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Applications of Geothermal Resources of Tapi Valley to Generate Electricity Using Binary Liquid Technology

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ABSTRACT

Tapi valley in the Maharashtra state, India hosts seven geothermal manifestations those are situated in between the southern foot hill margin of the Satpura hills and northern bank of the Tapi River. The belt of these hot springs extends over a length of 160 km and a width of 50-60 km in Dhule, Jalgaon and Nandurbar District of Maharashtra State, India. Thermal springs of this region are perennial; liquid dominated and discharge thermal water through either faults or dykes in the Deccan volcanic terrain at a constant rate through out the year. Regular observation indicates that one of these (Kundwa) releases gas bubbles. All of these are low to medium enthalpy springs with the surface temperature varying from $38^{\circ}$to 60°C, estimated reservoir temperature varying from 83^0C to 114^0 C and with a surface discharge rate of 10 l/min to 42 l/min (14400l\day to 60480l\day).

Thermal springs discharging water of low to medium enthalpy have been extensively tapped as non-conventional energy sources in many countries like New Zealand, United States of America, Iceland, China, Japan, United Kingdom and many other countries. India has yet to start utilisation of its geothermal energy resources as a substitute to the commercial energy resources. At present direct heat application is mainly for the purpose of promoting tourism by way of taking warm water bath to remove skin diseases, a number of other utilization have taken up on a small scale which includes space heating, poultry farming, green house cultivation, borax and sulphur extraction, cold storage, etc. but in the light of electricity generation plant installed at Lightning Dock near Animas, the new plant will incorporate an innovative binary liquid technology that allows it to make use of the site's low levels of geothermal energy (165^0f or 74 ^{0}c). Therefore, in order to establish the feasibility of electricity generation, by binary liquid technology, from the thermal spring water of Tapi Valley of Maharashtra State has been evaluated in this paper.

1. INTRODUCTION

Tapi valley in the Maharashtra state hosts seven geothermal manifestations those are situated in between the southern foot hill margin of the Satpura hills and northern bank of the Tapi River. The belt of these hot springs extends over a length of 160 km and a width of 50-60 km in Dhule, Jalgaon and Nandurbar District of Maharashtra State. Thermal springs of this region are perennial; liquid dominated and discharge thermal water through either faults or dykes in the Deccan volcanic terrain at a constant rate through out the year. Regular observation indicates that one of these (Kundwa) releases gas bubbles. All of these are low to medium enthalpy springs with the surface temperature varying from $38^{\circ}$to 60°C and with a discharge rate of 10 l/min to 42 l/min (14400l\day to 60480l\day).

Thermal springs discharging water of low to medium enthalpy have been extensively tapped as non-conventional energy sources in many countries like New Zealand, United States of America, Iceland, China, Japan, United Kingdom and many other countries. India has yet to start utilisation of its geothermal energy resources as a substitute to the commercial energy resources. At present direct heat application is mainly for the purpose of promoting tourism by way of taking warm water bath to remove skin diseases, a number of other utilization have taken up on a small scale which includes space heating, poultry farming, green house cultivation, borax and sulphur extraction, cold storage, etc. Therefore, in order to establish the feasibility of direct heat applications of thermal spring water of Tapi Valley of Maharashtra State has been evaluated in this paper.

2. GEOTHERMAL SCENARIO OF INDIA:

There is wide scope of geothermal energy and is a lot of thermal manifestations world over. The main countries where the major work has been done are: New Zealand, Iceland, Italy, Japan, United States of America, Russia, and Britain. These countries are exploiting their thermal resources for electricity generation and direct applications successfully. As early as in 1862 Schlaginwelt compiled a list of 99 thermal manifestations in India. Later, Oldham and Oldham (1882) gave a comprehensive account of the location of the thermal springs of India. Geothermal manifestations appear on the surface in the form of hot-springs which are wide spread in India. Geothermal fields of India can be grouped in the following regions:

2.1 Himalayan Region

In the Himalayan region majority of geothermal manifestations are closely associated with the main faults and thrusts of the subduction/collision zone. Manifestations of this region are suitable for both direct and indirect uses.

