Concentrated Solar Power Based Thermal Energy Storage for on Demand Heating, Cooling and Electricity Generation from Waste Heat using Stirling Engine

Prathamesh Sanjay Bhole[1] Uday Ravindra Bagul[2] Chetan Vijaygir Gosavi[3] Bhagyashri Patil[4]
[1,2,3]BE Student [4]Head of Department
[1,2,3,4]Department of Electrical & Electronics Engineering
[1,2,3,4]G.H.R.I.E.M., Jalgaon, M.S. India

Abstract— Using renewable energy sources besides fossil fuels in CCHP (Combined Cooling Heating and Power) system the efficiency increases with this new technology. Here solar heat in particular is used in CCHP systems. In micro scale, CSP (Concentrated Solar Power) is used for latent heat storage using TES (Thermal Energy Storage) for converting cold water into hot water to fullfill heating needs and this TES is connected to external heat engine for electricity generation. The use of hot water in cooling cycle reduces the energy consumption of compressor thus overall efficiency of CCHP system increases.

Key words: CCHP, CSP, TES, Trigeneration, CHP

I. INTRODUCTION

Non-renewable energy such as coal and petroleum, require costly explorations and potentially dangerous mining and drilling, and they will become more expensive as supplies dwindles and demand increases. Renewable energy produces only minute level of carbon emissions and therefore helps combat climate change caused by fossil fuel usage. Most renewable energy comes either directly or indirectly from sun. Sunlight can be used directly for heating and lighting homes and other buildings, for generating electricity and for hot water heating, solar cooling and variety of commercial and industrial usage. Concentrated Solar Power is becoming an attractive solution for countries with high level of solar radiation such as Lebanon, Iraq, India, Pakistan and Yemen, where many countries are prone to power outage which affects greatly their economies

The total number of individuals without electric power is put at about 1.1 billion, or a quarter of the world's population, concentrated mostly in Africa, Middle East, and Southern Asia.

Solar Photovoltaic (PV) Panels and Wind turbines are undoubtedly what come to people's minds when we talk about renewable energy. Unfortunately, PV and wind energy have intermittency issues, no radiation capture at night, cloudy or rainy weather, etc. Consequently, intermittency and unpredictability makes PV and wind energy less reliable a solution. For a continuous supply of electric power, PV requires not only Inverters but also storage batteries; thus increasing much the investment cost for PV panels considerably. In case of land-mounted PV panel installation, they require relatively large areas for deployment; usually a large land space must be committed for this purpose.

Solar thermal energy is the best, most economical and fastest choices compared to expensive photovoltaic cells, where energy storage capacitors for uninterrupted source of power supply such as batteries made from rare metals, are costly, bulky, unreliable and most importantly, damaging to the environment. Decreasing the price per kW over the long term seems a good reason to invest efforts in micro Concentrated Solar Power (CSP). As for example, a typical household application requires more than 1000m2 of PV panels compares to 20m2 of concentrated solar generator and a thermal energy storage of 2.0m3. PV efficiency levels are relatively low (between 14%-25%) compared to the efficiency level of Concentrated solar power (between 35%-65%).

The project we are developing is neither PV nor Wind turbine technologies. The micro Concentrated Solar Power generator will be using the solar radiation to generate electrical power from thermal energy with high efficiency ratios. Project features parabolic optical mirror collectors to capture, reflect and concentrate incoming sunlight into a highly efficient receiver which generates thermal energy. The receiver, consisting of high temperature-resistant material, converts the concentrated solar flux into thermal energy via a calorific medium fluid, molten salt. The heated fluid is pumped through a closed loop system and a heat exchanger that converts this thermal energy into electrical power through conventional stirling engine supplying of consistent and uninterrupted power supply. We are also developing a Thermal Energy Storage for storing the energy for night-time or cut-off operation.

