ELECTRICITY GENERATION THROUGH OIL AND GAS WELLS AT KANDHKOT GAS FIELD POWERING TO LOCAL COMMUNITIES.

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ABSTRACT: *World energy demand is increasing and non-renewable resources are decreasing by exponentially putting a huge burden on the energy sector specifically on the oil and gas industry. To overcome these challenges, renewable energy is the best option with production optimization in the oil and gas sector. However, among all renewable energies, geothermal is the most suitable energy due to its sustainability and presence around the clock. Moreover, there are three types of wells for harnessing geothermal energy such as: producing oil and gas well, abandoned oil & gas wells and geo-pressured brine well with dissolved gas. In this research study, the author's considers the technical aspects of electricity generation through oil and gas wells. The power capacity of these wells is determined by the production rate of the well mass flow (m) and temperature (T) of these wells. The main factors that control the wellhead temperature are mass flow rate and formation temperature. Our assessment of gas-producing well in the Kandhkot region showed the wellhead temperature of the produced fluid is too low, compared to ambient temperature for commercial generation of geothermal power. In our work, a conceptual design system to produce power from produced gas by using Solid Works Software is proposed and we have found some positive results. Seven well from the Kandhkot gas field were selected with different mass flow rates and negligible wellhead temperature difference. Author's found the minimum power net output 21kW at the gas mass flow rate of 0.098504 kg/s with 7.5% thermal efficiency and maximum net output 27.5 kW at gas mass flow rate of 4.102524 kg/s with 10% thermal efficiency. The overall net output power produced from seven well is 174kW and can supply to local communities.*

Keywords: Binary cycle power plant, geothermal energy, oil & gas wells and producing wells

INTRODUCTION

The world is facing challenges in the energy sector, due to increase in world energy demand. And decrease conventional resources. At that point that the demand of energy can be alleviated via renewable energy sources. Renewable energy section deals as single element in terms of a combination of different primary energy sources to come across these energy challenges [1]. According to the international energy agency (IEA), the half of the entire development of overall energy in a worldwide generation could be attained with a sustainable energy source over the time 2040 [2]. Several techniques such as hydropower, geothermal, wind, and solar photovoltaic (PV) are projected to gain momentum in the future energy supply. PV and wind energy are expanding their involvement in world primary energy, according to IEA and these nonstop innovative solutions development is required in order to contribute world energy [2]. Among all these solutions the geothermal energy is contributing in all day at present. The geothermal technique offers a constant base load nature generation, and the adjustable outcome obtained from solar photovoltaic (PV) and wind energy and it is declared as a potential factor of future of energy, mainly in terms of suitability, in industrialized and non-industrialized regions [3]. The geothermal energy resources fluctuate from location to location depending upon the various temperature ranges at that location including (a) lower (>90°C), (b) modest (more than 90°C>150°C), and (c) higher (<150°C) [4]. The type and design of geothermal plant varied with the temperature range of hot fluid, some geothermal plants are used for power generation in particular flash steam power plant, dry steam power plant and Binary cycle power plant. Geothermal Power Plant (GPP) consists of the machines for collecting, treating, hot fluid to the power plant and electric energy generation process contains transformer, generator, turbine, steam manifold, and re-injection system for condensed water into a geothermal well (W) [5]. Binary cycle geothermal power plants are designed to have less temperature (T). Hot fluid heat up binary working fluid having low boiling temperature commonly organic compounds in the heat exchanger. Due to the low boiling temperature, organic compound is converted into steam. That steam rotates the turbine and generates electrical energy output. Fluids used in the binary cycle power plant are:

- Geothermal fluid extracted from the geothermal reservoir.
- Working fluid commonly refrigerant having less BP [5].

Pakistan has bundles of a geothermal reservoir having hot water within them [6]. Therefore, a hot fluid commonly known as geothermal fluid and it is suitable for binary cycle power plant and further it can be used to convert the binary fluid into steam for generating electric power in Pakistan. In the USA, comparable technology is used for generating electric power from hot water geothermal [7]. Usually, GE has been essential to exploit the geothermal water present in the earth's crust for creating energy. Unusual generation of geothermal energy is a substitute access to hot fluids for generation of electric power from geothermal and it gives a new pace to researchers. Now researchers are focusing to harvest electrical energy using hot reservoir fluids which are produced in oil and gas well through application of geothermal technique [8-11]. The main aim of this work is to model a simple binary cycle power plant in which electric power can be generated using geothermal energy through the process of producing as well as abundant oil & gas wells by thermal energy potential. This approach will allow generation of geothermal energy in locations with existing wellbores but in the occurrence of flowing reservoir fluid. Through this technique, a large amount of power can be produced by utilizing flowing fluid during the oil and gas production from the oil and gas wells. This will contribute to revenue generation of that company and can fulfill the power requirement of plant present over there.