2.2 Sohana

Geothermal activity in Sohana valley is manifested by hot springs emerging through Precambrian rocks of Ajabgarh group of Delhi super group. Prominent geothermal manifestations of this region are associated with Delhi mobile belt. Manifestations of this region are suitable for direct use.

2.3 Sonata

In this belt several geothermal manifestations are found. Tattapani is the most promising geothermal manifestation in this belt. The hot springs of this field are discharging water at varying temperatures of 52^0c to 97^0 c. The hot springs of Tapi region covered in the present study, however, are confined to the Tapi lineament, which is a part of Son- Narmada–Tapi (SONATA) rift system.

2.4 West coast of India:

Geothermal manifestations of this belt extend from Cambay graben in the northern and eastern part of Mumbai off-shore to Konkan coast in the south. These manifestations are mostly associated with rifted part of peninsular India. Godavari and Mahanadi are also promising geothermal fields in India. The important sites being explored in India are shown in the map of India

Major geothermal energy resources in India

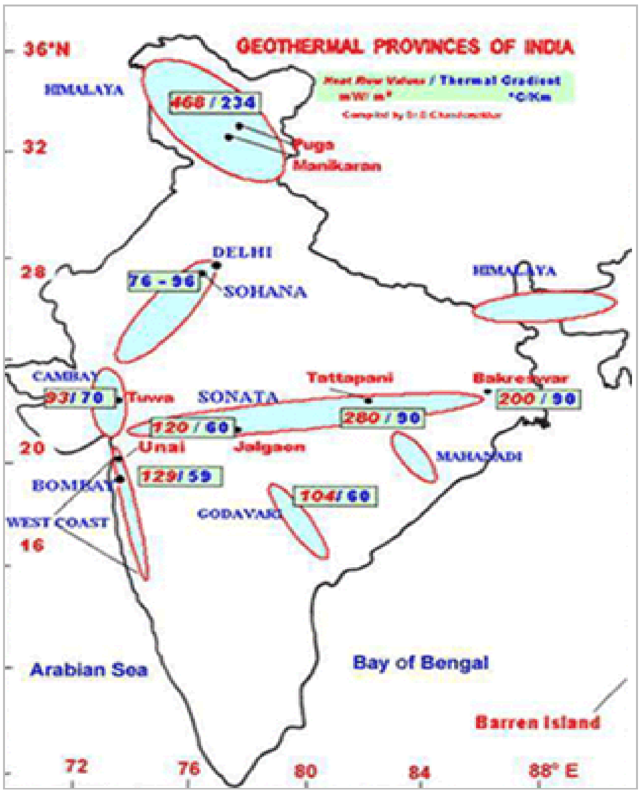

Figure 1

3. GEOTHERMAL ANIFESTATIONS IN TAPI VALLEY:

Tapi valley of Dhule, Nandurbar and Jalgaon district of Maharashtra hosts seven geothermal manifestations. These are located along dolerite dykes and more or less aligned along the southern foothills of Satpura ranges (Northern-valley slope of Tapi extending over a length of 160 km and associated with Tapi–lineament) at an average elevation of 230m from mean Sea level. (Figure 2) These dykes / faults and sets of fractures through which geothermal manifestation emerges are oriented almost parallel to the Tapi valley or Tapi lineament. Geologically all of these are confined within Deccan traps. Thermal springs of this region are perennial; liquid dominated and discharge thermal water through either faults or dykes in the Deccan volcanic terrain at a constant rate through out the year. Regular observation indicates that one of these (Kundwa) releases gas bubbles. All of these are low to medium enthalpy springs with the surface temperature varying from 38°to 60°C and with a discharge rate of 10 l/min to 42 l/min (14400l\day to 60480l\day) (Table 1).

