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Theoretical Investigation of Fuel saving In Power plant By Using Solar Energy

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ABSTRACT

At present scenario basically power plants are totally depends on fossil fuel specially coal and diesel. Common sources of energy are coal, natural gas and petroleum from fossil fuels. This growing consumption of energy has rapidly depleted non-renewable sources of energy. Rising price of fossil-based fuels and potential shortage in the future have led to a major concern about the energy security in every country. In the present theoretical investigation we have reduced the consumption of coal by 1100 kg/24hr by rising the temperature of makeup water from 25 ^{0}C to 80 ^{0}C by use of solar energy .Solar water heater can be implemented in any weather condition for thermal power plants for reducing the cost of sensible heat of makeup water; as a result the fuel consumption will be reduced. It can be used as an accessory of thermal power plant. The Present Investigation is done on 64 MW Thermal power plants (Ruchi Groups Gandhidham). Solar water heater can play an excellent role for increase temperature of makeup water; also it can increase the overall efficiency of boiler. Dependency on fossil fuel can reduce by using non conventional fuel in boiler. [1]

1. Introduction

A Power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fuel sources. Some prefer to use the term energy center because such facilities convert forms of heat energy into electricity. Some thermal power plants also deliver heat energy for industrial purposes, for district heating, or for desalination of water as well as delivering electrical power. A large part of CO_2 emissions comes from fossil fueled thermal power plants; efforts to reduce these outputs are various and widespread. [2]

- Boiler House
- Steam Turbine
- Condenser
- Cooling Tower
- Feed Pump
- Electric Generator

1.1 POWER PLANT EFFICIENCY

The energy efficiency of a conventional thermal power station, considered as salable energy as a percent of the heating value of the fuel consumed, is typically 33% to 48%. This efficiency is limited as all heat engines are governed by the laws of thermodynamics. The rest of the energy must leave the plant in the form of heat. This waste heat can go through a condenser and be disposed of with cooling water or in cooling towers.

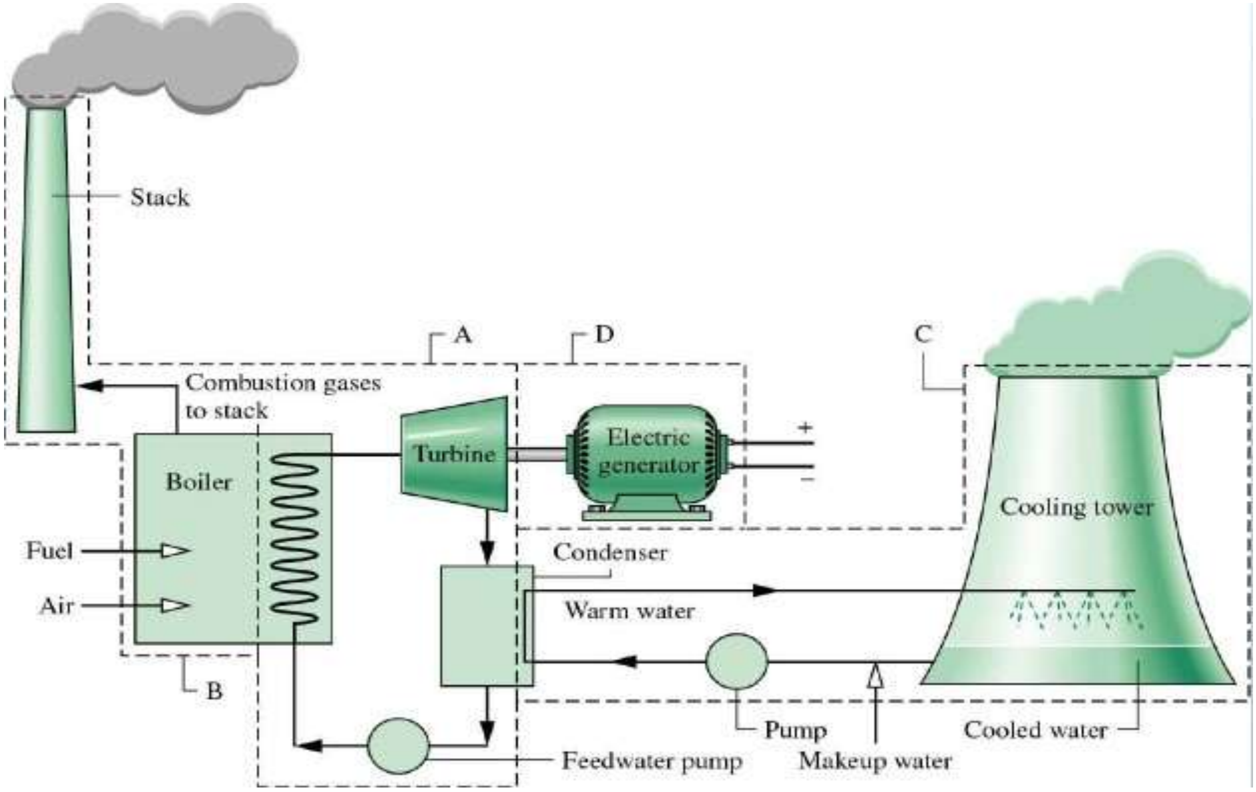

Fig 1.1 Working of Thermal power plant

1.2 HEAT REQUIRED FOR PHASE CHANGE, LIQUID TO VAPOUR

Latent Heat of Vaporization:

All pure substances in nature are able to change their state. Solids can become liquids (ice to water) and liquids can become gases (water to vapour) but changes such as these require the addition or removal of heat. The heat that causes these changes is called latent heat. Latent heat however, does not affect the temperature of a substance - for example, water remains at 100°C while boiling. The heat added to keep the water boiling is latent heat. Heat that causes a change of state with no change in temperature is called latent heat. [3]

1.3 WORKING OF BOILER IN POWER PLANT

Generally Boilers are used to produce steam at high pressure than atmospheric pressure. The steam generator is also known as boiler. Steam is the most important working substance used for power generation in steam engines and in steam turbines. The generation of steam is done by evaporating the water in boilers at appropriate temperatures and pressures. A "Boiler" may be defined as a combination of equipments to generate steam from water by burning fuel. In industries the steam may be used for different purposes.

