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Enhanced Geothermal System (EGS): A Review of Cambay Basins

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ABSTRACT

Geothermal energy is the heat stored in the earth's crust and it is a clean and eco-friendly energy source. India depends more on coal as it is cheaper but it causes environmental pollution so the importance of geothermal energy in India is to make a great contribution to India's long-term energy supply and knockdown greenhouse gas emission by establishing a safe, sustainable and secure geothermal energy industries. In Gujarat state, the Cambay basin is a rich petroleum region that is located on the western margin of India. In just one zone it holds 206 billion cubic feet of gases and 8 million barrels of condensate reserves. Depending on the types of geothermal systems, geothermal wells are designed. In the Cambay basin, more than 7000 wells are drilled. A geothermal dual well system contain at least one injection and one production well to produce geothermal energy effectively. Self-discharging well, production well, etc. are the type of well which are used. An enhanced geothermal system (EGS) is an artificial reservoir and it is created where there is a hot rock but low fluid saturation or natural permeability. It offers the opportunity to access clean energy sources. This paper discusses the scenario of EGS in Cambay basins.

1. INTRODUCTION

Geothermal energy is the thermal energy which is generated and stored in an Earth crust. It is originated in the original form and forms radioactive decay of materials. It is a renewable energy source and can be found in abundance. Earth is a huge storehouse of thermal energy. Geothermal energy since prehistoric time in the form of hot springs are used for various purposes like for space heating, bathing, etc. but it is now better known for electricity generation. Geothermal power plants do not use fuel to generate electricity so the level of air pollutant that is emitted is very low. Worldwide, in 2013 around 11,700 megawatts (MW) of geothermal power was available. Approximately 10 percent of carbon dioxide (CO2) and a small amount of methane (CH4) emission take place in open-loop geothermal system. An additional 28 giga watts (GW) of heat capacity is installed for space heating, industrial processes, desalination and agricultural application, etc. Geothermal water which is carried from the deep Earth carries a mixture of gases, notably carbon dioxide (CO2), ammonia (NH3) and methane (CH4). This pollutant can cause various problems like global warming, noxious smell and acid rain if released.

Enhanced Geothermal System (EGS) generates geothermal electricity without any need for natural conductive hydrothermal resources. Through a variety of stimulation methods, including 'hydrothermal stimulation', EGS technologies create geothermal resources in hot dry rocks (HDR). It is more efficient than any other geothermal system and it can supply a significant fraction of the low temperature thermal energy used. To decrease the dependency on naturally occurring geothermal reservoir it has suggested to create such reservoir artificially. This alternative is referred as Enhanced Geothermal System (EGS). It consists of withdrawing heat from "tight" rocks that had not fractured naturally and where the permeability is very low. The main focus is to use water as a working fluid for exploiting heat from rocks. When operating it, the main objective is to maintain the hot fluid output ratio at a satisfactory level for which plant is designed. CO2 is also used as a working fluid, then it is noted that at low pressure it is considered inefficient. It is an alternative to water to use as a working fluid; it is more efficient at high and medium pressure. The aim of "Enhanced" or "Engineering" geothermal system is to extract geothermal energy from the resources by producing permeability through hydraulic fracturing or stimulation.

Application of geothermal energy is an alternative as it is more suitable for environment, which is needed to be harnessed in India. Dholera which is located in Gujarat is a potential site for geothermal exploitation and exploration. It is located on the western margin of India. The highest geothermal spring in Gujarat is at Dholera. The most important aspect of geothermal system is to understand the heat source and its capacity for exploitation. The potential of Cambay Basin is to generate 100 megawatts (MW) of geothermal energy. In the paper we are discussing about EGS in Cambay Basin. It is to extract heat by generating a surface fracture system to which water can be added to injection wells. It can improves the natural permeability of rocks. This injected water is heated by contact with rocks and returns to the surface through production wells.