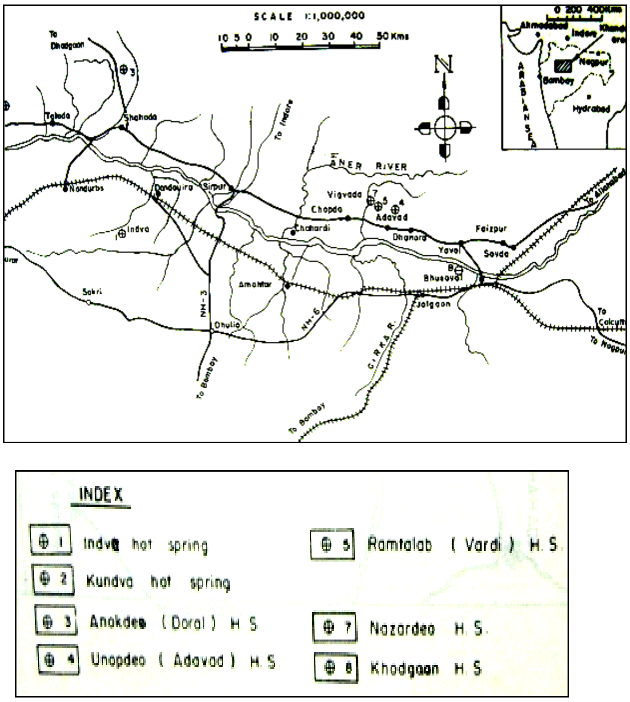

Figure 2: Locations of thermal springs in tapi valley Maharashtra

Table 1

Thermal spring	Discharge rate (lpm)	Discharge temp (^{0}c)	Estimated temp (^{0}c)
Kundwa	25	44	90
Anakdeo	42	45	108
Unabdeo	38	60	130
Ramtalab	24	40	102
Nazardeo	16	40	105
Indave	30	41	100
Khadgaon	10	38	112

4. GEOLOGICAL SET UP OF TAPI VALLEY REGION:

General regional geology of the area between Tapi and Narmada River valley consists mainly of basalts. Thermal springs of Tapi valley are located in the Deccan volcanic terrain. The alluvial deposits are also found in this region. Three thermal manifestations of Dhule and Nandurbar district are controlled by dykes, whereas, all the four thermal manifestations of Jalgaon district are discharging water through faults or other weaker planes. (Fig - 3)

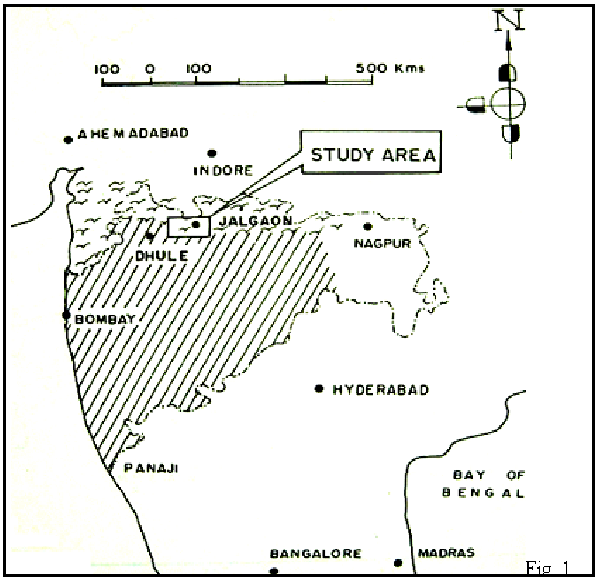

Figure 3: Regional geological map of Tapi valley

Table 2: Installed Geothermal Generating Capacities Worldwide

Country	1995 (MWe)	2000 (MWe)	Country	1995 (MWe)	2000 (MWe)
United States	2,817	2,228	Kenya	45	45
Philippines	1,227	1,909	Guatemala	33	33
Italy	632	785	China	29	29
Mexico	753	755	Russia	11	23
Indonesia	310	590	Turkey	20	20
Japan	414	547	Portugal	5	16
New Zealand	286	437	Ethiopia	0	8
Iceland	50	170	France	4	4
El Salvador	105	161	Thailand	0.3	0.3
Costa Rica	55	142	Australia	0.2	0.2
Nicaragua	70	70	Argentina	0.7	0
Total (MW)				6,833	7,974