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care. [4]

1.4 FEED WATER HEATING

The boiler system comprises of feed water system, steam system and fuel system. The **feed water system** provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair. The **steam system** collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges. The **fuel system** includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system. The water supplied to the boiler that is converted into steam is called **feed water**. The two sources of feed water are: (1) **Condensate** or condensed steam returned from the processes and (2) **Makeup water** (treated raw water) which must come from outside the boiler room and plant processes. **For higher boiler efficiencies, the feed water is preheated by economizer, using the waste heat in the flue gas.** [5]

Boiler component' means Steam piping, Feed water piping, Economizer ,Super heater, any mounting or other fitting and any other external or internal part of a Boiler which is subjected to pressure exceeding one kilogram per centimeter square gauge.
Steam Pipe means any pipe through which steam passes if-

(1) The pressure at which the steam passes through such pipe exceeds 3.5 kg/cm^2 above atmospheric pressure, or

(2) Such pipe exceeds 254 mm in internal diameter and pressure of steam exceeds 1 kg/cm^2 above the atmospheric pressure and includes in either case any connected fitting of a steam pipe. [6]

1.5 SOLAR ENERGY

Solar Energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass, account for most of the available renewable energy on earth. Only a minuscule fraction of the available solar energy is used. Solar powered electrical generation relies on heat engines and photovoltaic. Solar energy's uses are limited only by human ingenuity. A partial list of solar applications includes space heating and cooling through solar architecture, potable water via distillation and disinfection, day lighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes. To harvest the solar energy, the most common way is to use solar panels. [7]

In 2011, the International Energy Agency said that solar energy technologies such as photovoltaic panels, solar water heaters and power stations built with mirrors could provide a third of the world's energy by 2060. The energy from the sun could play a key role in de-carbonizing the global economy alongside improvements in energy efficiency and imposing costs on greenhouse gas emitters. "The strength of solar is the incredible variety and flexibility of applications, from small scale to big scale". [8]

1.6 SOLAR HEATING DEVICES

Concentrating solar collectors

Solar collectors are used to produce heat from solar radiation. High temperature solar energy collectors are basically of three types;

1. **Parabolic trough system:** at the receiver can reach 400° C and produce steam for generating electricity.

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2. Power tower system: The reflected rays of the sun are always aimed at the receiver, where temperatures well above 1000° C can be reached.

3. Parabolic dish systems: Parabolic dish systems can reach 1000° C at the receiver, and achieve the highest efficiencies for converting solar energy to electricity.

Parabolic Trough collector System

Trough systems use linear concentrators of parabolic shape with highly reflective surfaces; whish can be turned in angular movements towards the sun position and concentrate the radiation onto a long-line receiving absorber tube. The absorbed solar energy is transferred by a working fluid, which is then piped to a conventional power conversion system. [9]

Parabolic trough power plants are line-focusing STE (solar thermal electric) power plants. Trough systems use the mirrored surface of a linear parabolic concentrator to focus direct solar radiation on an absorber pipe running along the focal line of the parabola. The HTF (heat transfer fluid) inside the absorber pipe is heated and pumped to the steam generator, which, in turn, is connected to a steam turbine. A natural gas burner is normally used to produce steam at times of insufficient insolation. The collectors rotate about horizontal north–south axes, an arrangement which results in slightly less energy incident on them over the year but favors summertime operation when peak power is needed. [10]

Parabolic trough solar technology is the most proven and lowest cost large-scale solar power technology available today, primarily because of the nine large commercial-scale solar power plants that are operating in the California Mojave Desert. These plants developed by Luz International Limited and referred to as Solar Electric Generating Systems (SEGS), range in size from 14–80 MW and represent 354 MW of installed electric generating capacity. More than 2,000,000 m2 of parabolic trough collector technology has been operating daily for up to 18 years, and as the year 2001 ended, these plants had accumulated 127 years of operational experience. The Luz collector technology has demonstrated its ability to operate in a commercial power plant environment like no other solar technology in the world. Although no new plants have been built since 1990, significant advancements in collector and plant design have been made possible by the efforts of the SEGS plants operators, the parabolic trough industry, and solar research laboratories around the world. This paper reviews the current state of the art of parabolic trough solar power technology and describes the R&D efforts that are in progress to enhance this technology. The paper also shows how the economics of future parabolic trough solar power plants are expected to improve. [11]

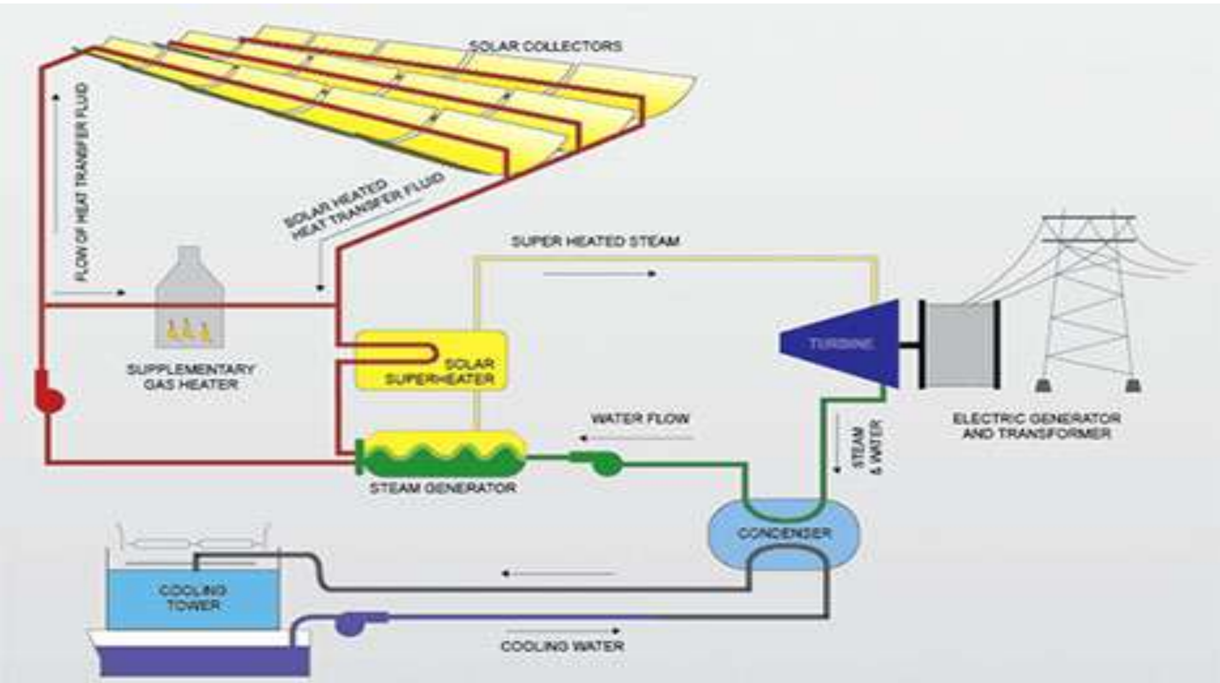

Fig: 1.2 Parabolic Trough collectors

Power Tower System

In power tower systems, heliostats (A Heliostat is a device that tracks the movement of the sun which is used to orient a mirror of field of mirrors, throughout the day, to reflect sunlight onto a target-receiver) reflect and concentrate sunlight onto a central tower-mounted receiver where the energy is transferred to a HTF. This energy is then passed either to the storage or to power-conversion systems, which convert the thermal energy into electricity. Heliostat field, the heliostat controls, the receiver, the storage system, and the heat engine, which drives the generator, are the major components of the system. [12]