There are several techniques are used to extract the geothermal energy from the earth's subsurface.**(a)** dry-steam power plant use for the production of power from thermal energy .It is a vapor dominant system and utilize dry steam directly into the turbine[12]. High enthalpy (h) geothermal systems temperature greater than 200 ^{0}C is the sources of dry steam. **(b)** flash steam power stations is used for geothermal energy extraction from wells having water with high temperature (T) and pressure (P) and it is picked to a lower pressure areas, this shifting of pressure vaporize water and steam emits out pressure to heat up fluid which runs the turbine. **(c)** single-flash steam power plant is usually installed at high temperature geothermal areas. These geothermal wells produce mixture of hot water and steam. The single-flash steam power plant is a relatively simple method to convert the geothermal energy into electric energy. Firstly the mixture is separated into liquid phase distinct steam with minimum pressure loss. The separator arrangement is an important part of the general design of the plant and there are several possible arrangements. After the separation of hot water and steam, separated steam directly goes into turbine. **(d)** double-flash steam power plant is installed at high temperature geothermal areas. The double flash steam plant is an improvement on the single-flash design. It can produce 15-25% more power output for the same geothermal fluid properties. The fundamental feature of double flash system is that the separated liquid is used to produce additional steam at lower pressure. Separated and additional steam both enters to turbine. Binary cycle power plant is recent and widely used technique for power production form low temperature wells. Uses low temperature geothermal fluid about 58 ^{0}C to heat the organic fluid of lower boiling point and turns turbines to generate electricity. In binary cycle power plant close cycles is used to generate power from hot fluid. One main type of binary cycle is Rankine cycle which is classified into many categories such as water Rankine, organic Rankine, and other multi-fluids cycles. The working fluids for the Rankine cycle are composed of water, organic fluids of different kinds, or mixture of multi-fluids or binary fluids. The Organic Rankine Cycle uses refrigerants or other organic working fluids with low boiling points as working fluid is widely used in power production technique from a wide range of low and medium temperature heat sources including geothermal, solar thermal, ocean thermal and industrial waste heat [13]. The selection of working fluid is based on the temperature of the heat sources, Based on the temperature of the reservoir [14].

ORGANIC RANKINE CYCLE PROPOSED MODEL

The conversion cycle of thermal energy into mechanical energy and thus mechanical energy into electrical energy is called organic rankine cycle, it utilize organic fluid of high molecular weight with low boiling temperature in rankine cycle. The phase change temperature of these fluids is lower than the water cycle one. This feature of organic rankine cycle allows producing electric energy from medium and low temperature heat sources. The basic components of organic rankine cycle are heat exchanger, turbine, pump and condenser. In order to overcome the expanses of well drilling oil and gas wells are proposed for harvesting geothermal energy. Proposed technique seen in Fig. 1 can be utilizes the heat of oil and gas wells for the generation of electricity to reduce the economic burden and meet power consumption even to supply power for local communities.

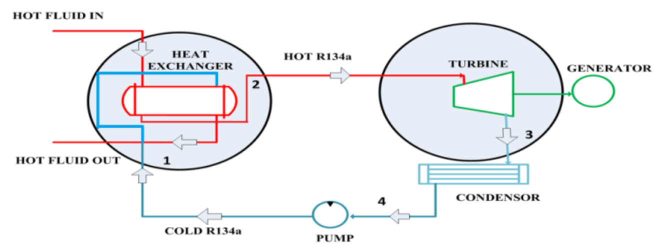

Fig.1: **Organic rankine cycle proposed model Layout.**

Hot fluid produced from the producing well and goes directly into heat exchanger where R-134a binary fluid is present commonly organic compound which vaporize and convert into steam as a heat of fluid passed in heat exchanger. Then steam of binary fluid will rotate the turbine blades which then operate the generator and produces electricity. As binary fluid passes through the turbine then start to condense in liquid form in the condenser. While the reservoir fluid goes to separator where oil, gas and water become separate and for the proposed model the system properties of fluid R-134a can be seen in Table 1

Table 1: Properties of R-134a

Properties	R-134a
Boiling point	-14.9 ^{0}F or -26 ^{0}C
Auto ignition temperature	1418 ^{0}F or 770 ^{0}C
Critical temperature	252 ^{0}F or 122 ^{0}C
Ozone depletion level	0
Solubility in water	0.11% by weight at 25 ^{0}C
Global warming potential	1200

System Modeling

In solid works design 3D model of the heat exchanger is drawn shown in Fig. 2. The copper is selected as material for shell and tube heat exchanger due to its good properties. It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity.

