Technical Feasible Study for Future Solar Thermal Steam Power Station in Malaysia

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Abstract. This paper proposed renewable energy which is potential to be used in Malaysia in generating electricity to innovate and improve current operating systems. Thermal and water act as the resources to replace limited fossil fuels such as coal which is still widely used in energy production nowadays. Thermal is also known as the heat energy while the water absorbs energy from the thermal to produce steam energy. By combining both of the sources, it is known as thermal steam renewable energy. The targeted area to build this power station has constant high temperature and low humidity which can maximize the efficiency of generating power.

1. Introduction
Electricity is one of the main things that are needed in human’s daily life [1, 2]. In the era of technologies, experts from related fields are working together to invent or to find out more ways to generate electricity instead of burning limited fossil fuel such as coal, natural gas and oil [3, 4, 5]. Renewable energy is in a form of source that continuously replenished when it is used for a long term such as the wind, hydro, biomass and solar power. These sources are required because a generator needs the energy to rotate the blade or turbine to generate electricity. In peninsular Malaysia, most of the power stations produce electricity from fossil fuels. Fossil fuel produces a huge amount of CO2 emission. Thermal steam power plant station is a power plant which converts heat energy to mechanical energy to electrical power. The research works covered the estimated cost of the project, type of fluid used to produce steam energy, the design of power plant, the design of turbine, total power that can be generated and location. The idea of developing potential renewable energy is required to overcome the problem of using limited natural resources such as burning fossil fuels to generate electricity because it is not continuously replenished once they are finished. To help in the growth of technology and economy of the country, a new idea of inventing a low cost and high efficiency of power plants are required as well [2, 5].

2. Methodology
Figure 1 shows a block diagram of the research process involved in this project.
Figure 1. Research Processes

The parts that involved in the power plant project are heliostats, receiver, thermal energy storage tanks, air cooled condenser, steam generator, turbine and generator as Figure 2.

Figure 2. Design of thermal steam power plant

2.1 Heliostat
The heliostat is also known as power towers which are defined as an apparatus containing a movable or driven mirror which is used to reflect light to a fixed direction [6,7,8]. It shaped like a flat mirror which helps in sun tracking and focuses sunlight onto a receiver at the top of a tall tower. The heliostats are computer-controlled mirrors; it makes a small adjustment to position the mirror in order to keep the sunlight on the target as the sun moves across the sky. It is used for the production of concentrated solar power to generate electricity [4]. The design for heliostat’s reflective components uses a second surface mirror which consists of a steel structural support, an adhesive layer, a protective copper layer, reflective silver and a top protective layer of thick glass to reflect sunlight fully.

2.2 Center Receiver Plant
The Center Receiver Plant is a type of solar furnace which is used a tower to receive the focused light from heliostats which are placed below it. The function of the receiver is to transform concentrated radiation into heat by transferring it to a fluid where water is chosen in this renewable energy proposal. Materials that will be used to build center receiver plant and heat pipe are by using copper [9]. The characteristic of copper is durable, corrosion-resistant, and strong and has a high melting point. Besides, copper also has a high thermal conductivity which is 394W/(mK). Heat transfers rapidly throughout the atoms in copper. Although silver has a higher thermal conductivity compared to copper in the aspect of price, silver cost much more which will then overall increased the cost of the project. Technology and absorber material of center receiver plant in concentrating solar power (CSP) system is capable of generating thermal power at a temperature greater than 650°C.

2.3 Thermal energy storage tank
The thermal energy storage acts like a battery for the power plant to overcome the problem of reduction in energy production when the weather is cloudy or rainy. In this project, two tank direct systems are applied. Solar thermal energy in this system is stored in the same fluid which is used to collect it [6]. The fluid is stored at one for high temperature and another one at low temperature. Fluid from low temperature flows through the solar receiver and it is heated, and then flows to the high temperature tank for storage [6, 8]. Fluid from the high temperature flows through a heat exchanger where steam is generated to produce electricity. Molten salt is used in the heat transfer. They are unique among solar electric technologies in the ability to efficiently store solar energy and deliver electricity to the grid when needed such as night or during cloudy weather.
2.4 Steam generator
The thermal energy storage tank stores thermal energy which is then transferred to water and converts to steam in the steam generator. The pressure and temperature keep on increasing till it becomes superheated steam energy which is strong enough to rotate the turbine of the power generator. Based on research, it may generate around 150 to 200 kg of steam in a day, depending on location and various other features that can save around 4500 liters of diesel in a year [9]. Meanwhile, to transfer steam energy, steam pipes are used.