For a large heliostat field a cylindrical receiver has advantages when used with Rankine cycle engines, particularly for radiation from heliostats at the far edges of the field. Cavity receivers with larger tower height to heliostat field area ratios are used for higher temperatures required for the operation of Brayton cycle turbines. These plants are defined by the options chosen for a HTF, for the thermal storage medium and for the power-conversion cycle. HTF may be water/steam, molten nitrate salt, liquid metals or air and the thermal storage may be provided by PCM (phase change materials). Power tower systems usually achieves concentration ratios of 300–1500, can operate at temperatures up to 1500o C. To maintain constant steam parameters even at varying solar irradiation, two methods can be used:

(1) Integration of a fossil back-up burner; or

(2) Utilization of a thermal storage as a buffer

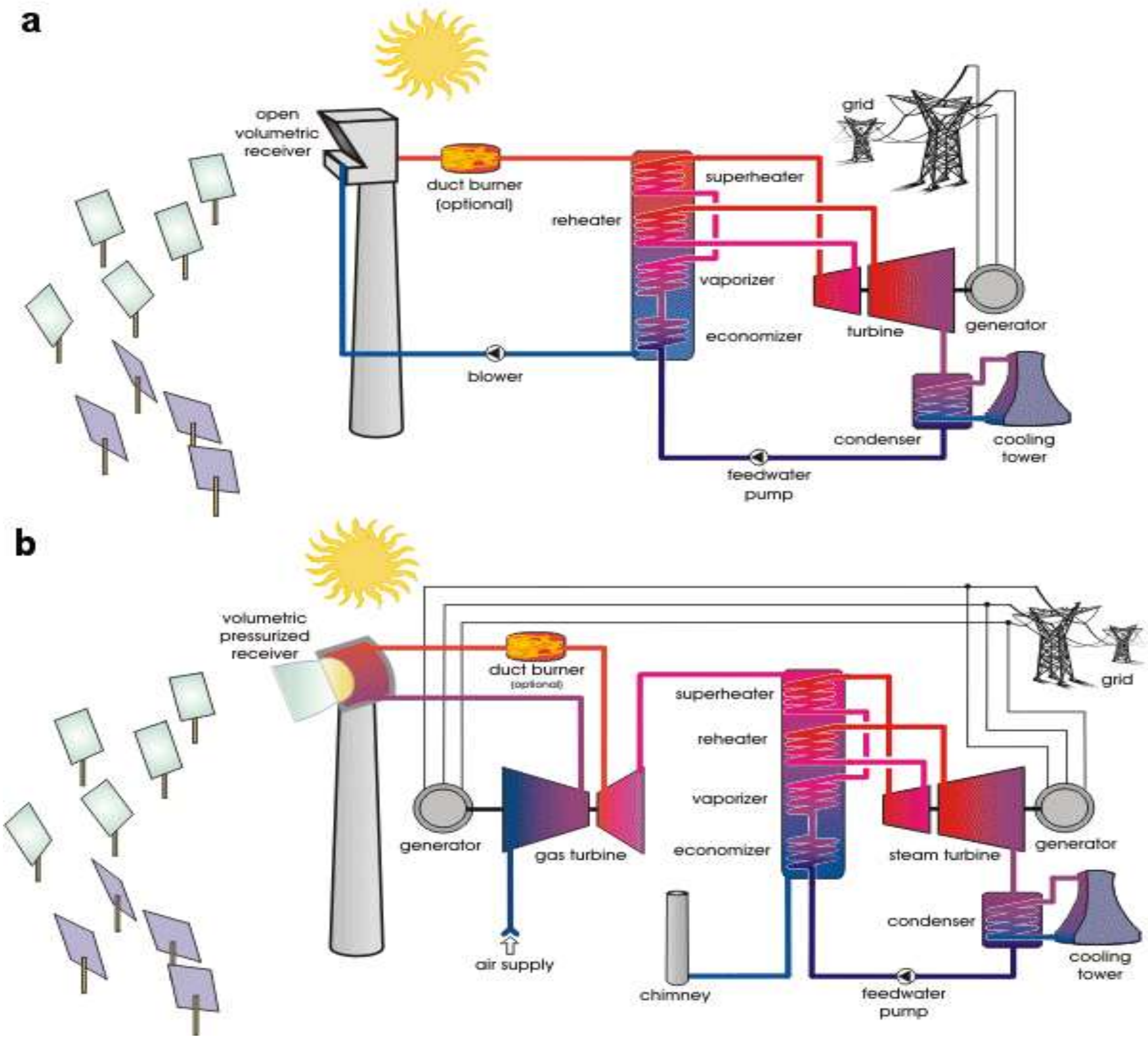

Fig: 1.3 solar receiver technologies

By the use of thermal storage, the heat can be stored for few hours to allow electricity production during periods of peak need, even if the solar radiation is not available. The modern R&D efforts have focused on polymer reflectors and stretched-membrane heliostats. A stretched-membrane heliostat consists of a metal ring, across which two thin metal membranes are stretched. A focus control system adjusts the curvature of the front. Membrane, which is laminated with a silvered-polymer reflector, usually by adjusting the pressure in the plenum between the two membranes.

Examples of heliostat based power plants were the 10 MWe Solar One and Solar Two demonstration projects in the Mojave Desert, which have now been decommissioned. The 15 MW Solar Tres Power Tower in Spain builds on these projects. In Spain the 11 MW PS10 Solar Power Tower was recently completed. In South Africa, a solar power plant is planned with 4000 to 5000 heliostat mirrors, each having an area of 140 m². [13]

Parabolic Dish system

The parabolic dish system uses a parabolic dish shaped mirror or a modular mirror system that approximates a parabola and incorporates two-axis tracking to focus the sunlight onto receivers located at the focal point of the dish, which absorbs the energy and converts it into thermal energy. This can be used directly as heat for thermal application or for power generation. The thermal energy can either be transported to a central generator for conversion, or it can be converted directly into electricity at a local generator coupled to the receiver.

The mirror system typically is made from a number of mirror facets, either glass or polymer mirror, or can consist of a single stretched membrane using a polymer mirror of thin metal stretched membrane The PDC (Parabolic dish collector) track the sun on two axes, and thus they are the most efficient collector systems. Their concentration ratios usually range from 600 to 2000, and they can achieve temperature in excess of 150000C . Rankin-cycle engines, Brayton-cycle engines, and sodium- heat engines have been considered for systems using dish-mounted engines the greatest attention though was given sterling-engine systems. [14]

Fig: 1.4 Parabolic Dish Collectors

The main challenge facing distributed –dish system is developing a power-conversion unit, which would have low capital and maintenance costs, long life, high conversion efficiency, and the ability to operate automatically. Several different engines, such as gas turbines, reciprocating steam engines, and organic Rankin engines, have been explored, but in recent years, most attention has been focused on stirling-cycle engines. These are externally heated piston engines in which heat is automatically added to a (normally hydrogen or helium at high pressure) that is contained in a closed system.
The Stirling Energy Systems (SES) and science Applications International Corporation (SAIC) dishes at UNLY and the big Dish in Canberra, Australia are representatives of this technology. [15]

