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ANALYSIS OF INTEGRATED SOLAR COMBINED CYCLE

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ABSTRACT

The sun continuously supplies a massive amount of energy. Because of the nature of this energy, which is spread out, it needs to be collected and concentrated to be useable. There are many applications and techniques where solar energy is utilized in solar thermal power plants, solar energy is absorbed as heat which is then transformed into electricity. Transforming the thermal solar energy to electricity can be conducted by different approaches. The most common techniques are concentrating solar power (CSP) plants and the solar chimney. The CSP techniques are: solar tower, parabolic dish and parabolic trough. In this research we will analyze using CSP to give solar energy to combined cycle.A combined-cycle power plant is a power plant that combines theRankine steam turbine and Brayton gas turbine thermodynamic cycles, by using Heat Recovery Steam Generator (HRSG) to capture the energy in the gas turbine exhaust gases for steam production to supply a steam turbine. Integrated Solar Combined Cycle (ISSC)Consists of a combined cycle power plant and a Solar Fieldconnected to the combined cycle. The thermal energy of both the combined cycle power plant and the Solar Field are converted into electricity in the same steam turbine.

Keywords: Benefits of ISSC, Combined Cycle, Heat transfer diagram, Integrated Solar Combined Cycle

I. INTRODUCTION

Currently, the bulk of the world's energy is supplied by fossil fuels. Their abundance, coupled with high energy densities and low prices, contributed to their almost absolute dominance throughout the 20th century. In the past decade, however, there has been a rapid and sustained growth in demand for cleaner energy sources. Societal expectations going forward are that greenhouse gas (GHG) emissions associated with energy production must be substantially reduced. Global concerns over climate change have prompteda renewed interest in clean technologies such as carbon capture and storage (CCS) and renewable energy. Renewable energy includes wind, biomass, and solar sources. Wind power is among the most mature renewable technologies whereas many biomass and solar technologies are still under development. Solar energy has gained tremendous popularity worldwide in the past decade, mostly in the form of Photovoltaic (PV) technology for power generation. However, a less-known solar technology called Concentrating Solar Thermal (CST) offers substantial advantages over solar PV and other renewable energies in terms of potential GHG mitigation options. We will use parabolic throat of concentrating solar power technique.Parabolic trough solar power plants are the most proven system of concentrating solar power (CSP) techniques. CSP plants are promising technologies to be the

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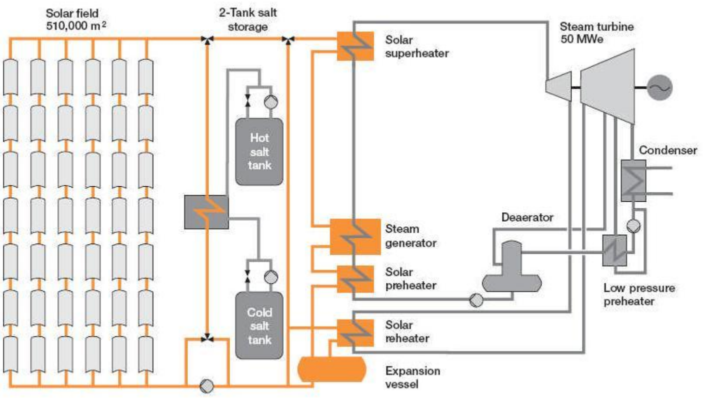
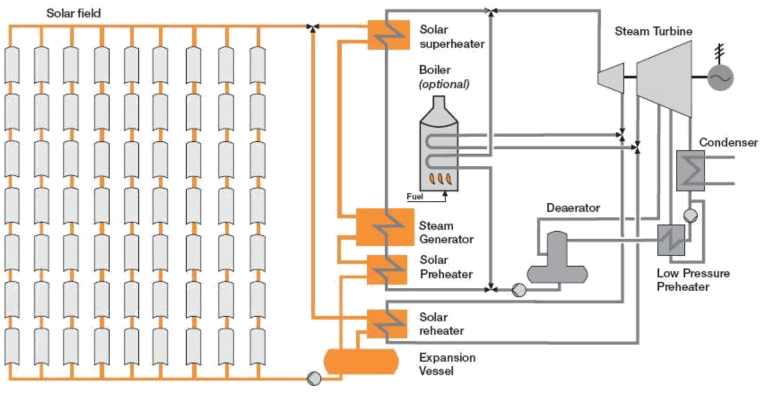
alternative clean energy resource to meet the increasing energy demand and thus reduce the environmental impact. It is predicted that CSP will play a significant role in providing the energy to meet the world's energy demands which are increasing rapidly in response to the growing economics in both developed and developing countries.Parabolic trough power plants can be operated in different configurations and operating systems. They can be operated in only solar mode where the solar collector's array is the only energy resource for the thermal cycle. Alternatively, they can be operated as a hybrid system, where a backup fossil fuel boiler is used in parallel to the solar collector's array. Most of the existing trough plants use synthetic oils as a heat transfer medium to supply the heat gained by the solar collectors to a Rankine cycle. Solar trough systems vary in configurations and operating systems. They can be installed in solar mode only where only heat from the solar field is used to operate the thermal cycle. However, these systems require a thermal storage facility to ensure operation stability.



