Big Data Report

Geothermal

Whitepaper

Table of contents

1. Introduction

This white paper has been produced by the Digital Bucket Company to explore the technological solutions in transforming the Geothermal energy industry to be a more sustainable and reliable source of energy.

The nature of Geothermal energy makes it an appealing source of renewable energy with huge sustainable potential, created from the Earth's core.The energy is created from the heat generated during the original formation of the planet and the radioactive decay of materials. This process has meant huge wells of thermal energy is stored in rocks and fluids in the centre of the earth. There are obvious signs there is a high chance of geothermal energy being stored, where there are volcanoes, hot springs, geysers, and fumaroles. The main reasons for using geothermal energy are its environmental friendliness and sustainability in the long term.

When geothermal energy is captured it can be harnessed for many reasons and these can include cooking or electrical power generation. Geothermal energy that can be recovered and utilized on the surface is 4.5×10^6 exajoules, or about 1.4×10^6 terawatt-years, which equates to roughly three times the world’s annual consumption of all types of energy.

The British Geological Survey describes geothermal energy as a “carbon-free, renewable, sustainable form of energy that provides a continuous, uninterrupted supply of heat that can be used to heat homes and office buildings and to generate electricity. However, this resource is only being used to produce electricity in only 20 countries of the world. There are several factors contributing to the limited use, such as the high cost of the plant, very location-specific resources, and the cause of mini tremors in the areas they operate in. Big Data and their related technologies can help in mitigating or reducing the impact of these factors.

The global energy market is shifting towards more sustainable sources of energy and this has accelerated the need for a shift to technological transformation. A key driver for this change has been the advancement in technologies such as ‘Internet of Things’ (“IoT”). The development and implementation of IoT systems is helping to drive this transformation around the world. It's revolutionizing nearly every part of the industry from generation to transmission to distribution and changing how energy companies and customers interact.

2. Extraction of Geothermal energy

The extraction of geothermal heat is both complicated and currently the rate of success is low and not meeting its full potential. The current process involves Geothermal well to be pumped with hot water and so the heat is extracted using a heat exchanger. The cooled water is then pumped back and eventually heats up again because of the heat in the Earth.

The heated fluid from a geothermal resource is tapped by drilling wells, sometimes as deep as 9,100 metres (about 30,000 feet), and is extracted by pumping or by natural artesian flow (where the weight of the water forces it to the surface). Water and steam are then piped to the power plant to generate electricity or through insulated pipelines—which may be buried or placed aboveground—for use in heating and cooling applications. In general, electric power plant pipelines are limited to roughly 1.6 km (1 mile) in length to minimize heat loss in the steam.

However, direct-use pipelines spanning several tens of kilometres have been installed with a temperature loss of less than 2–5 °C (3.6–9 °F), depending on the flow rate. The most economically efficient facilities are located close to the geothermal resource to minimize the costs of constructing long pipelines. In the case of electric power generation, costs can be kept down by locating the facility near electrical transmission lines to transmit the electricity to market.

2.1 Different types of Geothermal Energy

Traditional or Conventional Hydrothermal:

These have common ingredients of water and heat. These geothermal reservoirs of steam or hot water occur naturally where magma comes close enough to the surface to heat groundwater trapped in fractured or porous rocks, or where water circulates at great depth along faults. Dry steam (vapour) reservoirs and hot water (liquid) reservoirs are used to generate electricity.

Sedimentary & Geopressured:

Geopressured gas has been developed to produce geothermal electricity and these resources are found in Sedimentary & Geopressured Systems. This approach is described as the utilisation of kinetic energy, hydrothermal energy, and energy produced from the associated gas resulting from permeable layers at depths (typically between 2-5 km).

Enhanced Geothermal Systems (EGS):

These are hot dry rock systems and are located where hot masses of low permeability rocks are found at drillable depths.