LITERATURE REVIEW

Shahin Shoeibi et al. 2022, This study has investigated single-slope solar still using an evacuated tube heat pipe solar collector (ETHP-SC) and a new design of external condenser. The ETHP-SC increased the saline water temperature. On the other hand, the external condenser enhanced the condensation rate using a wind ventilator and a water cooling system. The pressure inside the modified solar desalination decreased by the suction of water vapor with the wind ventilator. The water vapor flowed to the external condenser and was distilled by hitting the perforated copper plate connected to the water cooling system. Results revealed that the fresh water generation of solar desalination using an external condenser and ETHP was about 2.13 times those of conventional ones. [16]

Oguzhan Erbas 2021. In this study, a coal-fired industrial type boiler's performance and emission tests were performed using the energy balance method. During the experiments, the directives in the test standard (ASME PTC - 4) were followed. This tested boiler has a capacity of 75t/h and is used in the mining industry. This boiler is a steam drum boiler equipped with an atmospheric circulating fluidized bed furnace. The furnace chamber with a rectangular cross-section has its width of 4250 mm and a depth of 4100 mm. In order to minimize the height of the furnace chamber and whole boiler, the middle wing walls are built-in the furnace chamber. As a result of the performance test, the boiler efficiency (in direct method) was found to be 93.07% (base on the lower heating value of fuel). [17]

M.J. Montes et al.2023 This work addresses the comparative thermo-economic study of different configurations of solar thermal power plants, based on super critical power cycles and pressurized central receiver systems. For all the cases examined, two innovations are introduced in the solar subsystem, compared to other similar studies. Firstly, the heat transfer fluid in the receiver is either a pressurized gas or a supercritical fluid. Secondly, the receiver is composed of compact structures performing as absorber panels, arranged in a radial configuration. The investigation considers different super critical CO_2 recompression cycles of $50MW_e$, including an oval proposal of a directly coupled cycle with heat input downstream of the turbine. Furthermore, the study evaluates different heat transfer fluids in the receiver, specifically CO_2, N_2, and He, concluding that the former is preferred due to its better thermal performance. [18]

V. Siva Reddy et al. 2013, Case studies of typical 50MW solar thermal power plants in the Indian climatic conditions at locations such as Jodhpur and Delhi is highlighted with the help of techno-economic model. Different solar concentrator technologies (parabolic trough, parabolic dish and central power tower) for solar thermal power plants are compared economically. It has been found that the parabolic dish concentrating solar Sterling engine power plant generate electricity at allow unit cost than the other two solar technologies considering 30 years life spanand10% investment. [19]

S. Sadhishkumar et al.2014, This review paper summarizes the previous works on solar water heating systems with various heat transfer enhancement techniques include collector design, collector tilt angle, coating of pipes, fluid flow rate, thermal insulation, integrated collector storage, thermal energy storage, use of phase change materials, and insertion of twisted tapes. This paper also discussed the methods to optimize and simulate the solar water heating systems to understand flow and thermal behavior in solar collectors that would lead to the improvement of the thermal performance of solar collectors. [20]

3. METHODOLOGY

3.1 Theoretical Investigation on coal based power plant of 64 MW by implement Solar Heaters for preheating of boiler makeup water of (50000 Liters) in every 24 hour.

Theoretical Investigation include :

(1) The capacity of SWH required maintaining the temperature of 80-90^{0}C in makeup water tank (feed water, 50000 liter)

(2) Type of solar water heater (Solar collector) required to maintain The temperature of 80^{0}C in Solar water tank.

(3) Cost required to implement setup (ETC) for preheat feed water Of 50000 liters

(4) Area required to installing solar water heater.

(5) Saving of coal by Implement solar water heater (Solar collector of Trough and Evacuated type) for preheat boiler feed water.

(6) Saving of money in terms of coal per day.

3.2 Available parameters from 64MW Coal based Power plant

Boiler Specifications
General Features of Boiler used in (Ruchi Groups Gandhidham)

Installed Capacity	64 MW
Fuel(Coal)	Bituminous F Grade
Boiler Type	Circulating Fluidized bed Combustion
Pressure	85Kg/mt2
Temperature	485degreeC
Steam Generation rate	144TPH
Fuel Burning Rate	24.5TPH
DM water tank Capacity	3 tanks each of 100KL
Make up water required for every 24 hours	50KL
Normal Temperature of DM water	25degreeC

3.3 Selection of Solar Collector for heat 5000 Liters feed Water up to Temperature of 80-90^{0}C

There are many types of Solar Collectors are used for heat water according to requirement

1. Parabolic Trough Solar Collector
2. Solar Power Tower Collector

3. Parabolic Dish Collector
4. Flat Plate Collector
5. Evacuated tube Solar Collector

Parabolic Trough, Power Tower System & Parabolic Dish Collector are already used in Solar Thermal Power Plant for their high temperature generation capacity. Flat Plate Collector & Evacuated tube Collector is used for heat Small Quantity of Water up to 50000 Liters and maintains a temperature of 90-100^{0}C. [26] For 25000 liters feed water heating, evacuated tube solar collector will be perfect to maintain a temperature of 90^{0}C. [21]

Conventional Flat Plate collectors are suited for warmer climates and for the times when the intensity of the solar radiation is substantially high. Their benefits are however reduced when they are exposed to cold, cloudy and windy days. Furthermore, when exposed to weathering conditions, the tubes and the insulation has a tendency to deteriorate thereby causing loss of performance. Each evacuated tube consists of two glass tubes made from extremely strong borosilicate glass. The outer tube has very low reflectivity and high transitivity that radiation can pass through. The inner tube has a layer of selective coating that maximizes absorption of solar energy and minimizes the reflection, thereby locking the heat. The ends of the tubes are connected to the copper header are fused together and a vacuum is created between them. This Process is called evacuation, as by definition, it means that the air is pumped out from the cavity. The vacuum is created for recreate the thermos flask effect as vacuum acts as an insulator and does not allow short wave radiation to escape through the glass tube. [15]

This traps the solar radiation much more effectively and hence higher temperature can be achieved it means that the evacuated tube collectors have a capacity to perform better than flat plate collectors in cold and cloudy climates. On the internal surface of the inner borosilicate glass tube there is a absorber plate which collects the radiation that passes through the glass layer. This absorber plate is mostly of aluminum or copper as both of these metals have a high heat reflectivity and transitivity quotient. It is also painted black so as to allow it to absorb maximum amount of solar radiation. [23]

3.4 Mechanism of Evacuated Tube Solar Water Heater

Solar Water Heating has been used for hundreds if not thousands of years to heat water. With advances in technology solar water heating systems have become more and more efficient, with Evacuated Tube Solar Water Heating offering efficiencies of well over 90%.[21] That means that more than 90% of the sun's energy landing on a surface is converted into heat which can be used to heat water. This is also one of the cheapest renewable; with costs starting from pennies per Watt required comparing to pounds per Watt for PV Solar and Wind Turbine power generation. Vacuum or Evacuated Tubes are made from glass - typically ultra-strong and heat resistant Pyrex with a double wall construction. [24]

Fig: 3.1 Evacuated tube solar water heaters

The glass on the inner tube is coated on its outer surface with an absorbent coating, and on its inner surface with a reflective coating. Inside each tube all air is removed making a vacuum and a copper heat pipe is located through the center of the tubes. Most of the infra-red radiation (i.e. heat) from the sun is absorbed by this sealed heat pipe which contains an anti-freeze type liquid. [25]

As heat rises, hot vapors from the antifreeze rise up to the top of the heat pipe where its copper tip connects with a header pipe through which more antifreeze flows. This hot antifreeze is then pumped through pipes inside the hot water tank with the end result that the water gets hotter and the antifreeze cooler. The antifreeze then continues its journey around the system and back out to the solar water heater to be reheated. The copper at the tip of the heat tube can reach well over 200^0C easily heating water to 90^0C on hot days and to 60^0C even in the winter. This simple system is completely sealed and needs minimal maintenance over its 20+ year's life.