2. STUDY AREA

The Cambay Basin in the Dholera region is located under the Saurashtra peninsula in Gujarat, India. This is one of the three significant geographical divisions of Gujarat State, located at 20˚30'E to 22˚30'N latitude and 69˚00'E to 72˚30'E longitude. It is a province rich in oil resources. The basin is a long and narrow internal craton rift basin in the late Cretaceous, which contains different basins and is full of sediments. Dholera is located in the Gulf of Khambat, 30 kilometers southwest of Dhandhuka village in Ahmadabad, and 60 kilometers north of Bhavnagar. It is surrounded by water on three sides, the Bavaliari Creek in the north, the Sonaria Creek in the south, and the Gulf of Khambat in the east. The geothermal hot springs in this area are located on the edge of the Saurashtra peninsula, which is located near the fault on the western edge of the Cambay Basin. The Terrain of Dholera is mainly covered by mudflats, and the basement is formed by the Deccan traps with a depth of 500-600 meters. The area is also occupied by Quaternary soil deposits up to a thickness of about 100 meters, followed by Tertiary sediments deposits on the Deccan Trap. The total area of the basin is approximately 53,300 square kilometers. Dholera in Gujarat is a potential site for geothermal exploration and development. In the survey area, the overall slope of the ground is from west to east. In Dholera, we have old mud flats, flood plains and salt flats. The soil in the Dholera area is mainly composed of alternating layers of fine to coarse sands and

clays. Chemically, the soil is fertile, mixed montmorillonite, calcareous, and most of it is salty. The Dholera hot springs is located above the high gravity area, indicating that the mantle is shallow and there are granite base rocks. A total of four springs are delineated within a 4 kilometer radius of Dholera, Swaminarayan temple, Uthan and Bhadiyad. In Gujarat, Dholera hot springs has the highest geothermal flow rate. An average width Cambay Basin is 50 kilometers, a length of 450 kilometers, and 7 kilometers of maximum depth. The basin has a history of active oil and gas exploration for more than 40 years.

