Geothermal Power Plant Design using PLC and SCADA

Aman Soni*, Debashis Singh Deo**

*(Department of Electronics and Instrumentation, Bharath University, Chennai-76
Email: aman.soni342@gmail.com)
** (Department of Electronics and Instrumentation, Bharath University, Chennai-76
Email:debashissinghdeo28@gmail.com)

ABSTRACT

At any place on the planet, there is a normal temperature of +30◦C per km dug into the earth. Therefore, if one digs 20,000 feet the temperature will be about 190◦C above the surface temperature. This difference will be enough to produce electricity. However, no useful and economical technology has been developed to extract this large source of energy. In this paper we are proposing a new economical method to harness this energy using PLC. Direct sources function by sending water down a well to be heated by the Earth's warmth. Then a heat pump is used to take the heat from the underground water to the substance that heats the house. Then after the water it is cooled is injected back into the Earth using PLC & SCADA.

Keywords

Geothermal energy, Graphical display, Input relay unit, Output relay unit, PLC (programmable logic controller), SCADA (supervisory control and data acquisition), Temperature sensor, THLS (Tank high level sensor), TLLS (Tank low level sensor), Turbine motor, Turbine speed measure.

I. INTRODUCTION

Geothermal energy is the heat from the Earth or more precisely that part of the Earth's heat that can be recovered and exploited by man. Evidence of terrestrial heat is given by volcanoes, hot springs, and other thermal manifestations. Early mine excavations showed that the Earth's temperature was increasing with depth, under a gradient of 2-3°C/100m. It provides us with an abundant, non-polluting, almost infinite source of clean and renewable energy. The heat originates from the Earth core temperature (4,000°C at 6,000 km depth) and the radioactive decay of rocks, long life isotopes of Uranium, Thorium and Potassium. The total heat content of the Earth stands in the order of 12.6 x1024MJ, and that of the crust of 5.4 x 1021 MJ, indeed a huge figure when compared to the total world energy demand which amounts to ca 61013 MJ/yr. i.e. a 100 million times lower. However only a fraction of it can be utilized by man. Our utilization of this energy has been limited to areas in which geological conditions allow a fluid (liquid water or steam) to "transfer" the heat from deep hot zones to near the surface, thus giving rise to geothermal resources. The heat outflows from the Earth's core, melting the rocks and forming the magma. Then, the magma rises toward the Earth's crust, carrying the heat from below through convective motions. In some areas it remains below the crust, heating the surrounding rocks and hosted waters. Some of this hot geothermal water migrates upwards, through faults and cracks, reaching the surface as hot springs or geysers, but most of it remains underground, trapped in cracks and porous rocks, forming the geothermal reservoirs. In such locations the geothermal heat flow can reach values ten times higher than normal. Almost all-industrial processes need some form of control system if they are to run safely and economically. Very few industrial plants can be left to run themselves, and most need some form of control system to ensure safe and economical operation. The route towards increased productivity is through increased automation of processes and machines. This automation may be required to directly increase output quantities, or to improve product quality and precision. In any form, automation involves replacing some or all-human input and effort required both carrying out and controlling particular operations. To achieve process automation, the operator must be replaced by a control system that has the ability to start, regulate and stop a process in response to measured variables within the process, in order to obtain the desired output. These objectives are obtained using a control system based on PLC microcontroller and using SCADA man-machine interface. This paper is further divided into the following parts. Part 2 explains the design of our proposed system. Part 3 explains the features and positive attributes of the system. In part 4 we conclude this paper.

2. GEOTHERMAL POWER PLANT DESIGN

In this design it consists of following:

Tank low/high level sensor (TLLS/THLS),Turbine speed measuring sensor, Temperature sensor, Turbine motor, Input/output relay unit, PLC (Omron),SCADA system

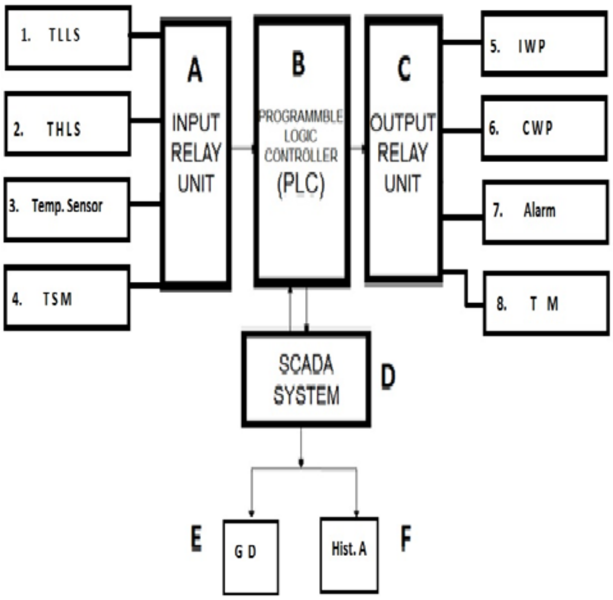

Fig.1. block diagram

2.1 TANK LOW/HIGH LEVEL SENSOR (TLLS/THLS)

This sensor(LM 324) are used to measure the low/high water level of the tank and providing the output to the PLC for processing.