The Advantage of using evacuated tubes is that they will work even during the coldest winter months unlike old style Flat Plate Solar Collectors. The vacuum prevents the heat tube from being cooled much by the ambient temperature which can be well below freezing, and so winter sun can easily heat water to 50+ degrees even in the depths of the coldest season. Even if it is very cloudy and very cold, enough sunlight gets through to keep the tubes well above freezing and so they will be still be pre-heating the water which can then be heated further by a standard immersion heater or gas burner reducing the costs of heating the water.

The Evacuated tube collector are design in such a way that hot water with temperature range 60-80^0C will be available for maximum no of days throughout the year however the system can deliver the hot water at the temperature varying from 60-80^{0}C depending on the season and availability of sunshine. Right from top to bottom available hot water temperature remains almost same due to non-mixing design of system and plumbing Evacuated tube collector is suit for any type of water. Unique feature of (ETC). is its special lined hot water tank which prevents from the scale deposition on inner side of tank, as well, in case of etc. water heating takes place in glass hence there is no bonding of scales possible on smooth surface of glass tube. However, there, can be some settlement of salt and dirt particles at the bottom of vacuum tube. There is a possibility of some stains or particle deposition on inner wall of evacuated tube due to inferior water quality, which can be easily removed at the time of servicing. [26]

Air between the gaps of two glass tubes is evacuated. It results in high level of vacuum, which acts as the best insulation to minimize the heat loss from inner tube. The **black** coating on the inner tube absorbs the solar energy and transfers it to the water. The water on upper side of vacuum tube becomes hot and thus lighter, so it starts moving upward from the tank and is stored at the bottom. The phenomenon is called as natural thermo siphon circulation, which occurs in every tube.

3.5 Advantages of Evacuated Tube solar collector water heating

Sunrays remain perpendicular to cylindrical absorber surface of vacuum tubes. It can absorb more energy resulting in more efficiency of the tubes. Even in smaller capacity range, many models are designed just by varying numbers of evacuated tubes. Hence wide ranges are available to select the exact system to match the individual requirement due to this feature, the system has become more economical and cost effective the flat plate collector uses costly metals like copper and aluminum. On the other hand the Evacuated tube collector requires only glass tubes. This is made possible due to technological advancement, which has resulted in substantial cost saving.

1. Reduction in peak load.
2. Reduction in rate of global warming.
3. Negligible scaling of tubes.
4. Higher efficiency on high temperature.
5. Less space & more economical.
6. Long life more than 15 years.
7. Maintenance Free.
8. Heat loss in the tubes during the daytime is negligible (evacuated tubes)
9. Convection and Convecting losses are low.
10. Satisfactory performance even in extreme cold condition (-18 deg. C)
11. Temperature range from 60deg. to 120 deg.
12. The collector glass tube absorbers being cylindrical the incident sun's rays on the
13. Tubes are at 90 degrees throughout the day. Hence peak heat absorption always.

3.6 Reasons for selecting evacuated tube solar collector

1. Due to high heat transfer rate of Evacuated tube solar heater, it will be efficient for Makeup water heating of boiler
2. Evacuated tube collector has more surface area than flat plate collector, for same Capacity. [30]
3. Evacuated tube collector is suitable for every weather condition.
4. In a cold season of winter evacuated tube maintain a minimum temperature of 60^{0}C
5. Evacuated tube collector is cheaper than flat plate for same capacity.
6. Evacuated tube collector need zero maintenance for any weather condition
7. For mass water heating evacuated tube collector are successful.

3.7 Maintenance and servicing of evacuated tube solar collector

Generally the water supplied through local municipal authorities is always of good quality. This is well treated, after demineralize the water in DM plant, the feed water become soft filtered and having hardness below 50 ppm. If such water is used through Evacuated tube, the maintenance and servicing required will be almost negligible. When the water hardness is higher or when the suspended dirt and impurities are present in the water, there is a possibility of stains dirt accumulation inside the vacuum tube. This can be easily removed by removing the evacuated tube and cleaning them properly. These services can be made available from trained solar plumbers through dealers. However for achieving consistent performance and better life of ETC. it is recommended to do servicing of whole system once in year, which includes cleaning of vacuum tubes and hot water tank. The rubber parts like seal, grommets etc. may require replacement while serving. This will be made available in the market. [27]

3.8 Cost Required for Implement Setup

In thermal power plant of 64MW, in every 24hr 50,000 liters makeup water is required. Temperature of makeup water is normally at 25^0C at atmospheric condition for maintaining a temperature of $70\text{-}80^0$C in 50000 liters makeup water. For capacity of 50000 liters solar water heater (ETC), money required is 50 lakh rupees.

3.9 Area required to implementing the setup

Area required to implement solar collector of evacuated tube type for 50000 liters is 8000^2ft. Total 100 Solar Arrays(Evacuated tube type) will require of capacity 500 liters each Solar array Dimension of Each array (Solar Collector) will be 12ft by 13ft. Tank of capacity 30000 liters will require to store 50000 liters hot water. [28]

3.10 Size of Solar Array (ETC) for 500 liters of water

Dimension of Single array of capacity 500 liters that require solar panel of size 12 by13ft that contains total 60tubes,30tubes in left and 30tubes in right Every 50 solar array will install in column & row wise that will capture area of 40002ft. ETC solar panel of 500 liter capacity of each has shown below

Fig: 3.3 Solar Arrays of capacity 500 Liters each

3.13 SYSTEM SPECIFICATION (Evacuated Tube type solar water Heater of Capacity 500 Liters) Table: 3.1

1.	System Capacity	500 liters
2.	No. of Tubes	60
3.	Tube Specifications	Length-1800mm,58 mm OD
4.	Vacuum Tube Material	Borosilicate Glass
5.	Absorber coating	Coating of Aluminum Nitride by worlds latest innovative technology "Magnetron Sputtering Technique"
6.	Absorptivity	>92%
7.	Thermal Expansion	3.3×10^{-6}degc
8.	Stagnation Temperature	>200^{0}c
9.	Weight of single tube	2.2Kg
10.	Tube Resting Caps	UV Stabilized ABS Plastic
11.	Water circulation	Natural Thermo siphon

