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Solar Hybrid Thermal Power Plant: A Future Approach for Energy Sector

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Abstract
Thermal Power Plants are major source of power supply in most of the countries including India. Coal based plants are mostly the Thermal Power plants because of abundance in those countries. But these thermal plants are associated with pollution factor and uncertainty of supply of coal as ingridient at appropriate time. Besides there is a fixed reserve of coal which is depleting day by day. To alleviate such problem alternate approaches to existing thermal power plants are to be found out. Therefore, a hybrid model for the integration of solar energy into thermal powerplants is suggested. The aim of the paper is to illustrate the methodology to bring abouthybridisation in conventional thermal powerplants.Hybridisation is achieved by integrating a solar thermal powerplant for heating the working fluid in the boiler to produce steam at supercritical temperature. So that, there is a partial replacement of the coal energy by concentrated solar power. Since, in the proposed system ,a solar thermal powerplant has been integrated into a conventional coal based thermal powerplant, therefore this system is called as solar hybrid thermal powerplant.

Keywords: *solar hybrid thermal powerplant, solar thermal powerplant, concentrated solar power, Solar Augmentation, solar hybrid efficiency*

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I. INTRODUCTION

Energy is a fundamental necessity for any nation in the industrial sector for production, modernisation, and economic growth. Each nation's industrial sector has a significant effect on economic growth. Recent energy production and consumption patterns in manufacturing industries are incredibly unsustainable as greenhouse gas emissions are increasing rapidly. Currently, 80% of the world's supply of primary energy comes from fossil fuels (i.e., oil, liquid petroleum, gas), which are now a depleting source of energy and emit significant GHG emissions, including CO2[7]. Therefore, the world needs another industrial revolution that provides competitive, available, and renewable energy sources. With this revolution, energy management, recycling, and decarbonisation of our energy systems are essential. Hence, solar hybrid thermal powerplant is needed to reduce the amount of coal consumption by augmentation of solar thermal powerplant into the existing conventional coal based thermal powerplants, which would reduce the amount of coal consumption in thermal powerplants for the same power output by partially substituting coal energy by concentrated solar energy.

II. BACKGROUND AND SCOPE FOR AUGMENTATION OF THERMAL POWERPLANTS

Thermal powerplants are the major source of electrical power of most of the nations. There are other sources of conventional energy production e.g., wind energy, geothermal energy, tidal energy, hydro power. But, all of the above are mostly minor sources and their geographical availability and utility is a matter of probability. Therefore, thermal powerplants which includes coal-based powerplants, and nuclear powerplants both are widely acknowledged as a major power sources.Owing to unavailability of nuclear raw materials and potential risk involved in the operation of nuclear powerplant. Coal is predominantly used as the fuel. Fundamentally, thermal powerplants used coal as a fuel to boil water and produce steam at supercritical temperature(373’C). the steam is then supplied to the turbines, where the isentropic expansion of steam happens, and in turn turbine supplies mechanical power to the generator for the production of electricity. But, the entire process constitutes a heavy usage of coal which causes a lot of carbon emission. Thermal powerplants consume about 550kg of coal for 1MWh of power production. Therefore, in this article it is endeavoured to reduce the coal consumption required for the production of unit power output. This is achieved by of partial substitution of coal by concentrated solar power, which includes the production of steam by concentrating(focussing) the solar power upon a receiver(boiler) which not only produces steam, but also superheats the steam to a supercritical temperature in day time and for night usage steam in steam drums can be utilised. Moreover, a higher overall thermal efficiency can be achieved by using concentrated solar technology in conventional coal based thermal powerplants.

This paper constitutes the detailed analysis and description of the various systems and their functionalities of solar hybrid thermal powerplant. Up till now, various research articles focus primarily on solar thermal powerplant(STPP) which is completely solar based, but in this report it is discussed about the hybridisation or inculcation of solar thermal concept with that of conventional coal-based powerplant[2][4]. Briefly, the concept involves the simultaneous usage of concentrated solar power and coal energy for steam production, which would reduce the coal consumption by partial substitution of coal energy by concentrated solar power which would eventually reduce the carbon footprint.