When the switches are closed, the resistance is summed and converted to current or voltage signals that are proportional to the level of the liquid. These sensors work well for liquid level measurements processing, waste treatment, and other applications.

2.2 TURBINE SPEED MEASURING SENSOR

Gas turbine temperature sensors measure the temperature at different points in a turbine, from the exhaust temperature to the bearing temperature.

But in this project we are using IR sensor to measure the speed of the motor. This special infrared sensor is not function as mechanical or other sensor but it uses to detect the changing of black and white colors. Those black and white colors are creating on a motor shaft or motor pulley. That pulley is connected to the motor shaft and the infrared sensor will placed near the pulley. The rotation of the motor will cause the changes of black and white colors. These changing of both colors produce the different signal or voltage and that voltage is compared using a comparator and other electronic device to work with digital output. Then, that output signal will display at seven segment display to show the speed of motor in rotation per minute (RPM).

Manufacturing Gas turbine temperature sensors are manufactured from Mineral Insulated cable. Depending on our application, these can be supplied in various grades of stainless steel and exotic alloys.

2.3 TEMPERATURE SENSOR

Here the temperature sensor which is used is LM 35.Which has operating degree from $-50^{\circ}C$ to $150^{\circ}C$.This sensor is highly sensitive to those of operating thermistor because of the coating of the pins which help for further oxidation. It is of low cost highly effective and efficiency in usage.

2.4 TURBINE MOTOR

Here the turbine motor used in our project is a DC 12V gear motor. A DC motor is a mechanically commutated electric motor powered from direct current (DC). The stator is stationary in space by definition and therefore so is its current. The current in the rotor is switched by the commentator to also be stationary in space. This is how the relative angle between the stator and rotor magnetic flux is maintained near 90 degrees, which generates the maximum torque.

DC motors have a rotating armature winding (winding in which a voltage is induced) but non-rotating armature magnetic field and a static field winding (winding that produce the main magnetic flux) or permanent magnet. Different connections of the field and armature winding provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems called DC drives.

The introduction of DC motors to run machinery eliminated the need for local steam or internal combustion engines, and line shaft drive systems. DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines.

2.5 INPUT/OUTPUT RELAY UNIT

A relay is an electrically operated switch. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. Relays were used extensively in telephone exchanges and early computers to perform logical operations. Here in our project relay plays an important role of converting the 12V operated output to that in 24V conserving output. A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor.

Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

2.6 PLC (OMRON)

Programmable Logic Controller is a digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions for the implementing specific function such as logic, sequencing, timing, counting and arithmetic to control through digital or analog input/output modules various types of machines or processes. The programmable controller offers solid-state reliability, lower power consumption and ease of expandability.
Overall a Programmable Logic Controller is a mini computer specifically designed for industrial and other applications.

2.7 SCADA SYSTEM

SCADA (supervisory control and data acquisition) is used to monitor and control plant or equipment. The control may be automatic, or initiated by operator commands.

SCADA provides management with real-time data on production operations implements more efficient control paradigms, improves plant and personnel safety, and reduces costs of operation. In this graphical display gives out the total over all picturesque view of system being operated in given located area. Whereas the alarm history gives the history of the process and proper verification can be done as required by the controller (human intrapets)

2.8 WORKING PRINCIPLE

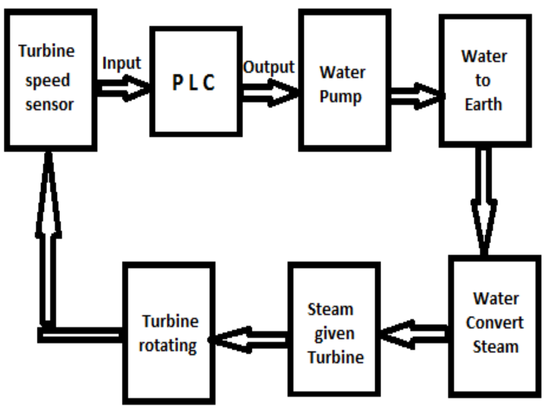

Fig.2 Process flow diagram

The working principle behind geothermal power plant using PLC and SCADA is done by using PLC and SCADA is the main processing unit. As PLC is a programmable logic controller, which controls all the basic operation of a system, it has a specific software which identically runs the system. The input of PLC includes speed sensor turbine which controls the speed of the turbine, tank high/low level sensor which measures the level of the tank, temperature sensor for measuring the appropriate temperature. The PLC has defined values for all these sensing unit and work according to the usage.
The geothermal power plant uses 190˚C for the production of electricity, which intern gets the output through ground water turning steam under high temperature and hence this steam is used in turning/rotating the turbine for the production of electricity. But using PLC, thermal power plant can also produce electricity at the temperature less than 190˚C temperature and speed sensor turbine as their main sensing unit.
Firstly, the speed sensor measures the speed of the turbine and hence sends the data to the PLC where the data is being checked, verified and sends the data to the output. The output data in term pumps the water through the water pump. This water is fetched to the earth water through water channels. The water in term gets changed to steam by higher temperature. This steam is again fetched to the turbine and in term the rotation take place. When the rotation of the turbine is equal to the required speed for the production of electricity, the PLC is switched OFF automatically and hence electricity is produced. And when the rotation/speed of the turbine is less than that of required speed, the process is carried on so that appropriate amount of water is transformed to steam and hence rotate the turbine.