3.14 Tank Specification (Solar heated water storage tank) Table 3.2

1.	Tank Capacity	25000
2.	Tank Material	SS-304L
3.	Tank Material type	Food Grade
4.	Insulation Material	PUF
5.	Insulation Thickness	50mm
6.	Type of Tank	Horizontal
7.	Tank cladding material	Pure polyester power coated cover
8.	Support Structure	GI- Powder coating

3.15 Solar water storage tank of capacity 30,000 liters

These tank contain the Quality of high pressure insulation, Special nonstick lining to prevent scale deposition & corrosion also heavy duty dished end steel tank enhances tank life. Increases strength, pressure stability and avoids stress corrosion. [29]

Renowned Research institute From Germany & Australia first invented & successfully experimented the solar collector with evacuated tube technology .this technology was commercially implemented by some chines companies & numbers of systems have been installed all over the country which is working very successfully since last 15 years . now in china, millions of etc. are being installed, many of them even in used in hospital, swimming pool heating. Now the technology is widely accepted all over the world, many systems are working successfully throughout the world, even in developed countries like USA, Japan, Germany, Australia, Spain etc. Though the technology seems to be new for country, it is a well-proven & highly reliable product. That's why Government of India (MNES) Ministry of Non-conventional energy sources have approved the product etc. & decided to promote its use throughout our country.

The evacuated tubes are made from specially developed thick borosilicate glass which can very well resist the hail stoning even up to 1" size. So after installation the chances of tubes breakage are almost nil. Only precaution required is not to feed cold water in the empty system during afternoon sunshine hours. The temperature inside dry vacuum tubes may go even to 250^0C during hot sunshine, if the cold water enters in such a condition there is a possibility of cracking of tubes due to thermal shock. So it is very necessary to fill the tank with cold water before 9 a.m. in the morning.

The evacuated tubes are design and manufactured in such a way that the expected life of the tubes will be minimum 15 years. Looking into the experience of many systems already installed in foreign countries like china, USA Germany the estimated life of system is about 10-17 years. With good water quality and proper precautions similar life can be easily achieved in Indian condition also. [30]

3.15 Time required for rising temperature from 35 to 80^0C

Six hour direct sunlight is required to rise a temperature in any season (Data collected from sudarshan Saur limited) **Table: 3.3**

Season	**Atmospheric Temperature**	**Temperature rise**	**ΔT**
Summer	25^0	80^0	55^0
Winter	20^0	65^0	40^0
Rainy	20^0	65^0	45^0

3.16 Performance Parameters on which Evacuated tube solar water heater work (Data collected from sudarshan sour limited)

Direct sunlight of six hour is required to rise temperature. Rise of temperature is not depend on season, it only depends on availability of sunlight for six hour Solar water heater of evacuated tube type is most suitable for Indian climate. In summer season rise in temperature is rapid. [31]

3.18 Existing layout of 64 MW Coal based power plant

Layout of thermal power plant are shown below these layout contain the complete working of power generation by using coal as a prime fuel These Layout Contains
DM Water Plant
Coal handling
Ash handling
Pulverizing of coal
Fly Ash removal