III. SOLAR HYBRID THERMAL POWER PLANT

Solar hybrid thermal powerplant involves the simultaneous usage of concentrated solar power as well as coal energy for the purpose of steam production. Both the coal energy and concentrated solar power produce steam which is eventually fed to a common steam drum(where the produced steam at supercritical temperature is collected). The steam is used to run the turbine for the production of electricity[2][8]. Since, the process involves the simultaneous usage of concentrated solar power as well as coal energy , hence comes the name solar hybrid thermal powerplant. The concentrated solar power provides a source of high temperature process heat in the range of 500 - 2000° C which is compatible with temperatures generated by combustion, to produce power, fuels and materials. Moreover, concentrated solar power can be stored for night usage in steam drums, or molten sodium chambers[8]. During a cloudy day or night if required the stored heat in molten sodium chambers can be utilized to produce steam, or the already stored steam in steam drum can also be utilized. This is a very cheap means of storage without worrying about batteries for the power storage. Solar hybrid system offers both low net CO2 emissions and firm supply, providing greater security of supply than is possible with only “dispatchability”. Perennially sufficient supply is increasingly sought in OECD countries because the growth in intermittent renewables is leading to the increased curtailment of their output, while the strong growth in total demand in non-OECD countries is providing strong incentives to install new plants that cannot provide firm supply[3][8].

IV. PROPOSED SYSTEMS OF SOLAR HYBRID THERMAL POWER PLANT

The concept of solar energy concentration and collection isbased on a field of heliostats that reflect the incident sunshine to a receiver (boiler) at thetopof acentrally locatedtower. Solar energy to be collected in the entire field, is transmitted optically to a small centralcollection region. Typically, 80-95% of the reflected energy is absorbed in the workingfieldwhichispumpedupthetowerandintothereceiver.Thehatedfluid(orsteam)returnsdownthe towerand into the receiver. TherearemanysystemsintheSTPP.Theyarenamelyasfollows:

- Heliostats
- Reflectors
- Receiver tower
- Operation control System

1. HELIOSTATS

Heliostat isaninstrumentconsistingofmirrorsmountedonanaxismovedbyclockworkbywhicha sunbeam is steadily reflected in one direction. The thin glass mirrors are supported by asubstrate backing to form a slightly concave mirror surface. The reflected surface ismountedor supportedona pedestalthatpermitsmovementaboutthe azimuthandelevationaxis.Reflectivityofanewclean mirror-0.90-0.94. Concentrated solar power technology is based on the principle of focussing of solar radiation on a receiver(which behaves as a boiler for production of steam at supercritical temperature), which receives the focussed radiation mounted on a central tower at a calculated height. When sunrays fall on the collectors, they focus the solar radiation(photons) on a very constricted area thereby providing an enormous amount of energy in a very limited available area which can be used for heating up the water for the subsequent production of steam. Solar collectors are often characterized by the solar concentration ratio[4][8]. It is an essentialconcept for a solar collector because it concentrates light on higher distribution temperatures(ibid). The definition of a concentration ratio is for evaluating and comparing different solarcollectorstoproducehightemperatures(ibid).Concentratingcollectors(PTC,LFR,PDR,andHFR) that can deliver temperatures up to 2000°C can achieve a higher concentration ratio intherangeof15–1500(ibid).Incontrast,non-concentratingcollectors(FPC,ETC,orCPC)canmake a lower concentration ratio of up to 240° C (ibid). There are two types of collectors :(1) *Parabolic Trough Reflector* , (2) *Field Reflector*

1.1. CONSIDERATIONSFORHELIOSTATS

While designing heliostats some points have to be kept in mind for making an heliostat which can rotate about its azimuthal axis for optimal reflectivity on the receiver tower they are illustrated as follows:

(a) ***Reflectivity*** :
The work of a reflector is to reflect the sun rays and focus upon the receiver. Reflectivity of an object is inversely proportional to absorptivity of a material, i.e, the material which absorbs light largely, causes lesser reflection of the incident light rays. Therefore, the reflectivity of a material is of utmost importance. The material for reflector should be a shiny one. Preferably mirror like material, e.g, mylar, polished anodized aluminum, acrylic mirror[8][3]. More reflective material ensures least absorption and maximum transmission of reflected radiation unto a receiver.