Solar thermal power plant with thermal storage system

In solar only mode with storage the solar field starts running from sunrise to supply heat to the Rankine cycle. For about 2-3 hours of solar radiation peak, the solar field is operated to supply some energy to storage system in addition to its primary task of running the steam turbine. When solar energy is not sufficient to run the Rankine cycle, the storage system starts to supply some energy to the thermal cycle. After sunset the plant runs completely on the storage system.

Hybrid systems use different approaches. Where the fossil fuel boiler (commonly natural gas fired) to supply the required energy for the thermal power plant is used. Boilers are connected in parallel to the solar field to heat up the feed water or to superheat the generated steam in the thermal cycle.



Solar trough system with fossil fuel backup

The hybrid system solar power generation concept uses a backup fossil fuel boiler which is used in parallel to the solar field to guarantee reliable operation at night-time or when no solar radiation is available. Many configurations have been introduced as hybrid systems. One fossil fuel boiler or more is used to supply the required energy for the thermal cycle. Boilers can be used to superheat the steam in the thermal cycle. Moreover in the hybrid systems one solar field or more is allocated in different positions either to heat the feed water or superheat the steam.

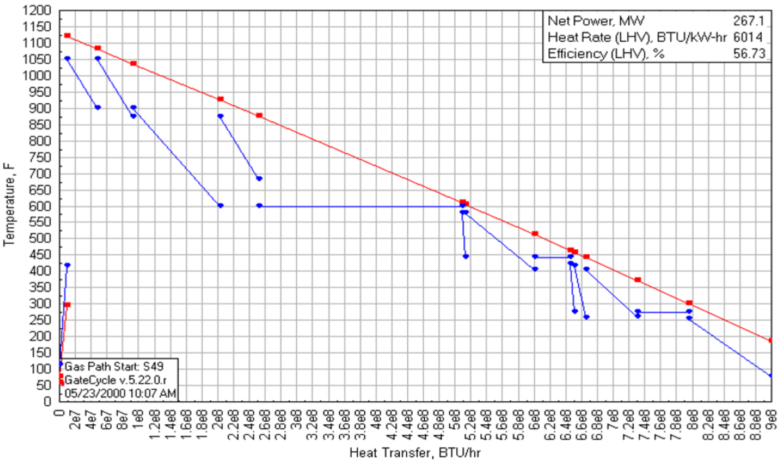
1.1 Analysis of Integrated Solar Combined Cycle

The ISCC system is a combination of a solar field and gas turbine-combined cycle. The waste heat from the gas turbine is used to generate some steam to be expanded in a steam turbine. In addition, the solar field supplies extra heat to the thermal cycle. The additional heat from the solar field results in electricity generation increase during sunlight time. This combination results in improving the overall thermal efficiency. The benefits of employing this technology are to overcome some problems related to startup and shut down in solar power plants, reduce the capital cost and improve the solar-to-electricity efficiency.

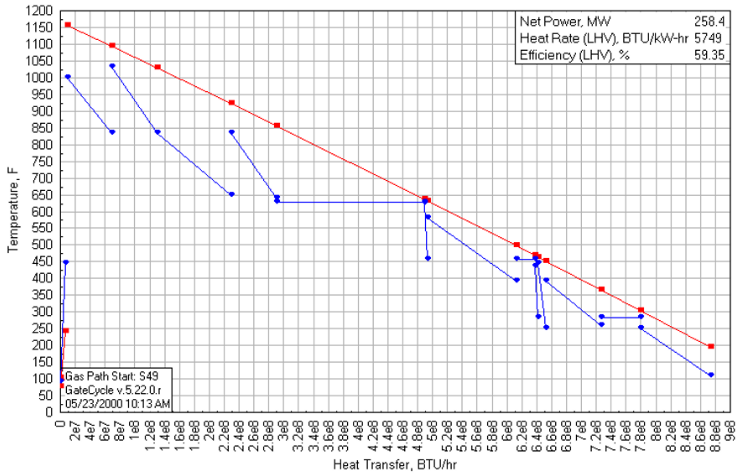
II. THERMODYNAMIC AND ECONOMIC BENEFITS

Incremental Rankine cycle efficiencies are 95 to 120 percent those of a SEGS plant, and up to 105 percent those of a combined cycle plant