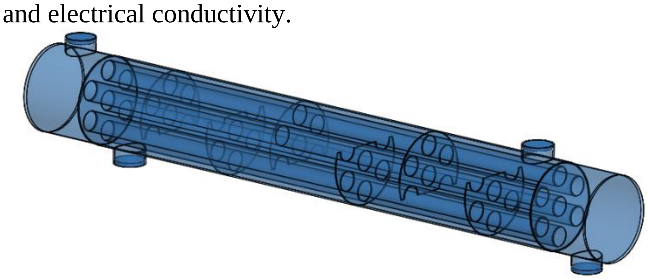

Fig. 2**: 3D View of copper made heat exchanger.**

Model is divided into several numbers of nodes and elements by applying core mashing for the better simulation run. However, designed system is analyzed and simulated through solid works software shown in Fig. 3. Numerical iterations are performed in this section till acceptable solution obtained. Boundary conditions for the model are given in Table. 2.

Table 2: Boundary Conditions for Heat Exchanger

W	m_{in} (NG) [kg/s]	T (NG) [^{0}C]	m_{in} (R134a) [kg/s]	T (R134a) [^{0}C]
1	0.098504	73.85	1	-36.15
2	0.517840	73.85	1	-36.15
3	1.137514	73.85	1	-36.15
4	1.885411	73.85	1	-36.15
5	2.299828	73.85	1	-36.15
6	2.854555	73.85	1	-36.15
7	4.102524	73.85	1	-36.15

***Fig. 3*: Temperature cut plots in Heat Exchanger.**

SYSTEM ENERGY ANALYSIS

Following assumptions were made during energy analysis of binary cycle:

a) Components of basic binary cycle heat exchanger, turbine, condenser and pump are steady flow devices and can be analyzed as steady flow processes.
b) The kinetic and potential energy changes small relative to work and heat transfer are usually neglected.
c) The heat exchanger does not involve any work, and therefore turbine and pumps assumed to be isentropic.
d) Heat exchanger assumed to be insulated no loss of heat and all heat transfer in between the gas and binary working fluid R134a.

The basic thermodynamics processes of Binary Cycle are presented by the equations (1) to (6).

The heat transferred to the working fluid in the heat exchanger is

$$Qe = m_{NG}(h_{S1} - h_{S2}) = m_{R134a}(h_2 - h_1) =$$

.

$$m_{NG}Cp_{NG}(T_{S1} - T_{S2}) \quad (1)$$

The work of the turbine (W_T) is

$$W_T = m_{R134a}(h_2 - h_3) = m_{R134a}\eta_t(h_2 - h_{3s}) \quad (2)$$

The heat transfer in the condenser is given by

$$Qc = m_{cw}(h_{CW3} - h_{CW1}) = m_{R134a}(h_3 - h_4) \quad (3)$$

The work of the pump can be calculated as follows

$$W_p = m_{R134a}(h_1 - h_4) = m_{R134a}\eta_t(h_1 - h_{4s}) \quad (4)$$

The work net output is

$$W_{net} = W_T - W_p \quad (5)$$

The thermal efficiency is

$$n_{th} = \frac{W_{net}}{Q_e} = \frac{(W_T - W_p)}{Q_e} \quad (6)$$

RESULTS AND DISCUSSION

The fundamental purpose of this research is to model and simulate shell and tube heat exchanger and perform thermodynamic analysis of organic rankine cycle such as heat exchanger inlet mass flow rate (m_{in}) and temperature (T). The effect of these parameters on turbine inlet temperature, net output and thermal efficiency is examined. Thermodynamic assessment of R134a under varying condition of turbine inlet temperature is carried out using energy analysis equations (1-6). R134a used in the system was in liquid state at the heat exchanger inlet and no need of preheating due to its low boiling temperature. Input parameter for the heat exchanger simulation is given in Table 2. Values shown in the table 3 are inlet parameters and outlets parameters of turbine. Seven dry gas wells were studied and assumed as geothermal wells for the numerical analysis. These wells have different mas flow rate and pressure but temperature is considered as average temperature keeping in view the region as one unit. While, mass flow rate of R134a is same for all wells.

