Application possibility of Parabolic Through Solar Thermal Power Plant technology in North Cyprus

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ABSTRACT

The purpose of this work is to investigate whether the installation of a parabolic through solar thermal power plant technology for power generation is economically feasible in Turkish republic of North Cyprus (T.R.N.C). Since such plants are based on the concentration of the solar radiation to achieve high temperature necessary for the thermodynamic progress, the application area is limited with the high direct solar radiation. A feasibility study involving all factors (land use, land cover, water and wind assessment and solar potential) must be implemented before the location is determined for a Concentrated Parabolic through Solar Power Plant. The electricity unit cost and the payback time are calculated for all cases. The study shows that, it is feasible to install a parabolic through solar thermal power plants under certain conditions.

Keywords: Solar Energy, Solar thermal Power Plants, Renewable Energy Sources, Solar Thermal Power Plant Technologies, CSP, North Cyprus

1 INTRODUCTION

Renewable energy is a growing need for a developing world. It is an energy derived from natural sources such as sun, water, wind, etc., which are renewable in nature. Solar Thermal Power is one of the alternative energy source which is using solar direct radiation to generate electricity by converting thermal and kinetic energy to electrical energy. There are three general types of solar thermal power technology; solar tower, parabolic dish and parabolic through. In this report, a feasibility study of solar thermal parabolic through power plant is briefly presented and analyzed including investment, efficiency, size and maintenance and their application possibilities in TRNC.

TRNC has one of the highest average annual sun shine hours (3000-4000 hours/year) and average annual irradiation rates (1800-2200 kWh/m2.year) in the world. [1] Converting solar energy into electricity can be performed indirectly by using concentrating technologies. The term of indirect conversion refers to converting the direct radiation to thermal energy by means of solar collectors or concentrators, carried by working fluid to a conventional process of electricity generation (Solar Thermal Power Plants). Since such plants are based on the concentration of the solar radiation to achieve high temperatures necessary for the thermo-dynamic power plant process, their application areas are restricted to earth regions with high direct solar radiation, such as TRNC.

2 REVIEW OF PARABOLIC THROUGH SOLAR THERMAL POWER PLANTS TECHNOLOGY

A parabolic through solar thermal power plant (PTSTPP) is considered as one of the most mature, successful, and proven solar technologies for electricity generation. [2]

A parabolic trough is a long, trough-shaped reflector with a parabolic cross-section. Parabolic trough power plants use parabolic reflectors in a trough configuration and are the most mature solar thermal technology. Troughs concentrate the sun up to 100 times onto a fluid-filled receiver tube positioned along the line of focus in the trough. Produced heat (up to 400 °C) is then coupled by heat exchanger in the steam cycle of the power plant. [3] The Figure 1 shows a schematic diagram of a PTSTPP with thermal storage.

Parabolic through along which these tubular receivers run may be 6m wide, 2m deep and up to 150m in length. PTSTPP are usually aligned with their long axes from north to south and they are mounted on supports that allow them to track the sun from east to west across the sky. Also, the conversion of efficiency is one of the key indicators. The reflecting mirrors must be both accurately shaped, and accurately positioned in order to achieve maximum sollar collection efficiency. Then the tracking system must ensure that each through is in the optimum position, all day. The peak efficiency is 25% and the conversion efficiency is 16 percent for the PTSTPP. The annual capacity factor is around 25% without thermal storage and 42% with the thermal storage. [4]

2.1 Components

The parabolic through solar thermal power plants consists of parabolic through collectors filled with thermal oil as heat transfer fluid, thermal storage and power block as seen in Figure1. Also, list of the major components of a parabolic through power plant can be seen in figure 2.

