject to fluctuations in fuel prices.
- **Availability:** unlike the wind or sun, geothermal power is available 24 hours a day, 7 days a week.
- **Flexible energy:** geothermal energy provides both base-load and flexible electricity due to its high capacity factor.
- **Low emissions:** geothermal plants do not burn fuels or coal, they don't release any emissions into the air.

1.5.3 Different types of geothermal power plants

There are three geothermal power plant technologies being used to convert hydrothermal fluids to electricity: **dry steam, flash steam and binary cycle [9].** The type of conversion used (selected in development) depends on the state of the fluid (steam or water) and its temperature.

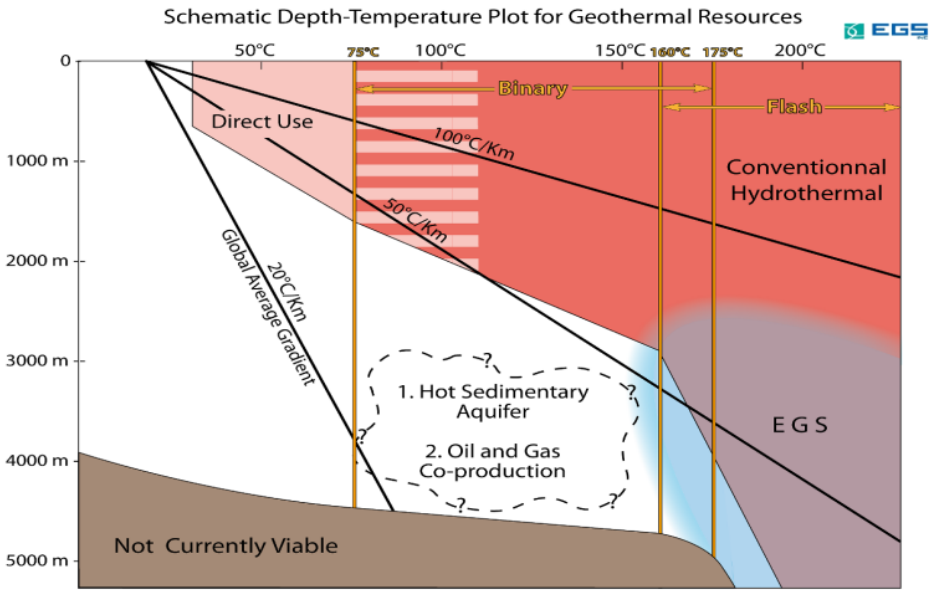

Figure 5 schematic Depth-Temperature plot of geothermal resources