Analysis shows the impact of mass flow rate of natural gas (NG). It is observed form Fig.4 that increasing mass flow rate of natural gas increase the turbine inlet temperature values, mass flow rate has directly impact on heat transfer rate. At minimum mass flow rate of 0.09834 kg/s temperature obtained at turbine inlet is 29.57 ^{0}C and at maximum mas flow rate of 4.02 kg/s obtained turbine inlet temperature is 36.04 ^{0}C

Table 3: Inlet and Outlet Parameters of Turbine

W	m(R134a) [kg/s]	T_2 [^{0}C]	P_2 [MPa]	T_3 [^{0}C]	P_3 [MPa]	h_2 [KJ/kg]	h_3 [KJ/kg]	W_T [kW]
1	1	29.57	0.105	-10	0.06	280.0	249	31.0
2	1	32.16	0.105	-10	0.06	282.0	249	33.0
3	1	33.70	0.105	-10	0.06	284.0	249	35.0
4	1	34.44	0.105	-10	0.06	284.5	249	35.5
5	1	35.30	0.105	-10	0.06	285.0	249	36.0
6	1	35.60	0.105	-10	0.06	285.5	249	36.5
7	1	36.04	0.105	-10	0.06	286.0	249	37.0

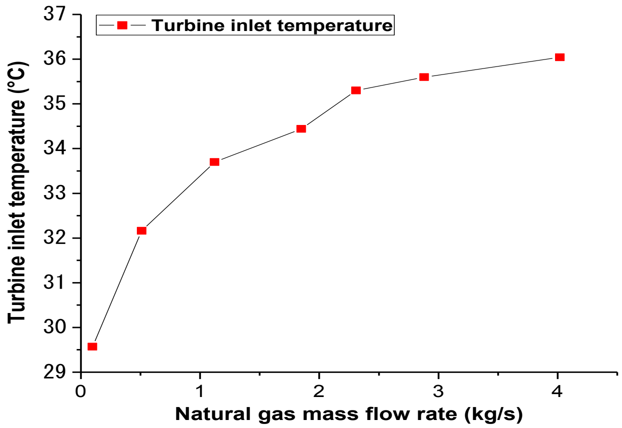

Fig. 4:**Geothermal natural gas mass flow rates Vs turbine inlet temperature.**

This analysis is based on assumption that the working fluid enters into the turbine is at saturated condition and the condensation temperature is kept -10 ^{0}C. Variation in turbine work output with increase in turbine inlet temperature is observed in **Fig. 5**. The turbine workoutput is increasing from 31 kW to 37.5 kW by increases temperature at turbine inlet from 29.26 ^{0}C to 36.04 ^{0}C.

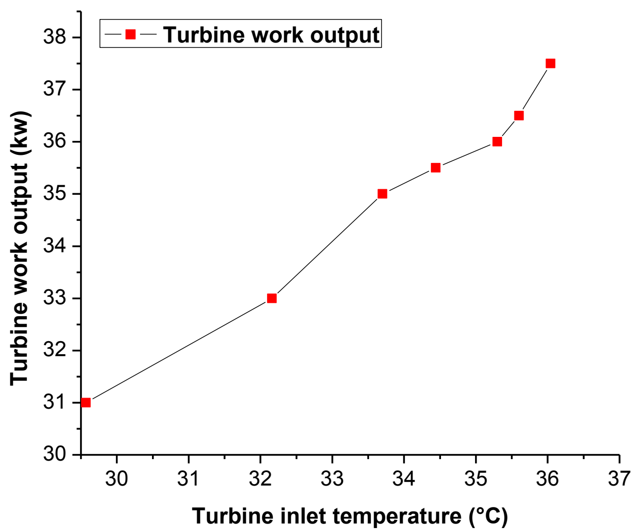

Fig. 5: **Turbine inlet temperature Vs turbine output.**

It is observed from the simulation that mass flow rate of primary fluid will have direct impact on heat transfer rate and temperature Relationship between natural gas mass flow rate in heat exchanger and turbine work output is depicts in **Fig. 6**. The graph in increasing trend shows the increase in turbine work output by increasing the natural gas mass flow rate in heat exchanger. At 0.09834 kg/s mass flow rate the output obtained is 31kW by increasing the mass flow rate up to 4.02 kg/s the output obtained is 37.5 kW.