II. LITERATURE SURVEY

The first documented use of concentrated solar power technology was in 1866, where Auguste Mauchaut used parabolic trough to heat water and produce steam to run the first solar steam engine. And now, in current technology, these CSP technologies are leading systems to become more and more efficient. By the use of parabolic trough, solar power towers, enclosed trough, Fresnel reflector, dish Stirling we can achieve more concentrated solar power. In our project, we use parabolic reflector dish as well as fresnel lens for concentrating the solar power. On the other hand, important role performed in project by Stirling engine. Stirling engines perhaps the simplest form of engine. It was first developed by Robert Stirling in Scotland, in 1816. They were used that Stirling engine to pump the water on farms and to generate electricity. Here, we use this Stirling engine, as a generator, to generate the electricity through concentrated solar power. Another concept in this project is performed by molten salt. Molten salt is a salt which is solid at normal temp; but when heated it enters to liquid phase. Molten salt is a mixture of sodium nitrate and potassium nitrate. This concept was discovered in 1951 by Paul Walden.

III. SYSTEM DESIGN

This project has 3 major forms of utilizing solar:

1) Concentrated solar power for electricity generation
2) Solar heating
3) Solar cooling

A. Concentrated solar power for electricity generation

Stirling engine is one of the best examples of heat engine which convert heat energy into mechanical work. Stirling engine is based on Stirling cycle. Stirling engine is also operated by heat from sunrays. The aim of this paper is to focus on solar dish stirling engine in order to generate electricity. Solar dish Stirling is efficient to convert 1/3rd of sunlight into electricity [5].

A Stirling cycle machine operates on a closed regenerative thermodynamic cycle using a Working gas, and subjects the gas to expansion and compression processes at different temperatures. Since Stirling engines are externally heated, environmentally very clean engine having high theoretical cycle efficiency, they can be powered using wide variety of fuels and heat sources such as, combustible materials, solar radiation, geothermal hot water, and radioisotope energy. Based on the fuel use for heating the Stirling engine it is available in different form and size. In solar technology, Stirling-Dish, the solar radiation is converted to electricity in three stages. In the first stage, radiation is converted to heat by focusing the solar radiation onto a light absorbing heat pipe by means of a parabolic reflector. In the second stage, the heat is converted to mechanical power by a Stirling engine. In the final stage, the mechanical power is converted to electricity by an alternator[5]. The dish modules convert sunlight in most climates, however they have proven to be most effective in hot and dry climates, where the system converts one third of the solar energy into electricity. [1]

B. Solar heating

1) Thermal energy storage (TES)

It is achieved with wide differing technologies. Counting on the precise technology, it permits excess thermal energy to be hold on and used hours, days, or months later, at scales starting from individual method, building, multiuser-building, district, town, or region. Usage examples are levelling of energy demand between daytime and night time, storing summer heat for winter heating, or winter cold for summer air conditioning (Seasonal thermal energy storage). Storage media embody water or ice-slush tanks, lots of native earth or bedrock accessed with heat exchangers by means that boreholes, deep aquifers contained between rubberized strata; shallow, lined pits crammed with gravel and water and insulated at the highest, further as mixture solutions.

Other sources of thermal energy for storage embody heat or cold created with heat pumps from off-peak , lower price wattage, a follow referred to as peak shaving; heat from combined heat and power (CHP) power plants; heat created by renewable current that exceeds grid demand and waste heat from industrial processes. Heat storage, each seasonal and short term, is taken into account an important means for cheaply levelling high shares of variable renewable electricity production and integration of electricity and heating sectors in energy systems almost or fully fed by renewable energy.

C. Solar CHP (Combined Heat and Power)

Cogeneration or combined heat and power (CHP) uses engine or station to come up with electricity and helpful heat at a similar time. Trigeneration or combined cooling, heat and power (CCHP) refers to synchronic generation of electricity and helpful heating and cooling from combustion of fuel or a solar heat collector. The terms cogeneration and trigeneration will be conjointly applied to the ability of systems generating electricity, heat, and cooling at the same time

Cogeneration may be additional economical use of fuel as a result of otherwise wasted heat from electricity generation is placed to some productive use. This can be conjointly referred to as combined heat and power district heating. Little CHP plants are a unit associate in nursing example of decentralized energy. By-product heat at moderate temperatures (100–180 °C, 212–356 °F) can even be employed in absorption refrigerators for cooling.