Table 3

Direct uses of geothermal energy sources

(Lindal diagram)

^{0}C Use

200 –

190—

180--- Evaporation of highly concentrated

5. UTILIZATION OF GEOTHERMAL ENERGY:

Many countries have profitably used this energy as an alternative source for conservation of oil, electricity, and fossil fuels. The experience gained by United State of America (USA), Russia, Iceland, Indonesia, Italy, France, New Zealand, Japan etc., in this respect is quite illustrative. About 8,000 megawatts (MW) of geothermal electricity are currently produced around the world. Worldwide status of electricity generation and direct uses of geothermal energy sources are summarized in tables 2 and 3 respectively.

Refrigeration by ammonium absorption

Digestion of paper pulp (Kraft)

170--- Heavy water via hydrogen sulphide process

Drying of diatomaceous earth

160--- Drying of fish meal

Drying of timber

150--- Alumina via Bayerm's process

140--- Drying farm products at high rates

Canning food

130--- Evaporation in sugar refining

Extraction of salts by evaporation and crystallization

Fresh water distillation

120--- Most multi-effect evaporation

Concentration of saline solution

110--- Drying and curing of light aggregate cement slabs

100--- Drying of organic materials, seaweeds, grass, vegetables etc.

Washing and drying of wool

90--- Drying of stock fish

Intense de-icing process

80--- Space heating heating (building and greenhouses)

70--- Refrigeration (lower temperature limit)

60--- Animal husbandry

50--- Mushroom growing

Balenology

40--- Soil warming

30--- Swimming pools, biodegradation, fermentations

Warm water for year round mining in cold climates

De-icing

20--- Hatching of fish, Fish farming

6. DIRECT HEAT UTILIZATION OF GEOTHERMAL ENERGY SYSTEM IN INDIA:

Geothermal energy sources in India are used for various purposes as mentioned below:

(i) Tourism Purposes-

a. Hot-baths at Basist and Manikaran (Himachal Pradesh).

b. Space-heating of small huts at Puga valley (Jammu and Kashmir), and Parvati

valley (Himachal Pradesh).

(ii) Mineral water tapping at Bakreshwar (Himachal Pradesh).

(iii) Extraction of borax at Puga valley.

(iv) Green house cultivation at Chumathang, Ladakh.

(v) Cold storage plant at Manikaran.

(vi) Mashroom cultivation and Poultry farming at Puga valley.

7. POSSIBLE DIRECT HEAT UTILIZATION OF GEOTHERMAL ENERGY IN TAPI VALLEY:

Study reveals that the reservoir temperature of Tapi geothermal systems ranges from 100^o to120^o C by different methods (table - 1). If the hot water is tapped at 3 km depth and the assumed loss in temperature is not more than 0.1^oC/km (as per a case study conducted in Aukland), the Tapi valley thermal springs should be able to yield water 100^o-120^oC at the surface for the generation of electricity using binary liquid technology. The hot springs of Tapi valley can be used for the various direct uses as discussed below:

7.1 Cold storage plants:

The reservoir temperature is estimated in the range of 83° to 133°C at thermal springs of Tapi valley. The discharge temperature of geothermal water is required for installation of cold storage at any site is 90°C. This temperature is available in most of the thermal springs of this area. The hot springs of Tapi valley are suitable for cold storage plants, for performing of such a unit only 90°C discharge temperature of water is required.