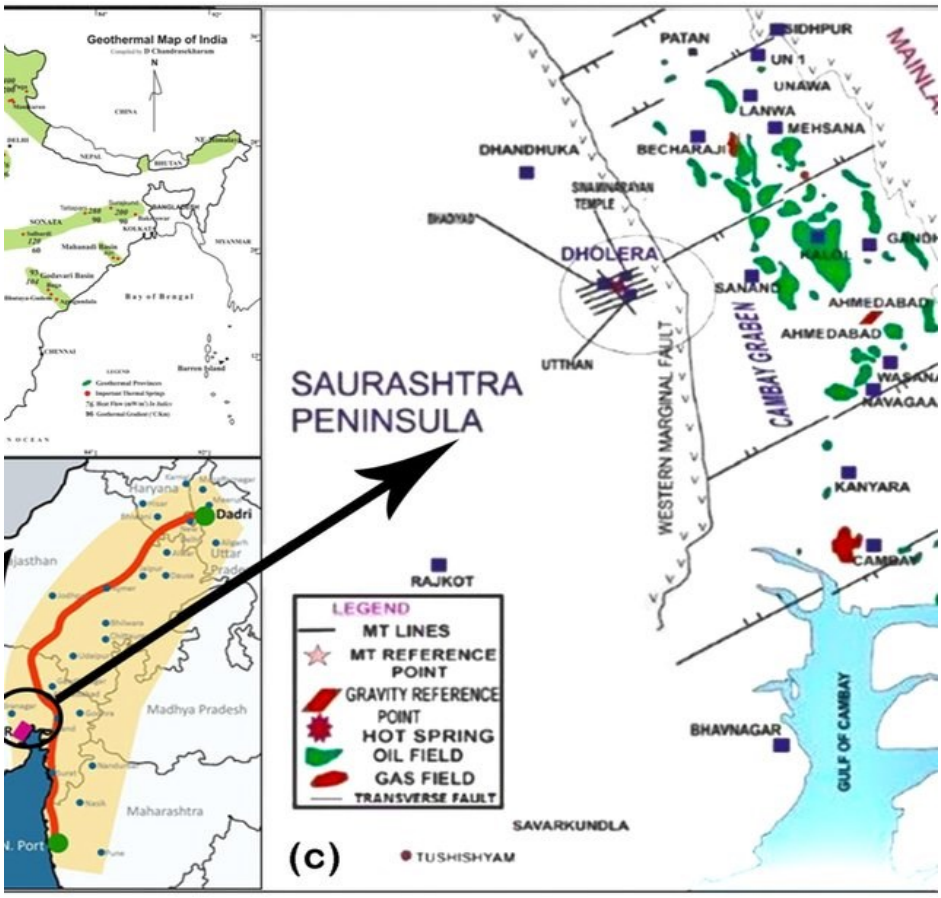

Figure 1: Location of Cambay Basin

3. METHODOLOGY AND IMPLEMENTATION OF EGS

Enhanced Geothermal System can be often developed by using hydraulic stimulation of a deep sandstone reservoir. There are three categories of it that is hydro-fracking, chemical incentive and thermally induced breaking. To form a doublet two wells have been made. The fluid that will come out from the well will be used to produce electricity. Both the wells which are drilled have the depth of more than 4 kilometers that is targeting broken volcanic rocks and penetrable sandstone. The stimulation was sketched (designed) based on the experiments conducted in laboratory that is on various treatment schedules that was analyzed by numerical stimulation and various types of proppants. To intensify the yield of reservoir and to maintain it for a long time period Gel-prop pant stimulation was chosen. Firstly, experiment was conducted in laboratory before the field tests to survey the effects that are caused by it and the hydraulic conductivity those changes in the middle and a type of proppants that has high durability.

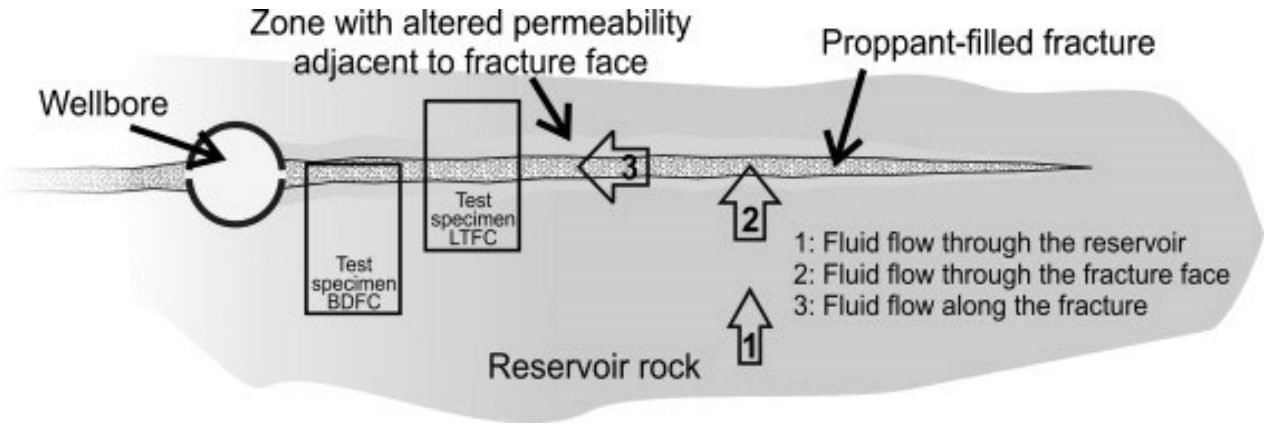

Figure 2 Hydraulic Stimulation of a Deep Sandstone Reservoir

Electromagnetic method are one of the method which is used for investigation and monitoring Enhanced Geothermal System. In the context of geo-technology project it is more appropriate for detecting the underground geothermal energy or carbon-dioxide (CO2) separation. In this, the design of survey greatly depends on the specific procedure that is used and the location is to be monitored properly. This will assist us to understand the particular behavior of electromagnetic fields and its complications in a three dimensional geological atmosphere. The hydrological perspective, geological characteristics and thermal resource is narrated by this method. In this the development of the current technique strongly depends on the rock electrical resistivity. It is seen that using a technique of time-lapse this method can keep an eye on the zone of stimulated fractured for deep geothermal energy. It is proved that for enhanced exploration, planning and monitoring assessment this realistic effective experiment is strong and cost effective. To most sites, framework and geophysical techniques this methodology is strongly applicable.