2.2 Uses

Geothermal heat pumps (GHPs)

These take advantage of the relatively stable moderate temperature conditions that occur within the first 300 meters (1,000 feet) of the surface to heat buildings in the winter and cool them in the summer. Consequently, that heat can be used to help warm buildings during the colder months of the year when the air temperature falls below that of the ground. Similarly, during the warmer months of the year, warm air can be drawn from a building and circulated underground, where it loses much of its heat and is returned. GHPs provide a whole lot of advantages yet the best way to get the most out of the GHPs is the precise identification of the resource.

Geothermal Power Plants

These are designed to produce electricity from steam. It is done by controlling the behaviour of the steam and using it to power electrical generators. Some geothermal plants simply collect rising steam from the ground.These are simply known as “dry-steam” operations. In other plants such as “flash steam”, high temperature water from under the crust of the earth is drawn to containers and they get suddenly depressurized causing them to vaporize into steam. The steam then powers a turbine-generator set.

Direct uses

A lot of applications use heated water from the ground without needing any special equipment. All direct use applications use low temperature geothermal resources which have a range between around 50 and 150 degrees celsius. Which have been used to warm single buildings and whole areas where many buildings are heated from a central supply source. Also swimming pools, spas,greenhouses and ponds have been heated with geothermal resources. Other direct uses are cooking, industrial applications such as drying fruit, vegetables and timber, milk pasteurization and snow melting.

3. Big Data and its relation to Geothermal Energy

Big data analytics helps businesses to get insights from today’s huge data resources. People, organizations, and machines now produce massive amounts of data. Social media, cloud applications, and machine sensor data are just some examples. Big data can be examined to see big data trends, opportunities, and risks, using big data analytics tools.

One such example of using data includes Heatmaps, this where companies and site workers visualize the depth and the locations from where geothermal energy can be extracted. Geothermal energy is best found in places with high gradients. If problem owners have multiple repositories that store data about locations, depth and potential amount of heat extracted and other key factors, data integration allows them to collate data sources and view them. When problem owners have a single view of all the data that is available to them.

3.1 What data do we need?

According to a study led by a group of Swiss researchers, the main measurements we need are: monthly ground temperature, the ground thermal conductivity, and the ground thermal diffusivity, in order to extract the very shallow geothermal theoretical potential (vSGP) for the surface layers or ground. Then to calculate these measures, different datasets were collected from various sources including federal offices, companies or particular studies. The table below lists the data gathered and their uses.

Data related to other processes are also required. For example, power usage data can serve as the basis for load forecasting. It can help in managing congestion along transmission and distribution lines and help ensure that all of the connected generation plants meet requirements related to frequency and voltage control. This power consumption data can also help companies decide where to build new infrastructure and make infrastructure upgrades.

3.2 Enhanced Insight & Process Automation

From resource assessment to well field development, investment decision to electricity production, we are leveraging more accurate forms of information processing that enable enhanced insight, decision-making, and process automation. The result is better business decisions for the development of geothermal resources to deliver more reliable and stable power.

3.3 Accuracy

Big-Data analytics can be applied to the traditional "hot-spot" geothermal approach resulting in greater precision to produce baseload renewable electricity. When a data-driven approach is applied to deep sedimentary basins, it can result in an ever-expanding map of the earth's interior fluid that is much more widely available than previously thought, thus bringing the possibility of geothermal electricity to more locations around the world with lower risk and greater accuracy.

4. Data integration and its relation to Geothermal energy

Data integration refers to the technical and business processes used to combine data from multiple sources to provide a unified, single view of the data. Data integration is the practice of consolidating data from disparate sources into a single dataset with the ultimate goal of providing users with consistent access and delivery of data across the spectrum of subjects and structure types and to meet the information needs of all applications and business processes. Data integration also makes way to remove data silos present within the organization.

The data integration process is one of the main components in the overall data management process as the need to share existing data continues to grow. By collecting data on usage and combining it with other sensory information, data analysis and computational models can calculate the highs and lows of extraction and replenishment rate, and when there is a surplus. Data integration allows problem owners/ clients in the geothermal industry to obtain a single view of all the data available to them. This helps them in taking better decisions and identifying locations and areas for geothermal energy extraction.