Table 1. Tabular representation of materials and their reflectivity

MATERIAL	REFLECTIVITY	ADVANTAGE
Polished Anodized Aluminum	~95%	Light weight, Durable, easy to shape
Mylar	>98%	Super reflective, light, cheap
Acrylic Mirror	99%	Very reflective, nearly unbreakable
Glass Mirror	99%	Super reflective, easy to shape

(b) ***Back support structure***: the back support structure is an important part of the design of heliostat. A proper structure supports rotational motion about elevation axis and azimuthal axis. The support structure should be able to dampen out the vibrations due to widespread, earthquakes and must keep the heliostats undeviated due to disturbances. The heliostatic temperature increases rapidly all time during the daytime because of the absorption of part of the incident sunrays on the heliostat. This increase in temperature over the long run causes creep and fatigue of the support structure material, thereby reducing the durability drastically. Considering all the above factors, the high carbon steel(HCS) is used as the support structure material, as it has good mechanical damping properties and less creep factor which will make the support structure a durable one[1].

(c) ***Azimuthal & Elevation drive***: the solar hybrid thermal powerplant implements the concentrated solar power technology to augment the steam production while reducing the coal consumption. Now, the sun moves from east to west in the daytime, so, the reflectors should constantly rotate so as to reflect the sunrays onto the receiver effectively. For this, there two LDRs present on diametrically opposite points on the reflectors which give different output when the light intensity on one LDR is more than the other LDR due to movement of the sun. This signals the motor to rotate the reflector in a particular direction which follows the sun’s movement. Therefore, the heliostatic movement happens accordingly to the sun’s movement is about the azimuthal axis.

(d) ***Pedestal spacing***: the heliostats must be spaced properly so that, shadowing & blocking loss does not happen. As we know, that during the early morning and sunset hours, the azimuthal angle of the sun with respect to ground is very low. This causes every vertically placed objects on the ground to cast a long shadow which can reach a very long distance[8]. The shadow length is minimum during the noon time and is maximum during the dawn and dusk. Therefore, the reflectors should be optimally spaced so that one reflector does not cast a large shadow on the reflectors placed behind it. This will ensure least shadowing and blocking decreases.

(e) ***Wind speed & dust in mirror:*** wind speed is a major factor for the disturbances in the heliostat orientation angles. the windspeed causes a lot of vibrations in the heliostats. Due to mechanical vibrations, there can be fatigue in the heliostat material which can eventually lead to unneccesary deformation of the heliostats. Which would render it incapable of perfect reflection because of change of its orientation. To avoid these unnecessary mechanical vibrations due to wind speed, the heliostatic material must be HCS(high carbon steel) which dampens the vibration[8]. Moreover, the heliostat must be provided with back support at more number of points on the reflectors so that the vibrations should be able to dampen it out properly. Dust in the mirror makes it more and more unreflective. Dust affects the reflectivity of the mirror material. So the mirror material must be non sticky or we can say that the mirror material must have least adhesive property so that the dust particles should not get attached to it properly. Moreover, pure conducting material should be avoided, instead Acrylic mirrors or normal glass mirrors should be used. The reason being, the pure conducting materials substrate gets polarized when the sunrays fall on them. The light facing side gets positively charged and the darker sides get negatively charged because of the motion of electron away from the light facing side because of photoelectric effect. Due to this polarization, the metal substrate attracts the dust particles towards them.

Fig1. Heliostatalongwith Field type Reflector

1.2. GEOMETRICALPERFORMANCEOFHELIOSTATS

Heliostat geometry is the single most important factor which determines whether the incident solar radiation can reach the receiver or not . as it is a known fact angle of incidence(i) is always equal to the angle of reflection(r) as per the laws of reflection. Therefore, different heliostats in different part of the field have different inclination towards the receiver Hindi Northern hemisphere, throughout the year the line of propagation of solar rays are more in client to the South field that the north field. Therefore the South field heliostat(Heliostat in the southern part of the field) must have lesser in connection with the ground that the north field(Heliostat in northern part of the field) heliostat as depicted in the figure 3.