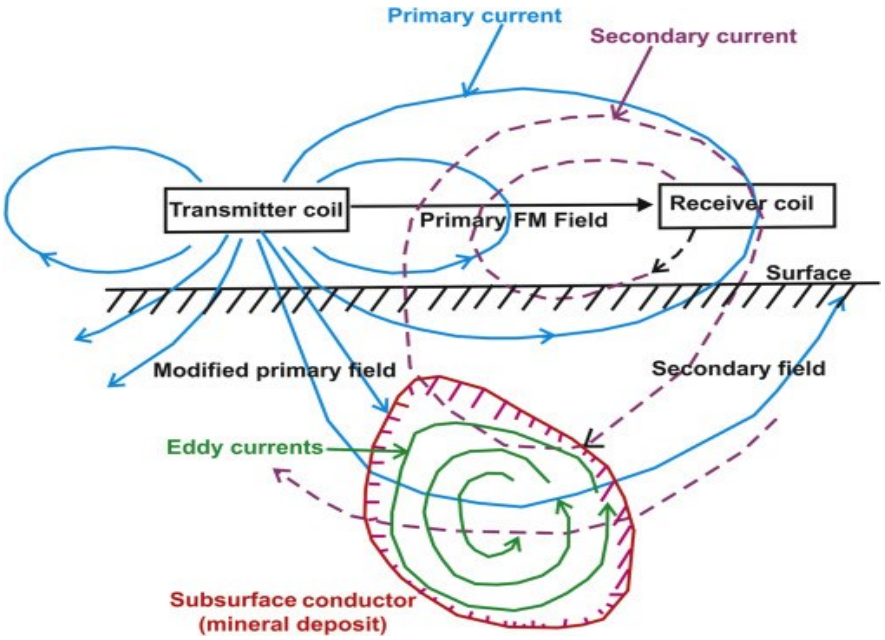

Figure 3 Electromagnetic Method for investigating and monitoring EGS

To improve the performance of Enhanced Geothermal System (EGS) for a long period of time Hybrid Optimization Approach is used. EGS reservoir holds a complex correlation between various frameworks with poly-phase action that makes the analysis and design of these system challenges. From the past years geothermal energy has been used, it is obtained from the natural hot springs and underground sources. To enhance well positions of a potential geothermal reservoir MARS (Multivariate Adaptive Regression Spline) based model were used. It was found that when dealing with the unpredictability of design variables a remarkable improvement was provided by MARS model. It was found that to gain a constructive system, Materialistic Enhanced Geothermal System should amalgamate both design and post design models. In order to gain optimal EGS design to calculate the influence of design variables, this methodology involves the Genetic Algorithm (GA) techniques and Finite Element (FE) analysis. To enhance performance and coherence of EGS reservoir this methodology is used which is based on the union of mass transfer FE procedure and coupled heat with a several aim GA. It was impossible to use conventional methods to get an optimum design as it is a complicated problem that includes various elements, with inter-connection between the factors and non-linear, non-trivial action. That's why there was a use of approach (techniques) i.e. the amalgamation of Finite Element (FE) investigation and improvement of Genetic Algorithm (GA). It was also seen that the production of greater thermal power is done by the greater liquid injection pressure, lesser distance between the production and injection wells, and greater permeability of a fractured zone.

In Enhanced Geothermal System, carbon-dioxide (CO2) is used as a working fluid. As there is a need to reduce CO2 emission, the concept of Hot Dry Rock (HDR) geothermal energy make use of supercritical CO2 in place of water as a fluid for heat conveyance and it would achieve storage of carbon-dioxide as an additional benefits . As CO2 has a capability to extract head from hot cracked rocks so CO2 is more superior to water. With respect to water well hydraulics it also gives some advantages, in that its greater compressibility and extension as collate to water that would increase buoyancy forces and would decrease the exploitative consumption of power of the circulation system of fluid. Into the fracture of hot rocks, injection of water can cause powerful dissolution and effect of precipitation that change permeability of fracture and make it very hard to utilize an EGS reservoir. For CO2 the ratio of density to viscosity is greater as compared to water and for these two fluids the condition of temperature and pressure is very different. Carbon-dioxide can be an alluring heat conveyance fluid not only for resource with greater temperature i.e. used for production of electricity, but it can even offer higher benefits for an immediate heat application of geothermal resource with lesser temperature.