Cogeneration was practiced in a number of the earliest installations of electrical generation. Before central stations distributed power, industries generating their own power used exhaust steam for method heating. Giant workplace and lodging buildings, hotels and stores normally generated their own power and used waste steam for building heat. Due to the large price of early purchased power, these CHP operations continued for several years once utility electricity became offered.

D. Solar cooling

Solar Cooling is another economical use of renewable energy technologies in order to cool our homes and work places. The requirement for air-conditioning for our homes in hot areas around the world and also the abundance of the sunshine at interval these areas has led to a willingness to mix the 2 for the advantage of the folks that live there. In distinction to alternative varieties of solar applications like solar heating, the largest demand for cooling happens once the solar radiation is at its most intense, thereby creating the fusion of solar thermal energy and solar cooling makes the system more attractive.

Although electrically driven air-conditioning units have reached a comparatively high customary, their energy consumption is continues to comparatively high as most refrigeration primarily systems use electricity to power a mechanical device, therefore any future-oriented cooling or refrigeration primarily based system needs a proper energy supply from a renewable energy source.

But using solar energy to produce cooled air could seem a bit unclear initially because the sun tends to be viewed as awfully giant heat supply instead of one we can able to use for cooling functions. However, by combining solar thermal energy and trendy assimilation technology, heat can be used to cool our buildings because the sun encourages thermal processes to occur manufacturing coldness for air-conditioning function or by directly driving a thermal heat pump.

IV. METHODOLOGY

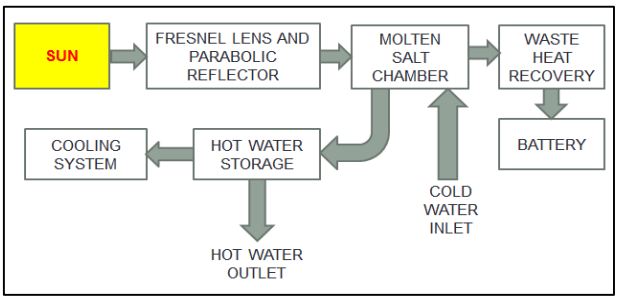

Fig. 1: Flow diagram

This system will provide heating, cooling, electricity from solar energy for 24 hours. The sunlight is a portion of electromagnetic radiations given off by the sun, in particular infrared, visible, and ultraviolet light. When direct solar radiation is not blocked by clouds, it is experienced as sunshine, a combination of bright light and radiant heat. When it is blocked by clouds or reflects off other objects, it is experienced as diffused light. So in order to gain maximum heat concentration from sun here dish type parabolic solar thermal collectors are used along with the Fresnel lens.

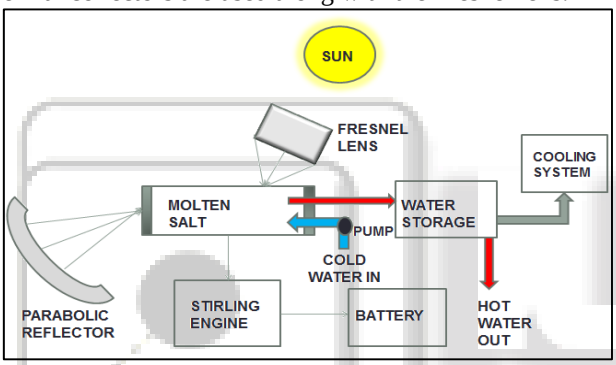

Fig. 2: Block diagram

Due to high concentration strength of Fresnel and parabolic reflector the intense heat is been focused on the molten salt chamber also known as thermal energy storage (TES). The TES is filled with mixture of sodium and potassium salts. In molten state these salts have high thermal storing capacity. The stirling engine is coupled with TES which gives mechanical motion and it is fed to the generator as prime mover. The generator converts this mechanical motion into electrical energy. This electricity is stored inside the battery. The battery is used to supply electricity to the various types of electrical appliances or loads.

The water is allowed to flow though tubes inside the TES chamber with the pump to regulate the speed of the water which will indirectly regulates the temperature of water. The hot water is then stored inside different container. This is the used to remove the moisture from air as form of desiccant system. The hot water is fed to the cooling system in order to reduce its energy consumption for cooling.

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