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Reduction In Parasitic Load In A Solar Thermal Power Plant To Improve Its Efficiency

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ABSTRACT

Rapid development in technology and improvement in life style of present generation has caused an increased dependence on electricity and hence on sources of energy which are unfortunately, non-renewable. The present world is looking up at renewable sources of energy to combat looming energy crisis. This is necessitated not only due to depleting non renewable sources, but also due to increased CO_2 content and consequent global warming. So far solar energy has been looked upon as the most ideal alternative source of energy. The reason behind this is the abundance of solar energy coupled with a large number of ways in which it can be harnessed for purposes such as heating, drying or for generating electricity. For large scale electricity generation with high degree of efficiency, solar thermal power is considered a better option over photo-voltaic. A few projects worldwide are operating and many are in different stages of construction in different parts of the world. As a learning technology, a large magnitude of research work over improvement in this technology is also going on. One challenge faced by industry is to reduce the parasitic load involved in generation of electricity in these plants. The parasitic load contributes in reducing the system efficiency and needs to be eliminated or minimized. The present paper investigates the causes of parasitic load in a solar thermal plant and tries to find out ways of its reduction.

KEY WORDS

Thermal energy storage (TES), auxiliary power use, Re-circulator, ISCCS (Integrated Solar Combined Cycle System)

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INTRODUCTION

The abundance of solar energy on earth can be appreciated by the fact that the direct irradiance received by 1% area of the Sahara Desert is sufficient to supply electricity to the whole world if harnessed completely. Though 100% efficiency is not received by any device, solar thermal power technology is on the way to achieve a high degree of efficiency by concentrating the DNI (Direct Normal Irradiance) for generating steam and run the dynamo. The technology is still developing to be as efficient as a conventional coal or gas driven thermal power station. [1]

The efficiency of a solar thermal power plant is affected by various factors. The major of these include receiver heat losses, mirror reflectance, optical efficiency, beam interception, parasitic load, thermal energy storage etc. [2, 3]

Parasitic load is one of the major factors which affect the efficiency of the power plant. It creeps in almost all the sections of the power plant, in all the stages of the power generation. We will now discuss in detail the parasitic load and its causes in a solar thermal power plant. The experimental section includes a detailed insight into all types of solar thermal plants to find out the various causes of the parasitic load. The findings will then be analyzed to find out ways to reduce the parasitic load to the minimum.

EXPERIMENTAL SECTION

The following study is done on the basis of investigation of the technology through extensive literature review using reports, books and the electronic media. The study includes all the types of the solar thermal power plants, i.e. parabolic trough solar collector (PTSC), solar power tower (SPT) Compact Linear Fresnel Mirror (CLFR). The findings were compiled together and then analyzed to identify the causes of the parasitic load. The conclusion part includes the suggestions for elimination and reduction of the parasitic load.

What is parasitic load?

In context of electricity production, parasitic load is the load or device which consumes electricity while contributing to the process of electricity generation or plant operation. This, hence does not add to the total plant yield, but reduces the gross yield by a considerable amount.

Thus, parasitic load is the in-facility electrical load which needs to be minimized. It is estimated to be 6.5% of the total electricity generated that is used in production and delivery of electricity. In a solar power plant, the main parasitic loads include motors used to run HTF pumps, cooling water pumps, cooling tower fans, boilers, condensate/feed water pumps, turbine starters, electric pre-heaters etc. In addition to that, instrumentation, controls, computers, valve actuators, air compressors and lighting within the power plant also add on to the parasitic load. Electricity is also consumed by heat recovery sections which increase the steam temperature, reheat the exhaust steam from first steam stage of steam turbine, heaters of condensed feed-water etc.[4]

Parasitic Load in STP

Limited data is available on the power tower technology due to lack of a long term experience in it. The studies of the commercial scale plants that are already functioning reveal the fact that the parasitic in this type of technology are likely to consume as much as 10% of the gross annual electricity. The major sources of parasitic load in the solar tower technology are receiver pumps which help in the transfer of the molten salt for steam generation, flanges, blowers and dampers.

To achieve high thermal energy storage target above 99%, the parasitic loads are also seen to increase though the net efficiency of the plant is found to increase. The parasitic power efficiency of a Solar Tower Plant depends on the plant size. The parasitic power efficiency is an exponential function of the plant size. It is found that the parasitic load decreases exponentially with an increase in the plant size. For example, on increasing the plant size from 15 MW to 100 MW, the parasitic efficiency improved from 3.6% to solar-to-electric efficiency of 16.6% of the plant. [5] The parasitic consumption in Solar 1 and Solar 2 was quite high. This was largely due to small plant size.