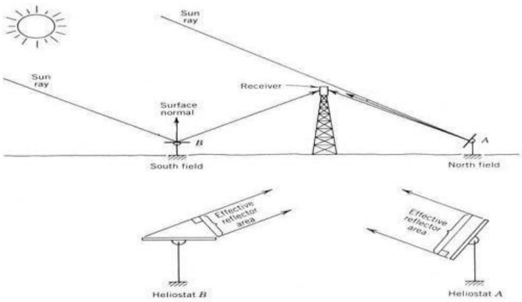


Fig2.Schematic Representation Geometrical Performance of Heliostat

2.SOLARREFLECTOR

Concentrated solar power technology is based on the principle of focussing of solar radiation on a receiver(which behaves as a boiler for production of steam at supercritical temperature), which receives the focussed radiation mounted on a central tower at a calculated height. When sunrays fall on the collectors, they focus the solar radiation(photons) on a very constricted area thereby providing an enormous amount of energy in a very limited available area which can be used for heating up the water for the subsequent production of steam[2][3]. Solar collectors are often characterized by the solar concentration ratio. It is an essentialconcept for a solar collector because it concentrates light on higher distribution temperatures. The definition of a concentration ratio is for evaluating and comparing different solarcollectorstoproducehightemperatures.Concentratingcollectors(PTC,LFR,PDR,andHFR) that can deliver temperatures up to 2000°C can achieve a higher concentration ratio intherangeof15–1500.Incontrast,non-concentratingcollectors(FPC,ETC,orCPC)canmake a lower concentration ratio of up to 240° C. There are two types of collectors :(1) Parabolic Trough Reflector , (2) Field Reflector

2.1.1. FIELD REFLECTOR

Field reflectors are the type of reflectors where the mirrors are flat. In this type reflector, there is a central tower where the absorption channel of the reflector is placed for the absorption of heat from the concentrated solar rays. This enables the direct heat to get focussed on the water for the production of steam at supercritical temperature. Unlike, parabolic reflector where there is continuous supply of solar energy to the working fluid, here the entire energy is focussed at once.

2.1.2. PARABOLICTROUGHREFLECTOR

The parabolic trough is based on the CSP line-focusing technology, which emerged in the1980sduetooilcrises.Ithassomedistinctivefeaturesandadvantagesoverothersolarsystems.Forexample,PTCsyste msareversatile,sincetheirtroughmirrorcomponentscanbemountedalong the focal line. As shown in following figure 6, It is the simplest type of the CST, whichconsists of rows of trough-shaped solar panels, usually reflections, with an integrated receiverloop(EuropeanCommission,2004).Thecollectorsareusuallymountedinlines,andtheentiresolarfieldconsists ofmultipleparallellines.Itwillbeconnectedtoasinglemotorpoweredbya solar tracking device to ensure the maximum sunlight reaches the concentrating device alldaylong.Thesolarreceiverisablack-coated,vacuumglasstubecontainingeitheroilorwater. There are lot of advantages of these systems because of their higher energy transfer efficiency as well as thermal efficiency. Parabolic trough collectors focus the sunrays on the channels of pipes passing through their focus. Thereby, gradually heating up the working fluid present inside the pipe channels, which increases the heat transfer efficiency in general. Moreover, due to gradual heating, we need small sized heliostats for the purpose. For which the cosine loss, attenuation loss and shadowing & blocking loss are very minimum[3]. Hence, optimal heat transfer is possible.

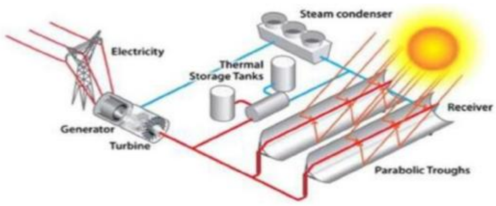


Fig.3ParabolicTroughCollector

The concentrated sunlight heats the heat transfer fluid to temperatures up to 400°C so thatelectricitycanthenbeproducedusingaturbineandanelectricalgenerator(EuropeanCommission, 2004). As shown in the following figure 7, the parabolic trough collector is thebest solution for low-temperature applications, such as detoxification, fluid waste recycling,andheating water even atmedium temperature.

3.RECEIVERTOWER&BOILER

- The receiver system has a boiler which is mounted on the top of the tower. When the reflected sun beam from the Heliostats converge at the receiver, the working fluid (generally, water) gets heated to supercritical temperature. This steam then goes to the steam drum which eventually sends the steam to turbine for expansion. it contains receiver pipe which contains oil which absorbs the heat incident on it in the form of concentrated solar power. Therefore, the pipe is coloured with a very deep black colour the receiver fluid absorbs the heat and transfer it to the fluid inside the other set of pipes bracketed contains water as the working fluid bracket close these pipes contain water which is to be eventually heated for the purpose of production as well as heating heat up to supercritical temperature for the purpose of expansion in the generator.The receiver, placed at the top of a tower, is located at a point where reflected energy from the heliostats can be intercepted most efficiently. The receiver absorbs the energy being reflected from the heliostat field and transfers it into a heat transfer fluid[3].