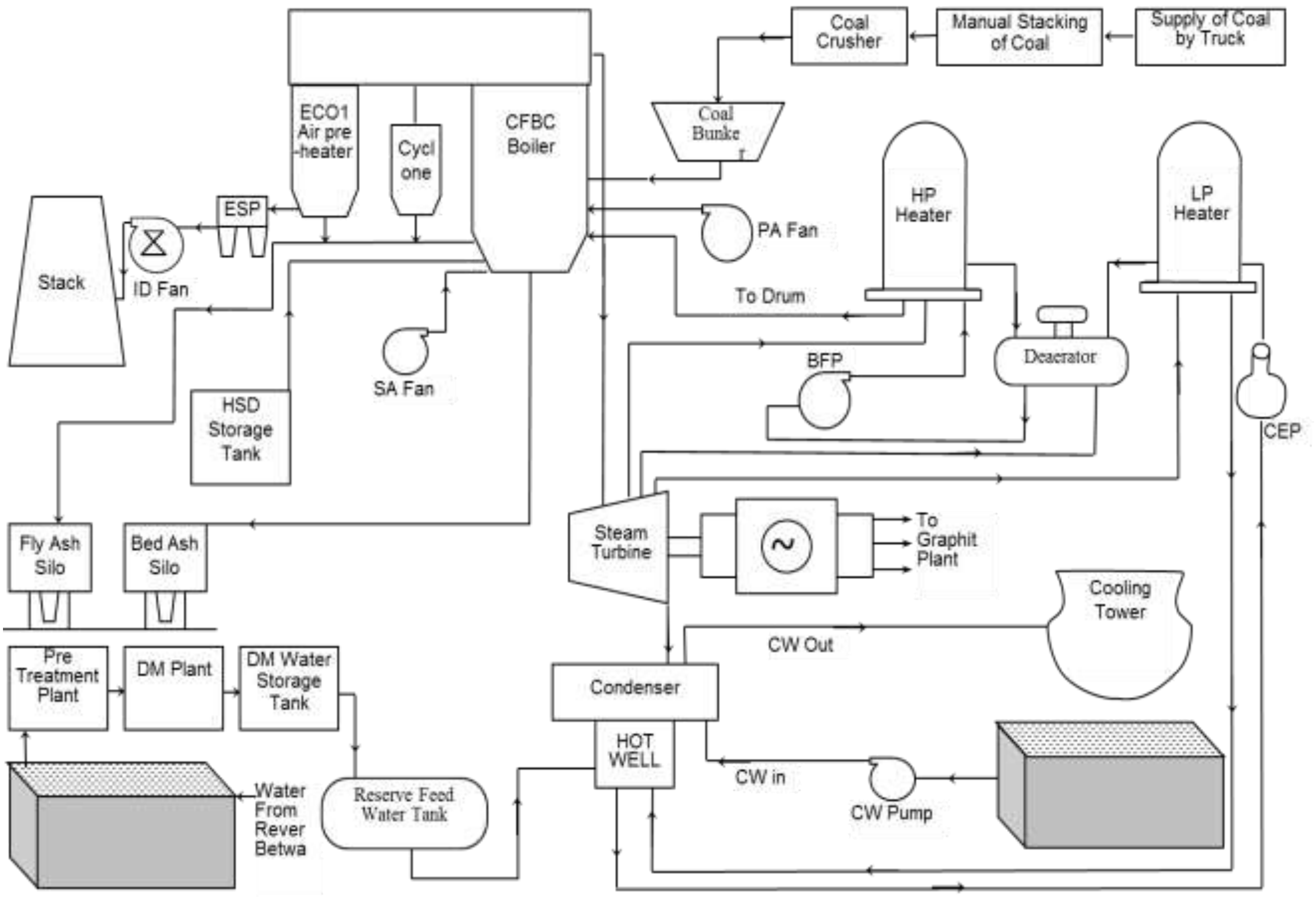

Fig: 3.4 layout of power plant

3.4 Proposed layout of 64 MW Coal based power plant

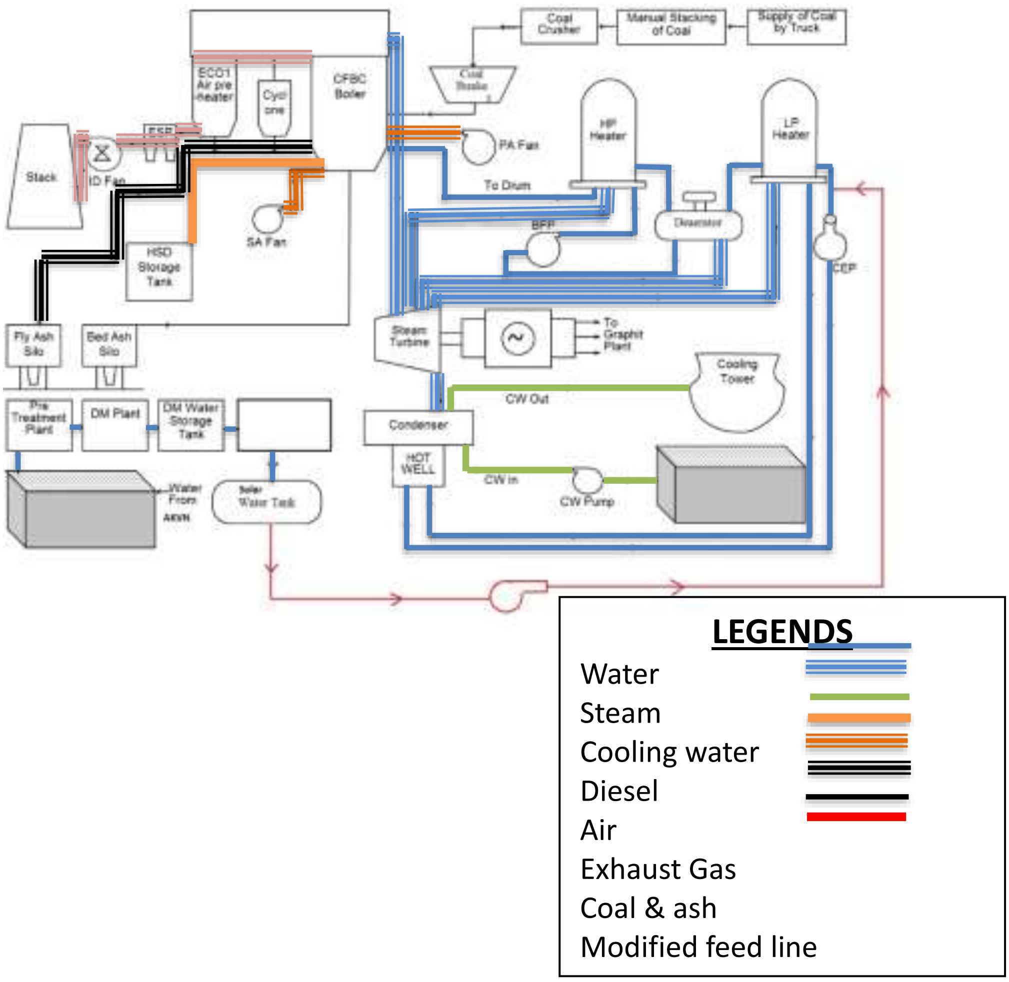

Fig: 3.5 proposed layout

In Proposed setup Solar heated feed water is directly send to boiler by feed pump Solar Panels will install near makeup water plant So water comes from DM Plant(Demineralized) will pass through Solar water heater of evacuated tube type than after rising temperature it will store in tank of capacity 30000liters(adiabatic chamber) It will maintain the temperature of hot water for 10-12 hours. Solar water heater cab be used as an accessory for preheat feed water in a thermal power plant.

3.20 Water Treatment plant for capacity 64 MW Thermal power plant

In a Water treatment plant , Water comes from AVKN, (Audyogik Vikas Kendra Nigam). During water treatment, removes all the impurities contain in water and also demineralized the water by using chemical solution and acids and make water perfect for boiler feeding. Water treatment plants contain three tanks each of capacity 100KL.

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Fig: 3.6 Water treatment plant of 64 MW Thermal power Plant

Since there is continuous withdrawal of steam and continuous return of condensate to the boiler, losses due to blow down and leakages have to be made up to maintain a desired water level in the boiler steam drum. For this, continuous make-up water is added to the boiler water system. Impurities in the raw water input to the plant generally consist of calcium and magnesium salts which impart hardness to the water.

Fig: 3.7 DM Water Storage tank-1 of capacity 100KL

Hardness in the make-up water to the boiler will form deposits on the tube water surfaces which will lead to overheating and failure of the tubes. Thus, the salts have to be removed from the water, and that is done by water demineralizing treatment plant (DM). A DM plant generally consists of cat ion, anion, and mixed bed exchangers. Any ions in the final water from this process consist essentially of hydrogen ions and hydroxide ions, which recombine to form pure water. Very pure DM water becomes highly corrosive once it absorbs oxygen from the atmosphere because of its very high affinity for oxygen.

Fig: 3.8 DM Water Storage tank-2 of capacity 100KL

The capacity of the DM plant is dictated by the type and quantity of salts in the raw water input. However, some storage is essential as the DM plant may be down for maintenance. For this purpose, a storage tank is installed from which DM water is continuously withdrawn for boiler make-up. The storage tank for DM water is made from materials not affected by corrosive water, such as PVC. The piping and valves are generally of stainless steel. Sometimes, a steam blanketing arrangement or stainless steel doughnut float is provided on top of the water in the tank to avoid contact with air. DM water make-up is generally added at the steam space of the surface condenser (i.e., the vacuum side). This arrangement not only sprays the water but also DM water gets deaerated, with the dissolved gases being removed by a de-aerator through an ejector attached to the condenser.

Fig: 3.9 DM Water Storage tank-3 of capacity 100KL

RESULT & DISCUSSION

Calculation of coal saving is done on the basis of temperature rise of makeup water (50000 liter) in every 24 hours by solar energy. Temperature rise of makeup water by solar radiation is free by implementing solar water heater. Normally makeup water is send to boiler assembly at temperature of 25^0C, but by implementing solar water heater we can rise the temperature of makeup water up-to 90^0C without any running expense. By energy unit conversion we can calculate exact amount of coal save per day. By using the formula of temperature rise, $Q = mc_p\Delta t$ we can calculate the quantity of heat required to rise the temperature. We know that heat is a form of energy and also coal contains energy in the form of calorific value.