The dual axis control of the heliostat is done separately in the STP unlike the PTSC system in which an array of collectors is managed by a single control forming one SCA (solar collector assembly). This increases the parasitic of the system, hence reducing its overall efficiency. The salt valves and other flow loop hardware contribute to increase the parasitic load in these plants. Power is also required by the flow and pressure sensor equipment used in the plant. [6]

Parabolic Trough Solar Collector Plant

80% of the total solar thermal plants functioning in different parts of the world are based on PTSC. The main causes of the parasitic load include the tracking system of the SCA in the solar assembly which encompasses the drive, sensors and the control devices.

In ISCCS, the turbine size is increased with the aim of handling the increased steam generation. However, this approach is seen to have increased the parasitic load by more power required to operate the steam valve and the turbine starters. Electric geysers are required to maintain the temperature of the steam in the heat storage chamber. The turbine size is increased with the aim of handling the increased steam generation. However, this approach is seen to have increased the parasitic load by more power required to operate the steam valve and the turbine starters. Electric geysers are required to maintain the temperature of the steam in the heat storage chamber. These contribute largely to the system parasitic load. Steam pressure and temperature sensors also consume a considerable amount of power. These loads are in addition to those mentioned in the previous parts of this section.

The modern technology of PTSC uses the automated speed drive (ASD) mechanism for plant motor in order to vary the motor speed to match the mechanical load. This improves the system efficiency, but increases upon the parasitic load of the system. [7]

The circuitry of the system, the fire extinguishing system, the oil expansion tank valves etc. all require electric power for their operation. The heat exchange process between HTF and steam involves pumping parasitic in it.

The Compact Linear Fresnel Reflector (CLFR)

The parasitic load arises in this technology through collector field tracking drive, feed water pump, rejection pump and fans etc. the fixed parasitic of the system include plant lighting, site operation and control and the parasitic associated with the operation of auxiliary fossil equipment. The maximum parasitic load is accompanied with the heat rejection equipment. The tracking losses in the CLFR system are less than the PTSC because the weight of mirrors is reduced. However, it adds on to the cost of the system.

In re-circulator (RC) steam system, the boiler design adds to parasitic. In this, the water and steam exit the boiler as a two-phase mixture which is managed by the valves. Also the steam mass fraction in the mixture (called steam quality) is maintained to the desired value by the RC pump. [2] This is done at the cost of parasitic load. At the outlet of the boiler, dry steam is separated from the liquid and sent to super-heater section or turbine, and the saturated liquid returns to the inlet of boiler section. Also, temperature sensors used to detect turbine inlet temperature add to parasitic load. The turbine inlet valve and the boiler inlet valve are managed through automated system. Thus, re-circulator requires phase separator, re-circulator loop pump, additional piping and valving loads.

Another cause of the parasitic load is the minimum back up power level requirement in which auxiliary boilers are connected in parallel to reach user specified operation level. In supplemental operation, additional flow is required for reaching the user specified thermal energy level. In re-circulator system, mass flow rate in the boiler section is iteratively varied to match the desired boiler steam quality using automated system. The variation in mass flow during the loop phase to match the temperature of design point valve and the outlet point causes load constraints in the system.

RESULT AND ANALYSIS

The study of the various causes of the parasitic losses during electricity generation reveals that a lot of electricity is used up in the running of the plant itself. It also explains the urgency of reduction in the same in order to ensure the increased efficiency of the plant and hence better performance. The following practices and methods are taken for improvement in losses due to parasitic.

- In PTSC thermal power plant, the flex houses are replaced with ball joint assembly in solar field. This reduces the parasitic caused by the former method by increasing the thermal energy storage. This spreads the station load over increased annual generation.
- The thermal oil is changed to molten salt HTF. Due to high density of molten salt, there occurs a lower volumetric HTF flow rate and hence less pumping power is required.
- The improvement in the thermal energy storage technology increases the annual generation, though at the cost of parasitic load, resulting in the net improved efficiency.
- In solar towers, the pressurized gases like air, helium, nitrogen etc. may be used for HTF. This causes less pressure losses and low parasitic consumption.
- The variable speed drive (VSD) is used for pumps and fans as they run at a partial load. A small speed reduction reduces highly on power consumption. Its benefits include soft starting of the motor and the pump, reduction in mechanical flow regulator wear, reduction in short circuit duty on auxiliary bus and high power factor operation.[8, 7]
- To reduce auxiliary power use the suggested step is use of automated sensor in outdoor lighting. Also the PC must be switched off when not in use through judicious use. [9]
- The fed steam to the turbine contains non-condensable gases (NCG) including CO_2 and H_2S. These increase a back-pressure on the turbine, reducing system efficiency. Removal of NCG by steam jet ejectors, vacuum pumps, turbo-compressors etc. adds to parasitic load, but raises the net output by a much greater ratio.

- In CLFR power plant, ‘once through’ steam flow reduces the steam separator and transport equipment, reducing parasitic losses. But it has a negative effect on the heat transfer stability. At higher temperature, the power production is reduced due to increased thermal losses.

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