Geothermal energy is used most widely only in a few countries throughout the world. The reason behind this is, the amount of usable energy depends on depth and extraction method. Using high power predictive analytics and data integration tools, we can identify these resources more efficiently.

Normally, heat extraction requires a fluid (or steam) to bring the energy to the surface. Locating and developing geothermal resources can be challenging. With the help of ETL(Extract, Transform, Load) data integration tools, it is possible to gather real time information about crust conditions and temperatures. Data can also help in ensuring that the replenishment rate is lower than the extraction rate, thus making sustainability uncompromised.

5. IoT and its relation to Geothermal Energy

Internet of Things (IoT) is a network of physical objects or people called "things" that are embedded with software, electronics, network, and sensors that allows these entities to collect and exchange data. With the power of data collection, IoT makes everything “smart”.

The Internet of Things acts as a catalyst for the modern energy in helping to connect all elements of the industry and gain visibility in the process.Technologies such as IoT offer a wide number of applications that improve overall efficiency of energy production by allowing operations to be streamlined and increase productivity that in turn increase revenue for the organisation or business. Furthermore, IoT can be employed for improving energy efficiency, increasing the share of renewable energy, and reducing environmental impacts of energy use.

This is possible by affixing IoT sensors to the transmission and distribution network that can enable energy companies to monitor the network remotely. These sensors measure parameters such as vibration, temperature and overall condition of the network to optimize maintenance schedules. This information can then be fed through a centralized dashboard that can help with identifying maintenance issues early and predict any future problems. This can significantly improve reliability by keeping equipment in optimal condition and providing the opportunity to make repairs before it fails.

With any energy utility the risks attached to any facilities are high, with the risk of fires and explosions apparent on a minute-by-minute basis. IoT sensors can help to maintain a safer environment, by utilizing internet-connected sensors to pipelines that can help detect leaks. Currently there are risks of being left unaddressed, may result in fires or explosions. In addition, leaks also amount to wasted resources and work against any sustainable goal to tackle global warming.

According to the United Nations Industrial Development Organization (UNIDO) collecting and communicating data, the “internet of things” will - proponents say - change our lives by making every home “smart”. But few people know that the technology can be used to help overcome global issues such as climate change. In East Africa, the “internet of things” will soon be used to make geothermal electricity production cleaner and more efficient.

6. A case study on Artificial Intelligent & Big Data Mining

The case study talks about how an artificial intelligent and big data algorithm is used to examine and control the geothermal heat pump system (GHP). A heat pump system takes heat energy from a cold medium to a warm medium. The main point of this is to model, design, examine, control and make the performance better for a desert underground system based on AI machine learning.

The calculations done show that the system is very economic and competitive compared to the normal cooling and heating systems. One of the main uses of this system is to cool down the roof water tank for domestic and personal usage. Artificial intelligence and big data is used to analyse the weather conditions related to the system performance based on a large number of thermal observations recorded between the years of 2015-2018. Also, the mean switch-off control hours of the system is analysed by developing a supervised learning predictive model. For the validation, a four ton Bosch system unit is chosen as a benchmark. The switch-off control hours per month for the whole geothermal data set are shown using a linear regression model that helps to control the controller to switch the system on and off without needing the real data measurements.

"Technologies that can transform the Geothermal Energy sector"

Geothermal heating and cooling system makes its energy to cool or heat residential and commercial buildings by using the temperature of earth, saving 40% to 70% energy compared to the normal heating and cooling systems . Geothermal heat pumps use electrical power to get rid of the heat from the soil into houses.
They have used geothermal heat pump big data tall arrays which are made up of a large number of rows of thermal observations compared to a few number of columns of variables such as temperature, thermal radiation, day, week, etc. The tall arrays are used to analyse the big data. The good thing about tall arrays is that it can carry out many calculations on different types of data which is out of memory. Also the calculations can be done only when they are needed to be performed which saves time. The missing data can be replaced by a non available data to make it more accurate. They can deal with any type of data such as numeric, logics, day, time, duration, location or strings. The data can then be sorted by reducing the number of data points using sampling.