4. CHALLENGES AND FUTURE SCOPE

For other different appellation such as Hot Wet Rocks (HWR), Hot Dry Rocks (HDR), Hot Fractured Rock (HFR), etc Enhanced Geothermal System is an Umbrella Term. At the depth the heat exchanger is the central piece for the insertion on an Enhanced Geothermal System (EGS). In order to be technically realistic and economically feasible it must have a number of properties. These mention the total surface of heat exchange, volume, the obstruction of flow, and the properties of thermal and stress-field. The main challenges faced is that, in EGS the heat exchanger that is needed, is situated several Km deep, so there is no other way to analyze and to make some changes in its properties by direct monitoring. So because of that, at wellhead based on the activity and interruption there is a need to install 'remote sensing' and 'remote control'. Some tools are provided to carry out such type of

performance i.e. to analyze data of underground well and their changes that occur with time HEX-B software is used to calculate in-field conditions from data of well head, to calculate and plan hydraulic stimulation the HEX-S software package is used mainly to detect advancement of distribution of permeability in time and place. Factor of regaining is the main (key) factor that can change with time period. This factor of recovery can be increased by the improvement in permeability but it can be decrease due to short circuit. The approximation of profit about manufacturing, installation, cost of maintenance remains uncorroborated without having experience of field scale. The geothermal energy future mainly depends on, up to what level geothermal power plant formation can move further. Provided that a strong commercial collaboration can take place, development of EGS can develop step further. In Enhanced Geothermal System, challenges are introduced by systems feasible operation, as a fractured that is opened recently can again get closed with decrease in the pressure of reservoir or due to the chemical interaction of liquids.

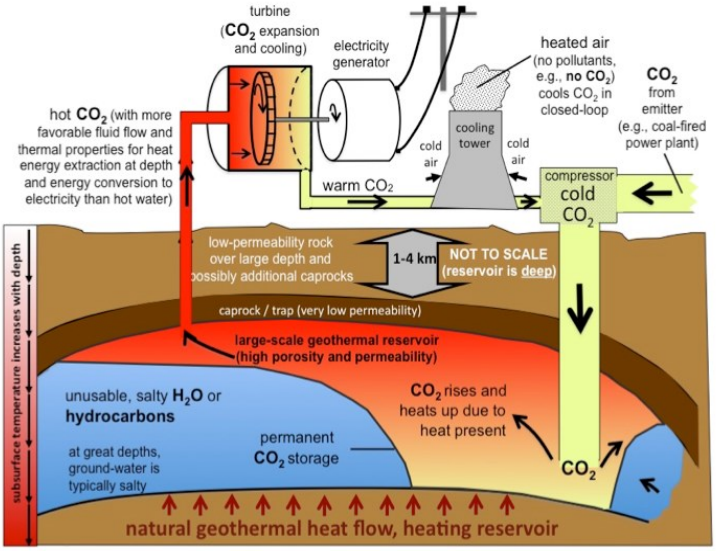

Figure 4 CO_2 as a Working Fluid in EGS

5. CONCLUSION

A huge possibility can be seen in Enhanced Geothermal System (EGS). EGS principle is simple: in the deep underground where the temperature is very high can produce electricity, an extended network of fractures is made to perform pathways for a new liquid and at the same period as an exchanger of heat. When operating a reservoir of EGS, the objective is to sustain the ratio of output of hot liquid at an appropriate level throughout the time for which the plant is developed. Developing a reservoir is a critical stage of the process of insertion, especially to develop a path that is required for the liquid to flow efficiently from the injection to production wells, hydraulic stimulation are taken. At Dholera geothermal site, to present the geothermal survey a large-scale activity of examination is carried out. To detect the water's chemical and physical properties geochemical detection of boiling water from hot spring at Dholera was carried out which was very useful to know about the nature of geothermal reservoir. To evaluate the underground gradient of geothermal, temperature log is used to drill the wells and to record the data. There is 85 percentage of probability that the EGS electricity production by the year 2050 will be 70 GWe and in the sector of Geothermal Science the Enhanced Geothermal System will become a new area.

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