The components of receiver tower are:-

(a) ***Absorber Channels:*** Absorption channel contains a set of pipes which are large in size(For the focus proper get incident and observed) and black coloured for perfect absorption. The fluid in the pipe is an oil of lost capacity show that the upon absorption of heat, the oil must witness large rise in temperature. A larger Temperature of working fluid(oil) ensures that the effectiveness of transfer transfer via Counter-flow heat exchanger in the steam channels is very high for proper heat transfer[3]. The run out of the absorption channel is coated with a white colour for lesser radiative heat transfer as well as the run out pipe is enclosed inside a vacuum pipe for no convective heat transfer so that the loss of heat could be as low as possible.

(b) ***Boiler:*** steam channels contain water for the production of steam. Unlike thermal powerplant, in solar hybrid thermal powerplant the water inside the boiler is not heated up by flue gas. Here, the water is heated via, a counterflow heat exchanger where, the absorption channel and water channel meet. For the heat transfer to take place from the absorption channel. The absorbed heat is sufficient for the water to convert to steam at supercritical temperature(373C). the generated steam is forwarded to the common steam supply line of thermal powerplant for the purpose of expansion in the turbine[3].

(c) ***Steamdrum***: steam drum stores steam after steam production. The formed steam is stored and is sent back to the absorber when the steam production phase is complete, so that superheating of the formed steam can take place. Steam drum also stores steam for night use, or for sufficing the sudden steam requirement. This steam drum is made up of an insulating material with an outer white coloured surface for the radiative heat transfer to be minimum. Moreover steam drum is a two layered object where the space between the outer layer and the inner layer is a vacuum space so that convective heat transfer could be avoided. Steam drum stores the steam for night use as well as to augment the sudden ramping up of demand of power.

3.1. WORKINGFLUIDS

The working fluids for the CRSP has the following characteristics:

(a) **Good thermal characteristics:** Here the working fluid refers to the working fluid of the absorption channels. The working fluid of the absorption channel must have low specific heat capacities(Cp and Cv values) so that upon absorption of less amount of heat, it witnesses large rise in temperature. A larger rise in temperature results in higher effectiveness of heat transfer in the counterflow heat exchanger downstream. The larger the heat transfer effectiveness the better the heat transfer to the boiler channels for the production of steam at supercritical temperature() for expansion of turbine.

(b) **Non-corrosive,non-Toxic,Non-Flammable:** the working fluid must not be corrosive so that the absorption channel does not get corroded due to its corrosive effect. The working fluid must not be a hard alkaline, or acidic as well as it should be non- ionic compound. So that, it does not act as electrolyte inside the metallic absorption channel. Which would cause the dissolution of metallic pipes into the working fluid. Moreover, it should not contain any unwanted impurities as impurities cause scaling of the absorption channel. Moreover, the fluid must of least viscosity for easy flow through the pipes and for least drop in enthalpy because of flow.

(c) **Cheapandabundantlyavailable:** the working fluid must be cheap as well abundantly available. Unless the fluid is cheap and abundantly available it can’t be used as working fluid in the solar hybrid thermal powerplant.

4.FACTORSAFFECTINGEFFICIENCYOFSOLAR HYBRID THERMAL POWERPLANT

The factors affecting the efficiency of the solar hybrid thermal powerplant are as follows:

4.1.COSINEFACTOR

The efficiency depends on both the sun's position and the location of the Individual heliostat relativetothereceiver

$$\cos 2\theta = \frac{(Z_0 - Z_1)\sin P - e_1\cos P\sin A - n_1\cos P\cos A}{\sqrt{(Z_0 - Z_1)^2 + n_{12} + e_{12}}}$$

where P and A are the sun's altitude and azimuth angles, respectively, and Z, e, and nare the orthogonal coordinates from a point on the tower at the height of the heliostatmirrors.Yearly averagecosinefactorforanorthheliostatfield is 0.71-0.91.