3. FEATURES & POSITIVE ATTRIBUTE

Geothermal power plant has the following advantages:

3.1 No fuel is required fuel is required in the thermal plant and nuclear power plants use fossil and nuclear fuels respectively to heat water and generate steam for production of electricity. The geothermal power plants use the readily available hot water from the geothermal reservoir so no fuel is required.

3.2 Clean source of power The fuels used in conventional thermal power plants produce lots of toxic gases and particulate matter polluting the surrounding atmosphere. Electricity can be produced from geothermal reservoir without creating any air-pollution.

3.3 Less area is required the land required for the geothermal power plant per megawatt of power produced is much lesser than that required for the other types of power plants.

3.4 Unhindered production of power the energy from geothermal reservoir is available 24 hours a day and all the days of the year without any breakage or change during varying seasons, natural disaster and political turmoil. Thus geothermal energy is the reliable source for producing electricity continuously without any hindrance.

3.5 Additional capacity the geothermal power plants are very flexible and adding additional capacity for producing more power due to higher demands is quite feasible and affordable.

3.6 Saving money the fossil fuel used for the thermal power plants has to be imported. By using geothermal energy lots of local currency is saved.

3.7 Electrification of the remote places The geothermal energy reservoir present in the far off and remote areas especially villages can be utilized for the electrification of these areas. It may be very difficult to supply power to these places by the national grid.
The first commercial geothermal power plant was developed in the year 1904 in Italy. At present throughout the world more than 7000 MW of power is being generated by using the geothermal energy. In US about 2700 MW of electricity is generated from geothermal energy reservoir.

4. CONCLUSION

The purpose of this project was to study the functioning of PLC in geothermal power plant along with its applications in automated power plant industries**.** The goal also consisted of evaluating how it could be improved in terms of its usability. The design process of the model was examined in a group setting. Geothermal power plants are most often located in remote areas and it is, therefore, difficult to assign people to 24-hour shifts. The remote control systems enable people to solve this problem, making it possible to control from a remote site. Nowadays the automation of control equipment increases the flexibility of operation. The automation technology also provides more than one independent control system level in single or multiunit power plants.

Journal Papers:

[1] Liping Guo,'Design projects in a Programmable Logic Controller Course in electrical engineering', *The Technology Interface Journal/ Fall* 2009.

[2] Teague newman,' SCADA and PLC vulnerabilities in correctional facilities'.

[3] M.N.Lakhoua,'SCADA Applications in thermal power plants', *International Journal of the Physical Sciences*, Vol 5(6), pp.1175-1182, June 2010.

[4] Ruzhekov.G, Skvov.T, Puleva.T, 'Modeling and implementation of hydroturbine adaptive control Based on gain scheduling technique', *International conference on Intelligent System Application to Power System*, 25- 28th Sept 2011.

[5] Sharma.J.D, ArunKumar, Singhal .M.K, 'Real Time Digital Simulator for small Hydro Power Plants', *International Conference on small hydroplants*, 22-24th Oct 2007

Books:

[6] Geothermal power,By Josepha Sherma, Fact finder Publisher.

[7] Geothermal Power Plants: Principles, Applications, Case Studies and ...By Ronald DiPippo, B.H Publisher.

[8] Introduction to Programmable Logic Controller Gary Dunning (2ND edition).

Theses

[9] Aquater, 1979: *Geothermal exploration project.* Ministry of Energy and Mines, Ethiopian Institute.

[10] Bell, D., 1988: Puna geothermal venture's plan for a 25MW commercial geothermal power plant on Hawaii's big island, Geothermal Resources Council, Trans., 2, 351-358.

[11] Blackburn, J.L., 1976: Applied protective relaying. Westinghouse Electric corporation.

*[12]*Bronicky, L., 2000: Innovative geothermal power plants, fifteen years of experience. Proceedings of the *World Geothermal Congress 2000, Kyushu - Tohoku, Japan, 2089-2095.*

[13] Culver, G., 1986: Performance evaluation of Ormat unit at Wabuska, Nevada. Geo-Heat Center in cooperation with TAD's Enterprises, Ormat Systems, Inc., Sierra Pacific Power Company, Electric Power Research Institute, Idaho Power Company, and the Bonneville Power Administration.

[14] EEPCo., 2002: Basic problems of Aluto –Langano geothermal power plant. Ethiopian Electric Power Corporation, unpublished report, 20 pp.