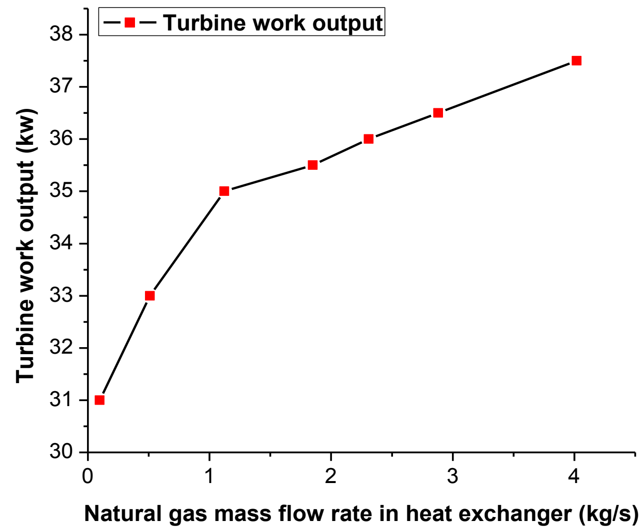

Fig. 6**: Natural gas mass flow rate in heat exchanger Vs turbine output.**

This graph shows relationship between natural gas well mass flow rate Vs net power of turbine and thermal efficiency of plant. The trends of graph shown in **Fig. 7** shows increasing value of natural gas well mass flow rate which is dependent on the pressure of primary fluid causes the net power produced by turbine and the thermal efficiency increases. The maximum net power produced from turbine is 27 kW and maximum thermal efficiency is 10% at maximum natural gas well mass flow rate of 4.02 kg/s.

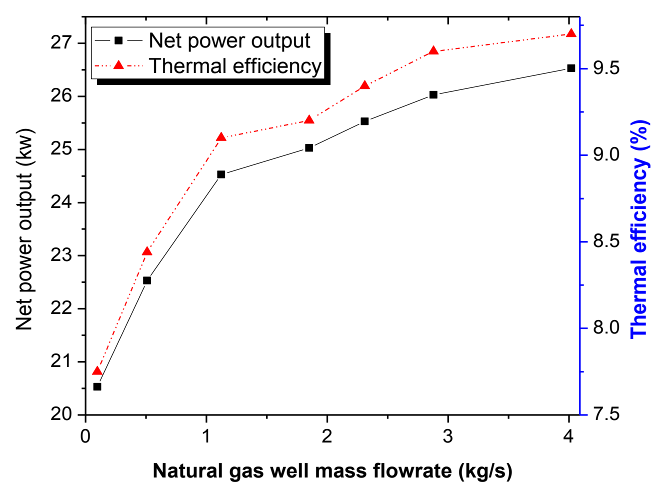

Fig.7**: Natural gas well mass flow rate Vs net power output and thermal efficiency.**

Direct relationship between geothermal natural gas well and the power produced from each well at average flowing temperature and different pressure is shown in **Fig. 8**. Well # '1' having minimum mass flow rate and average reservoir temperature of 73.85 ^{0}C produced 21 kW power and well #. '7' having maximum mass flow rate and same temperature produces 27 kW of net power.

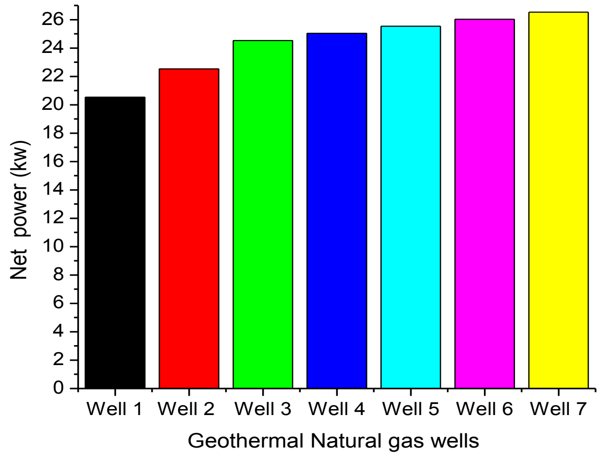

***Fig.8*: Geothermal natural gas well and net power from each well.**

CONCLUSION AND FUTURERECOMMENDATIONS

In this research work, authors introduced a novel approach based on binary cycle power plant for oil & gas wells as geothermal well. It is further concluded that:

- Shortage of energy and economical burden on oil and gas industry can be minimized by implementing this technique.
- The technique use hot natural gas form well to generate electricity.
- Power of 37.5 kW could be generated using natural gas as hot fluid with mass flow rate of 4.02 kg/s
- Increasing mass flow rate causes increase in working fluid temperature but also increase power output.
- Overall gross power production from seven well is 244 kW and Net power is 174 kW at temperature of 73.85 ^{0}C at varying mass flow rates of different wells.

Finally, the future recommendations for power productions can be described as follows:

- Proper selection of binary fluid.
- To select gas wells with high temperature and mass flow rate
- Producing oil and gas wells with thermal potential
- Abandoned oil & gas wells with thermal potential.

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