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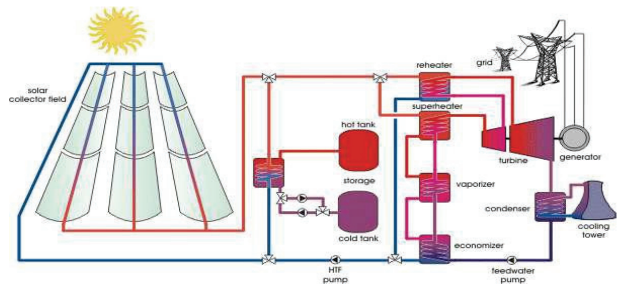

Figure 1: A Schematic Diagram for a Parabolic Through Thermal Power Plant [5]

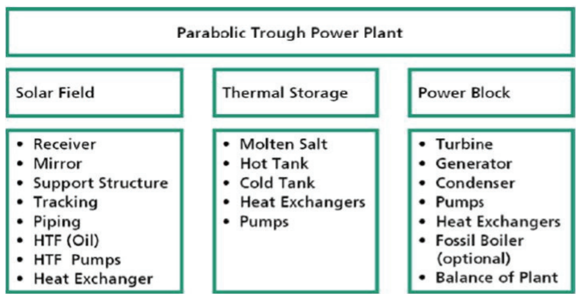

Figure 2: Components of a parabolic trough power plant are the solar field and the power block. Optionally, thermal storage may be integrated [6]

2.2.1 Solar Field

A solar field consists of thousands of solar collectors components, which are independently tracking assemblies of parabolic through collectors. Each solar collector contains receiver, mirrors, metallic support structure, tracking mechanism, exchangers and pumps. In order to reach the operational conditions, the solar collector assemblies are arranged in a series configuration normally known as a loop; the length and the shape of the loop depends on the parabolic through collector performance, but it usually has a U shape to minimise the pressure drop through the pipe header. The parabolic through solar collectors are oriented in north-south direction where it can track the sun from east to west.

2.2.2 Thermal Storage

A The thermal energy storage is used as a fuel to generate power during the night time where there is demand of electricity generation. It is capable of supplying the energy for several hours. Thermal energy storage is economically and practically feasible already, even in smaller scale applications. Normally, it is charged during in the day and discharged after the sunset, enables for plant operation in concordance with load requirements from the utility grid as the electricity demand peak is after sunset in T.R.N.C. The storage material needs to be cheap, due to a large requirement. Storage enables continuous production or shifts production to periods of peak demands. The peak load for T.R.N.C. is 12.00-15.00 pm in summer and 17.00-22.00 pm in winter.

2.2.3 Power Block

The power block acts as a brain where it supplies reliable, efficient power. The power block commonly used in CSTPP is a regenerative Rankine Cycle for electrical power generation which contains a heat exchanger for the steam generation, the steam turbine driving the generator for the electricity production.

3 POTENTIAL USE OF PTSTPP TECHNOLOGY IN TRNC

Evaluated siting parameters for centralized concentrating solar power plants are required before locating a real plant. The potential for CSP performance in North Cyprus depends on identification and analyzation of technical and economical parameters and issues which are listed in Table 1 where they are studied, in addition to other parameters.

SITING FACTOR	Requirement
Solar Resource	Abundant – $1800kWh/m^2/year$
Land use	$18000m^2/MWe$
Land Cover	Low diversity of biological species, limited agriculture value
Site Geography	Flat
Infrastructure	Proximity to transmission-line corridor
Water Availability	Adequate supply, otherwise dry cooling

Table 1: Main sitting factors of concentrating solar power plant[8]

Energy requirements of Cyprus are completely dependent on imported fossil fuels. Currently, solar energy is used extremely for water heating in the domestic and touristic sector. It is estimated that, around 90% of individual houses and 80% of hotels are equipped with solar-water heating systems. At the moment, the Kib-tek, Local Electric Power Utility, is still the sole producer of electricity on the island and operates two thermal and one solar power stations with a total installed capacity of approximately 400MW, where the part of the power is produced for sale purposes for an independent producer. There is only small percentage of solar power energy systems where it is used for small applications in homes and factories. The power generation relies totally on imported fuels such as heavy fuel oil and diesel due to lack of information and finance. According to TRNC State Planning Organisation [7], the electricity consumption has risen from 341.4GWh in 1990 to 887.7 GWh in 2010 which means 160% increase, averaging 8% per year. The average price of electricity for the year 2012 was approximately 0.23 Euro/kWh.