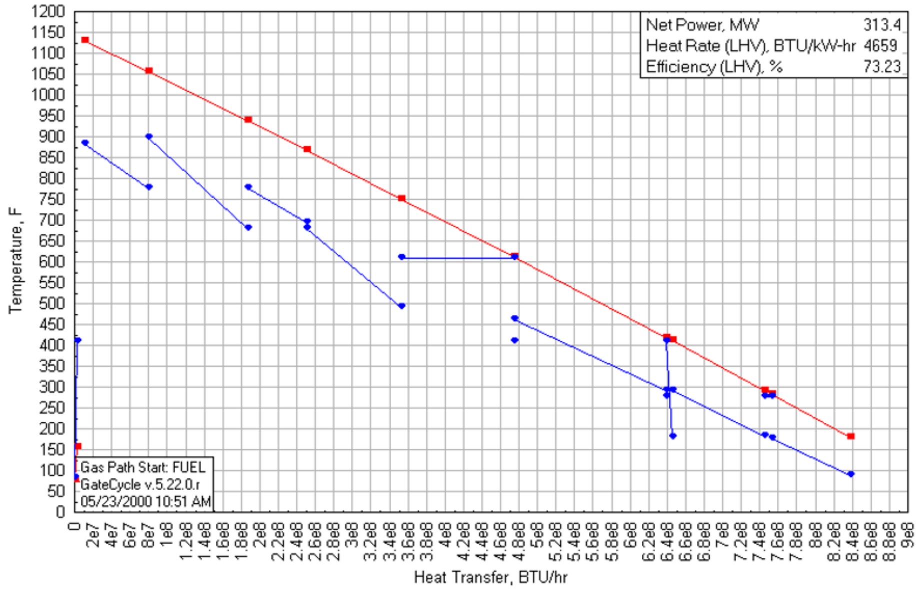
a) Daily steam turbine startup losses are eliminated
b) Incremental Rankine cycle power plant costs are 25 to 75 percent those of a SEGS plant
c) Solar conversion efficiencies are higher than conventional plants, yet Brayton and Rankine cycle conditions remain unchanged
d) Thermodynamic availability is improved by reducing temperature difference in heat transfer
e) Largest Rankine cycle temperature differences occur in high pressure evaporator of the heat recovery steam generator
f) The most efficient use of solar energy is displacing saturated steam production
g) Corollary: Sensible heat transfer has the smallest temperature differences; thus, the least efficient use of solar energy is feed water preheating and steam superheating



Heat Transfer Diagram for Combined Cycle Plant



Integrated Solar Combined Cycle with Small Solar Inputs



Integrated Solar Combined Cycle with Larger Solar Input

III. INHERENT LIMITS

a) If solar conversion efficiencies are to match or exceed Solar Energy Generation System (SEGS) plants, annual solar contributions are limited to 2 to 7 percent

b) Annual contributions above 10 percent can be easily achieved without the use of thermal storage, but net solar-to-electric conversion efficiencies will be below 30 percent

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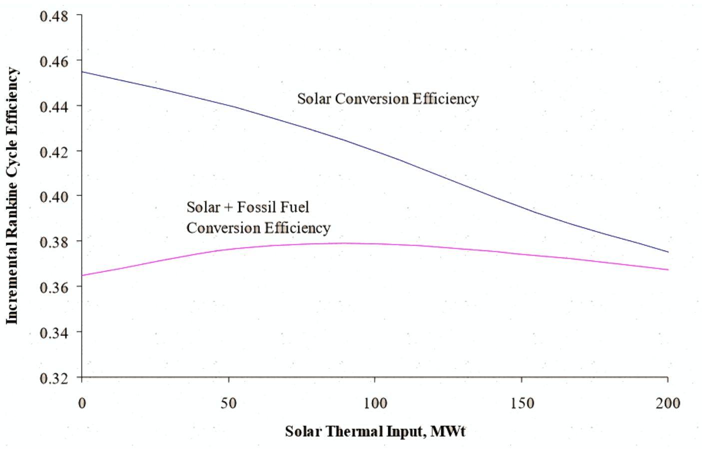

Benefits and Limits

IV. PART LOAD RANKINE CYCLE EFFICIENCY

a) Declining conversion efficiency with increasing solar contribution is not due to decrease in turbine efficiency at part load

i. Steam flow rates, and therefore pressures, are high during the day, and lower at night

ii. Throttling introduces a loss in thermodynamic availability; thus, sliding pressure operation is preferred

iii. Extraction feed water heaters are not used; thus, the final feed water temperature is independent of Rankine cycle load

b) Turbine efficiency

i. At night, the decay in steam flow rate is matched by a decay in steam pressure

ii. Volume flow rate remains almost constant; thus, the turbine blade velocity vectors remain close to design values

c) Rankine cycle penalties during majority of operating hours can be very small

V. CONCLUSION

The steam turbine of the ISCC has to be designed for maximum solar heat, i.e. it will be larger than in a CC with the same gas turbine. Hence, at operating points with no solar irradiation the steam turbine will operate in part load conditions whereas in the CC it would operate at full load. Usually, from 100% to 85% of the nominal load the efficiency of the steam turbine is approximately constant. Hence, by limiting the Electric Solar Capacity to 15% the negative effects of increased part load become negligible. Thermal inputs to low pressure evaporator, intermediate pressure evaporator, feed water preheater, super heater, and reheater are thermodynamically much less efficient. Variable pressure/variable temperature designs offer reasonable efficiencies, less complex operating procedures, reduced water consumption, and improved availability. To maintain reasonable conversion efficiencies, solar contributions above 10 percent are best provided through the use of thermal storage.

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