2.5 Air cooled condenser
The air cooled condenser is needed in heat transferring system. It is a device used to condense a substance from gaseous to a liquid state. The steam condenser is installed on the exhaust steam from thermal power station where in this condenser; heat exchanger converts steam to the liquid state at a pressure below atmospheric pressure. The surface of the condenser which is normally used the water cooled shell and tube heat exchanger is installed on the exhaust steam. It is also acting as the separator of steam and water mixtures. Thus, steam is drawn out and distributed for further processes. Heating on saturated steam will make superheated steam to drive the steam turbine which is then used in generating electricity.

2.6 Turbine
Turbine, consists of a series of curved vanes or blades on a central spindle, is the device of a generating unit which is spun by the force of steam energy to drive an electric generator. In thermal steam power generation, steam is heated till it becomes superheated steam and causes the turbine to be spun at a very high pressure and temperature [7, 8]. A typical steam power plant steam turbine rotates at 1800-3600rpm. Non-condensing (back-pressure) and condensing steam turbine (extraction steam turbine) are the two types of steam turbine. Figure 3 below shows condensing steam turbine.

Figure 3. Diagram of flow of steam energy to turbine
It is most typically found in electrical power plants as these steam turbine exhaust steam in a partially condensed state. It has openings in its casing for extraction of a portion of steam at some intermediate pressure before condensing the remaining steam. The superheated vapor which contains high energy enters the turbine after it has exited from the boiler at high temperature and pressure. The high heated and pressured steam is converted into kinetic energy using the nozzle. Once the steam has exited the nozzle, it moves at high velocity and continues to flow to the turbine. A force is created on the blade due to the pressure of the vapor on the blades and causing them to rotate. Extraction steam turbine does not cool the steam so much, as it uses the remaining heat to make hot water in a system which known as combined heat and power (CHP).

2.7 Synchronous Generator
It is defined as a machine that converts mechanical power derived from steam, gas or hydraulic-turbine to alternating electric power. The chosen rotor design is non-salient pole which the utilization is for the high speed synchronous machine. As applied in the thermal steam power station, the prime mover of the generator will be rotated by steam energy which produced from the steam generator. However, the steam energy produces a very high pressure and temperature, thus direct-conductor cooling is needed by using water as coolant [9, 10].
Figure 4 shows the flow of diagram for three phase power emission. The turbine of the generator rotates and produces an alternating current which then flows to the rectifier to convert to direct current. It passed through a smoothing and filters circuit to produce a better characteristic of the waveform. Direct current continues to flow to an inverter which converts direct current to alternating current and finally the power is supplied to transmission tower to targeted areas.

![Flow of diagram for 3 phase power emission](image)

Figure 4. Flow of diagram for 3 phase power emission [10]

2.8 Location
The targeted location for this project must be a place with high temperature throughout the year [11]. The chosen location is Chuping, Perlis. Chuping is a small town of Perlis locating at the northeast of Kangar. According to Star News, Chuping has recorded the highest temperature of 40.1°C in the year 1998. On humidity research, Chuping received only 2000mm of rainfall annually which is then marked as one of the driest towns in Malaysia. Normally, the hottest and driest seasons occur from December to February.

3. Estimated cost
The cost estimation is based on the market research analysis on thermal steam power plants.

| Parts                        | Cost (Ringgit Malaysia) |
|------------------------------|-------------------------|
| Heliostats                   | 1.0mil                  |
| Receiver                     | 600,000                 |
| Thermal energy storage tank  | 0.5mil                  |
| Steam generator              | 70,000                  |
| Air cooled condenser         | 400,000                 |
| Condensing turbine           | 0.5mil                  |
| Synchronous generator        | 30,000                  |
| Total                        | 3,000,000               |

From the data analysis, the heliostats take up about 30% of the total investment of the project. Although the initial set up for the heliostat as the heat reflector to start up the power plant is high, but in the aspect of the long run, it is beneficial and profitable because it does not require any fossil fuels burning to produce the initial energy but only maintenance cost after it started to operate.

**Payback Period (PP) = The Costs of the Project / Investment**

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\text{Annual Cash Inflows/Savings} = \frac{\text{RM 3 000 000}}{\text{RM 90 000}} = 33.33 \text{ years}
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4. Results & Discussion
The total estimated power emission from the thermal steam power plant is targeted to be 1 MW which is able to supply the whole Chuping’s street lights, homes and industry with enough electricity. One heliostat produces about 2000 watts, which by building 500 heliostats, the estimated power is 1
megawatts. The emission of power will be divided into 3 parts; one is the facilities on streets, housing area and industrial area. The electrical consumption for one LED Street light is 900mW, this project target is to build 2000 street lamps to upgrade the current’s roads quality to enhance safeness and to promote a convenient journey for citizens and also tourists. The remaining power of 60% is supplied to the housing while 40% to the industrial area.

5. Conclusion
To conclude, the solar and steam energy is one of the most potential renewable energy sources. It is a backup power generation for the power station to work and to sustain balance and continuous electricity supply throughout the year. This project is aimed to be highly potential to work in Chuping, Perlis, Malaysia.

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