3.1 SOLAR RESOURCE/POTENTIAL

Only the direct normal insolation can be used which limits the high quality concentrated solar power sites to areas with low levels of moisture and particulates, little or no cloud cover and high levels of direct normal insolation around the year. North Cyprus lies in a sunny belt with an average yearly solar potential is around 1800kWh/m^2. [1] The North Cyprus is exposed to sunlight radiation 12 hours per day on yearly average. On the other hand, according to the government officials, the insolation time over the quasi-totality of the national territory exceeds 3200h annually which means; the North Cyprus is one of the countries with the highest solar radiation level with a potential production more than 6 billion GWh/year.

3.2 Land Usage

The concentrating solar thermal power plants need 20,234 m^2 of land per MW of electricity production capacity. Plants with thermal storage and higher capacity factors will require more land per MW. According to Cohen and Cable [9], the land with overall less than 1% slope is the most economical site to install a concentrated solar thermal power plant. Also, this site should require low cost to connect transmission lines, water and natural gas or fuel. Moreover, regarding the large area need, the land should have low value for agricultural or residential use and have low biological habitat in order to be eco-friendly. There are other several factors that should be included during the feasibility study, in order to prevent the loss of effectiveness of the power plant, such as flood potential, stability of soil, potential obstruction of the sun, seismic history and dust ratio.

3.3 Water Assesment

The water is required for the cleaning of the mirrors and cooling the power cycle, replenishment of the working fluid; if a steam cycle is used. The water usage is around 3 to 3.5 m^3 per kWh, where only 5% of this is consumed for the cleaning and the rest is used by the cooling process. Water based cooling is considered as the most effective and efficient cooling technology available. On the other hand, this makes the power plant dependent to the water where it is costly and a precious resource. Another option for the cooling process is the dry cooling, the component are 4 times, more expensive than the water cooling system and lowers the overall efficiency which cause more than 10% increase in the electricity cost.

3.4 Wind Assesment

The structure of the solar field is almost covers 40% of the total cost and the wind speed is easily affects the design of the collectors structure. Currently, solar thermal power plants operate at wind speeds lower than 35mph and can operate in protected mode in wind speeds up to 80mph. According to this information, the site should have less wind speed in order to design cheaper and feasible solar thermal power systems.

3.5 Investment and Maintenance Costs

The Figure 3 shows the major cost categories for parabolic through power plant. The estimation is done for 100MW power plant and the solar collectors have the biggest share of cost, which is 58% as shown. Figure 4 shows the solar field component cost breakdown for a PTSPP. The metal support structure with 29% has the biggest share in all.

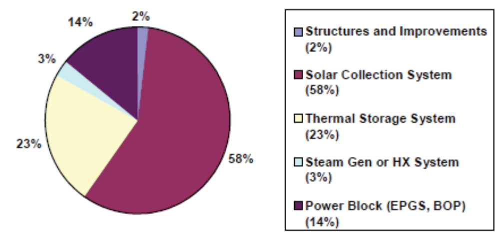

Figure 3: Major Cost categories for Parabolic through plant[14]

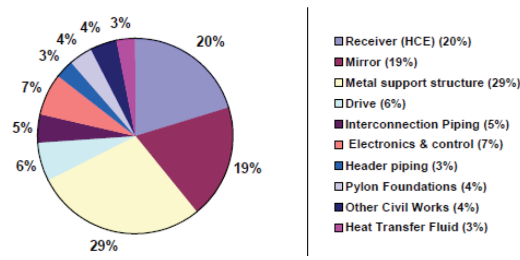

Figure 4: Solar Field component Cost breakdown for Parabolic through Power Plant [10]