To develop the machine learning of the geothermal heat pump system, the data is split into two groups: a training subset and a validation subset by using random sampling and supervised linear regression learning mode. So that the system will predict the switch-off control hours and make it clever. Also, it will control the system to switch on and off without needing to sense and measure real data. The hotter the weather is, the longer the system will be switched on for.

In conclusion, one of the main results obtained is being able to make the system performance better, also to save main input energy and operation periods. Also, the results show that 33% of the year is in a switched-off saving mode , compared to 67% in switch-on mode. This smart big data control will give a life-cycle saving of $27,020.

7. Conclusion

About 40% of the world’s geothermal energy is located in Indonesia. However, in terms of development, Indonesia is lesser than the United States and the Philippines. Indonesia seeks to achieve a goal to produce more than 9000MW of geothermal power by 2025. By taking advantage of the recent developments in Big Data and IoT devices, problem owners can facilitate all the major concerns and achieve their objectives by analysing the data and making the process more efficient. It will also make the country more eco friendly because geothermal energy is a renewable energy source.

To find out more on how data solutions can improve the energy sector, drop us an email on info@digitalbucketlabs.com.

8. References

1. https://media.proquest.com/media/hms/PFT/1/P4gfA?_s=e3SmH1dfVVPpOxZI4s%2BsOmdzEPw%3D
2. https://www.power-technology.com/features/what-is-geothermal-energy/
3. https://www.thermalep.com/tep-geothermal-advantage
4. https://geothermal-energy-journal.springeropen.com/articles/10.1186/s40517-019-0135-6#Sec7
5. https://www.renewableenergymagazine.com/emily-folk/how-iot-is-transforming-the-energy-industry-20190418
6. https://data-ogauthority.opendata.arcgis.com/datasets/1482ef2b441c4eb9a17a94181874d154
7. https://www.nrel.gov/news/program/2018/nrel-data-and-tools-accelerate-geothermal.html
8. https://www.renewableenergymagazine.com/emily-folk/how-iot-is-transforming-the-energy-industry-20190418
9. http://lsa.colorado.edu/essence/texts/geothermal.html
10. https://www.unido.org/stories/using-internet-things-improve-geothermal-Energy-production-africa
11. https://www.britannica.com/science/geothermal-energy
12. https://www.mdpi.com/1996-1073/13/2/494/htm
13. https://www.digiteum.com/iot-green-energy/
14. https://www.guru99.com/iot-tutorial.html

15. Haseeb, K.; Almogren, A.; Islam, N.; Ud Din, I.; Jan, Z. An Energy-Efficient and Secure Routing Protocol for Intrusion Avoidance in IoT-Based WSN. Energies 2019, 12, 4174. [CrossRef]
16. Höller, J.; Tsiatsis, V.; Mulligan, C.; Avesand, S.; Karnouskos, S.; Boyle, D. From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence; Elsevier: Amsterdam, The Netherlands, 2014.
17. Atzori, L.; Iera, A.; Morabito, G. The Internet of Things: A survey. Comput. Netw. 2010, 54, 2787–2805. [CrossRef]
18. Hui, T.K.; Sherratt, R.S.; Sánchez, D.D. Major requirements for building Smart Homes in Smart Cities based on Internet of Things technologies. Future Gener. Comput. Syst. 2017, 76, 358–369. [CrossRef]
19. Evans, D. The Internet of Things: How the Next Evolution of the Internet is Changing Everything. CISCO White Pap. 2011, 1, 1–11. 36. Motlagh, N.H.; Bagaa, M.; Taleb, T. Energy and Delay Aware Task Assignment Mechanism for UAV-Based IoT Platform. IEEE Internet Things J. 2019, 6, 6523–6536. [CrossRef]