Anakdeo, Unabdeo, Ramtalab, and Nazardeo hot springs are the best suited for installation of cold storage plants. Shahada and Chopda are the Taluka places near these thermal springs where the production of crops such as potatoes, bananas, pomegranates etc. are the main crops. If cold storage facility is provided these crops may yield better values in monitory terms in off-seasons.

7.2 Green house cultivation:

Water temperature in between 70^oc and 80^oc is required for the cultivation of vegetable, fruit etc. in green houses. In geothermal manifestations of this area the required temperature and discharge of water is suitable for this purpose.

7.3 Poultry farming:

Poultry farming and hatching needs water temperature of 50° to 60°C, which is available at almost all hot springs of this area. Water at 50°–60°C temperature can also be made available to ‘cold-storages.’

7.4 Dehydration of vegetables:

Geothermal water of this area may be utilized for dehydration of vegetables in a heat exchanger that dehydrates onion (83% moisture) and banana (4% moisture), which are the main crops of the area.

7.5 Bio-fertilizers:

A range of temperature varying from 50° to 60°C is required for the manure processing which will be available after various direct uses as mentioned above in the different thermal springs of the area. The locally available waste products of banana and onion can be utilized for the production of bio-fertilizer.

7.6 Mineral water:

Thermal water to be used for bottling as mineral water from different hot springs of the area should be chemically safe and free from undesirable elements.

8. GEOTHERMAL POWER PLANTS

Three types of geothermal power plants are in operational in the world these are as follows:

8.1 Dry steam plant:

This type of geothermal plant uses piped steam, having temperature more than 235 ^{0} c, directly from a geothermal reservoir to rotate the generator turbines. Tuscany, Italy was the first place where first geothermal power plant was built in 1904.

8.2 Flash steam plants

Flash steam geothermal power plant uses hot water more than 182 ºC from the geothermal reservoir.[15] When the water is pumped to the generator, it is released from the pressure of the deep reservoir. The sudden drop in pressure causes some of the water to vaporize to steam, which rotates a turbine to generate electricity. Both dry steam and flash steam power plants emit small amounts of carbon dioxide, nitric oxide, and sulfur, but generally 50 times less than traditional fossil-fuel power plants.[16] Hot water not flashed into steam is returned to the geothermal reservoir through injection wells. Figure 3 is a schematic of a typical flash steam power plant.[17]

8.3 Binary power plant

Binary-cycle power plant uses moderate-temperature water in between 107 ºC–182 ºC from the geothermal reservoir. In binary systems, hot geothermal fluids are passed through one side of a heat exchanger to heat a working fluid in a separate adjacent pipe. The working fluid usually is an organic compound with a low boiling point such as Iso-butane or Iso-pentane, is vaporized and passed through a turbine to generate electricity. An ammonia-water working fluid is also used in what is known as the Kalina Cycle. Makers claim that the Kalina Cycle system boosts geothermal plant efficiency by 20–40 percent and reduces plant construction costs by 20–30 percent, thereby lowering the cost of geothermal power generation. Now a days innovative binary liquid technologies are available that allows it to make use of the low levels of geothermal energy (**165^0f or 74 ^{0}c**) to generate electricity.

9. DISCUSSION AND CONCLUSION

Observation reveals that geothermal manifestations from Tapi valley region of India discharging water at constant rate throughout the year on the surface. The discharging temperature also remains constant for all the manifestations in the region. Geothermal gradient in this region is three times higher than that of global average. This area falls in the zone II (100-180 mw/m^2) heat flow values (Ravishankar, 1988). The reservoir temperatures of these springs were estimated by chemical geothermometers. The result shows reservoir temperature of about 100^0c for Kundwa and 120^0c for Unabdeo. Since none of these springs show evidence of salinity these results using conventional geothermometers may be considered true. Considering the issuing temperature, discharge rate and estimated reservoir temperature the thermal springs of Tapi valley can be used for the generation of electricity using binary liquid technology which allows it to make use of the low levels of geothermal energy (**165^0f or 74 ^{0}c**) to generate electricity.

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