In T.R.N.C., the annual solar capacity is around 1800 kWh/m^2 and the capacity factor may vary from 25% to 100% depending on the thermal storage capacity. The solar to electricity efficiency is 16% and the total loses including transformer losses in the power plant is almost 14%. The capital cost range is 2000 (without storage) to 8000(with storage) Euro per kilo-watt depending which technology and storage is used. The amount of saved CO_2 emission is 800g/kWh. The annual operation and maintenance cost is 4,000,000 Euro. The feed-in tariff assumed to be the same as the selling tariff which is 0.23 Euro. The economic life of a solar thermal power plant is taken as 20 years. [10,11,12]

The capital cost includes feasibility study, land leasing, collector system, power block, development and design study, engineering works, road construction, transmission lines, commissioning and training, substation, etc.

The required land for a 100MW solar thermal power plant without storage is around 2,249,616 m^2 that is a square plot of 1500m x 1500m. The required land for a 100MW with thermal storage for 24h per day operation of full power is approximately

10,798,160 m^2 that is a square plot of approximately 3286m x 3286m.

100MW solar thermal power plant with only 5h working per day (without storage), in the case of capital investment is 4000 Euro/kW and the land leasing price of 1.5 Euro/m^2 year, the electricity price cost is approximately 24 Euro-cent/kWh. The electricity unit loss is 2 Euro-cent per kWh.

100MW solar thermal power plant with 24hour working per day (with storage), in the case of capital investment is 8000 Euro/kW and the land leasing price of 1.5 Euro/m^2 year, the electricity price cost is approximately 8 Euro-cent/kWh. The electricity unit benefit is 14 Euro-cent per kWh.

The net present value (NPV) and return of investment (ROI) is directly related to the cash flow of the investment and the electricity unit benefit or cost. Also, the size, capital investment and operating hours of the parabolic through power plant are critical parameters for this kind of projects which is directly affects the pay-back period.

3.6 Efficiency

The Solar Field is defined by the collector area in square meters (m2), which can be estimated by the following simplified equation: [10]

$$C = (kW\ d\ x\ CF\ x\ h)\eta\ x\ I \tag{1}$$

Where:

C = Collector area square meters (m2)
kW d = electric generation design capacity, kilowatts
CF = Capacity Factor = kWh actual / (kWd x 8,760)
h = hours per year (8,760)
η = net annual solar-to-electric efficiency
I = annual insolation (kWht/m^2)
kWe = kilowatts electric
kWht =kilowatts thermal

For a given plant size and capacity factor the net annual efficiency is the determining factor in the collector area; as the efficiency increases the collector area decreases on the same percentage basis.

4 CONCLUSION

The aim of this report was to investigate whether it is feasible to install a parabolic through solar thermal power plant in North Cyprus or not. The study includes all relevant datas including solar potential and the current renewable energy policy of the Turkish Republic of North Cyprus. As T.R.N.C. is one of the best situated country for the use of solar thermal power plants, their use would bring the country many advantages, especially, through the substitution of environment threatening and damaging emissions of conventional energy sources being currently in use for electricity generation.

The results obtained concerning the annual electricity generation from a 100 MW parabolic through solar thermal power plant examined for two different operating hours indicated that as the size and operating hour's increases, the electricity production increases as well. Also, the land requirement increases when the size of the power plant and operating hours increases. Therefore, increasing the size of the power plant with the thermal storage, the investment becomes more attractive. For a 100MW parabolic through power solar thermal power plant, 5 hour working hours will cause a loss of 0.02 Euro per kWh where with the 24 hour working hours causes a gain of 0.14 Euro per kWh. However, this increase in the working hours causes an increase in the capital investment simultaneously. The estimation of a cost for solar thermal power plants are extremely difficult to make, however, it is expected that cost reduction will result from technical progress.

The overall results indicate that, installation of a parabolic through solar thermal power plant is economically feasible depending on the stated conditions which are mostly affected by the size and capacity of storage, initial cost and the land fee.

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