Performance Parameters

Thermal power plant of capacity	=	64MW
Amount of makeup water feed in every 24 hours	=	50000 liter at 25^0C
Required temperature of makeup water	=	90^0C
Calorific value of coal used	=	2500kilo-calorie per kg
Rise of temperature at constant pressure	=	1bar
Specific heat at constant pressure (C_p)	=	4184 J/kg/°C
Price of coal in India	=	4000 to 7000 Rs per ton

Calculation of coal saving

Heat required Q to rise temperature of makeup water from 35 to 90^{0}C can be calculated by the formula given below Table: 4.1

Sr.No. 1	Performance Parameters	Symbol	Formula	Unit
1.	Heat required	Q	Q= mcpΔT	joule

Where Q = Heat required
M = mass of water
C_p = Specific Heat at Constant Pressure = 4184 J/kg/ºC

Coal Prices in India according to Grade and Calorific value (Data Collected from coal India limited) Table 4.2

Unit/Grade of Coal	Calorific value(Kilocalorie/Kg)	Rs/Tonne
A	4000-3000	7100
B	2500-3000	4500
C	Below 2500	Below 4000

Calculation of coal saving in measured by equating the calorific value of coal and heat required to rise temperature of makeup water (energy balance).

Temperature rise of water is measure by using formula

Q = mcpΔT

Where;

Q = heat generated
Cp = Specific heat at constant pressure = 4184 J/kg/ºC
ΔT = Temperature rise
m = Mass of water
C = 2500 Kilocalorie/kg

For 64 MW power plant

Calorific value of coal used in thermal power plant = 2500 kilocalorie/kg
Makeup water required per 24 hour = 5,0000litres
Temperature of makeup water at atmospheric condition = 25^0C

Case: 1

Q = Heat required to convert 25^0C feed water to 80^0C
Q = mcpΔT
= (mass of water) (Specific heat at constant pressure) (rise in temperature)
= (50000kg) (4187 J/kg/ºC) (55 ºC) = 11514.25MJ

Calorific value of coal used 2500kcal/kg
11514250000joule =2751971.8 kilo calories
11514.25MJ heat is generated by burning of 1100.7 kg of coal
1100.7 kg of coal can save per day.
Case: 2

Q = Heat required to convert 25^0C feed water to 70^0C
Q = mcpΔT
= (mass of water) (Specific heat at constant pressure) (rise in temperature)
= (50000kg)(4187 J/kg/ºC)(45 ºC) = 94207.5MJ

Calorific value of coal used 2500kcal/kg
9420750000joule =2251613.29 kilo calories
9427.5MJ heat is generated by burning of 900 kg of coal

900 kg of coal can save per day.
Case: 3

Q = Heat required to convert 25^{0C} feed water to 60^{0C}
Q = mcpΔT
= (mass of water) (Specific heat at constant pressure) (rise in temperature)
= (50000kg) (4187 J/kg/ºC)(35 ºC) = 7327.25MJ

Calorific value of coal used 2500kcal/kg
7327250000joule = 1751254.780kilocalories
7327.25MJ heat is generated by burning of 700 kg of coal

700 kg of coal can save per day.

Case: 4
Q = Heat required to convert 25^0C feed water to 50^0C
Q = mcpΔT
= (mass of water) (Specific heat at constant pressure) (rise in temperature)

= (50000kg)(4187 J/kg/ºC)(25 ºC) = 5233.75MJ

Calorific value of coal used 2500kcal/kg
5233750000joule = 1250896.27 kilocalories

5233.75 MJ heat is generated by burning of 500 kg of coal

500 kg of coal can save per day.

Saving of money in terms of coal consumption reduction per day

Table: 4.3

S no	Calorific value of coal	Prices of coal	Coal saving in diff cases per day	Saving of money per day
1.	2500kilocalorie/kg	25Rs per kg	1100 kg in case 1	Rs 27,500
2.	-	-	900 kg in case 2	Rs 22,900
3.	-	-	700 kg in case 3	Rs 17,500
4.	-	-	500 kg in case 4	Rs 12500

As we can see in above table of money saving us can save coal 1100 kg per day of price 27,500 Rupees by implementing evacuated tube solar collector setup for preheat make up water of capacity 50000 liter per day.

Saving of coal & money per year

Table 4.4

S no	Coal saving per year	Money saving per year	Calorific value of coal
1.	1100 × 365 = 401500 kg	25 × 401500 = 10037500	2500 kilocalorie/kg
2.	900× 365 = 328500 kg	25 × 328500 = 8212500	2500 kilocalorie/kg
3.	700 × 365 = 255500 kg	25 × 255500 = 6387500	2500 kilocalorie/kg
4.	500 × 365 = 182500 kg	25 × 182500 = 4562500	2500 kilocalorie/kg

As the result shows above table that after installing evacuated tube solar collector for preheating make up water of capacity 50000 liters per day as a result we can save coal 401500 kg per year of price 10037500 lakhs rupees.

All the above calculation of coal saving is done by using the coal of calorific value 2500kilocalorie/ kg if the thermal power plant use coal of higher calorific value then we can save more money per year. Also solar water heater is ecofriendly to environment it left zero emissions to the environment like Co_2 , So_2, No_2. (MNES) Ministry of Non-Conventional Energy Source also recommends the solar water heater for water heating so that the pollution spread by fossil fuel will reduce.

Payback time of proposed setup

The one time installation cost of solar water heater setup is 50lakhs Rupees that will be for forever there is no running cost required to maintain these setup as we can see in results we can save coal 401500kg per year of price 10037500 Rupees. So the payback time of proposed setup is only six month. Also this setup requires zero running & maintenance cost for at least 25 years.

5 CONCLUSION

There are many types of solar collectors are used in solar thermal power plant like parabolic trough collector, parabolic dish collector, power tower system. And also many successful research have done for implementation of solar energy in existing thermal power plant for reduce the dependency of coal. In addition to environment and long-term financial advantages, solar thermal technologies will provide a number of further benefits, which are difficult to quantify. This includes a reduction of the dependency from imported fossil fuels as well as a growth in local employment.

In the present work we have done the implementation of solar energy in 31 MW thermal power plants for heat makeup water 50000 liter from 25 to 90^{0}C in every 24 hours by using evacuated tube solar collector. The evacuated tube solar collectors provide a substantial difference in the temperature of the working fluid. The amount of heat transferred to the working fluid depends on the incident flux of solar radiation and on the aperture area of the tubes. The heat transfer coefficient of the air gap in the tubes plays a major role in facilitating the heat transfer. Also evacuated tube solar collector is easy to service & maintain.

The following conclusion has been found by preheat makeup water 50000 liter from 25 to 90^{0}C of 64MW coal based power plant

1. By rising the temperature of makeup water of quantity 25000 liter per 24 hour from 25 to 90^{0}C, saving of coal will be 1100 kg per day of price 27,500 Rupees.
2. For the whole year we can save coal 401500kg of price 10037500Rupees.
3. There is no running cost is required for evacuated tube solar collector also it has zero maintenance cost.
4. Also it reduces the problem of smoke emissions.

6 Future Scope of work

Future scope of the work is that the use of solar energy should be in small capacity power plant so that the dependency of coal will decrease. These are the following areas where research should be continue for better optimization of solar energy in conventional thermal power plant.

1. More research is required to store solar energy so that it can also work at night for steam generation.
2. Solar collectors should be making more economic so that it can be affordable for residential & commercial purpose.
3. More research should be done for different kinds of solar collector so that their efficiency can be increased to a extreme level.

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