4.2.SHADOWING&BLOCKING

Shadowing occurs at low sun angles when a heliostat casts its shadow on a heliostat located behind it. Therefore, not all the incident solar flux is reaching the reflector. For that reason, the heliostats are spread over large area and the heliostats closer to the receiver tower is placed at an adequate distance such that shadowing does not occur. As it happens during low sun angles(closer to sunset), as such not much power generation is expected, hence not much harm is done even when shadowing occurs.
Blocking occurs when a heliostat in front of another heliostat blocks the reflected flux on its way to the receiver. This happens specially at low sun angles, but it can also happen at other time of the day if there is no adequate spacing between the heliostats. The amount of shadowing and blocking in a particular field layout is a function of the heliostat spacing, tower height, and sun angle.

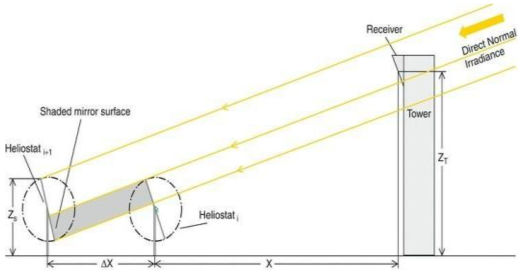


Fig.4 Schematic Representation of blocking

4.3.ATTENUATIONLOSS

Attenuation loss happens when the reflected sunlight from the reflectors to the receiverundergoes scattering and dispersion in the air medium. Due to this there happens to be lossesintheoriginal energy inthebeam just beforereflection.This is actually a minorloss. The reflected solar rays undergo scattering when the rays travel in the air medium. Due to this scattering, some quantity of solar radiation gets absorbed in the air medium and the rest is transmitted or gets focused finally. Although minor loss, yet it would be preferable to even take care of this minor loss. Therefore, the solar hybrid thermal powerplant must be placed at a place where the dust level is minimum(Ideally, below 1000 PPB).

5.OPERATIONALCONTROL SYSTEM

Automationreferstothe processofpartiallyorfullyautomatinganentiresystem.Inthiscase,we need to automate the reflectorsfor focusing thesunlight better. The reflectors mustcontinuously rotate with the sun's movement just like a sunflower faces the sun. since, themovementof sunis gradual andadaylong process,henceweneed toautomatethis motion. The sun's position varied continuously from one point of time of the day to the other as well as it changes from season to season. During the summer, the sun is above the Tropic of Cancer. In the winter, the sun is above the tropic of Capricorn. Therefore, the sun continuously changes its position, so no fixed timer can be set to rotate the heliostat. Therefore, a solar tracking system has to be created which can track the sun's position so as to focus the sunrays properly on the receiver with minimum field losses incurred.

5.1.WORKINGPRINCIPLE

Thereare2LDRSensorsmountedontwodiametricallyoppositepointsofthereflector.Since,there is movement of sun, the light intensity on one sensor gradually increases and decreaseson the other sensor. This leads to one LDR becoming a conductor whereas the other LDRbecoming an insulator. The conductor LDR gives output as 1. Whereas, the insulator LDRgivesoutput as 0. Thus thereis a differenceintheoutput from both theLDRs. LDR is connected to a Microcontroller(Arduino NANO) and so, the output from each LDR isfedtotheMicrocontrollerwhichdirectstheMotorDrivertorotatetheGearMotorinaspecificdirection[4][5].

5.2.HARDWAREUSED

Theautomaticsolartrackerssystemconstitutesfollowhardwaresnamely:

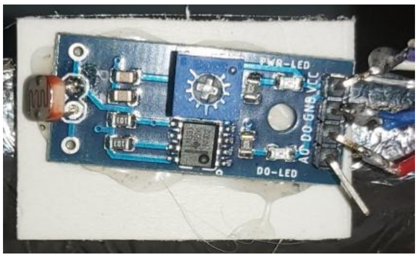
- LDRsensors(2)
- ArduinoNANO (1)
- MotorDriver(1)
- 9VDC source(2)

Thedescriptionof eachindividualparthasbeenillustratedbelow:

5.2.1.LDRSENSORS

LDR sensor are used to detect the difference in the light intensity on 2 diametrically opposite points on the reflector. is a photo-resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells[4][5]. Photo conductivity is an optical phenomenon in which the material's conductivity is increased when light is absorbed by the material. The most common type of LDR has a resistance that falls with an increase in the light intensity falling upon the device (as shown in the image above). The resistance of an LDR may typically have the following resistances:

Daylight = 5000ΩDark=20000000Ω



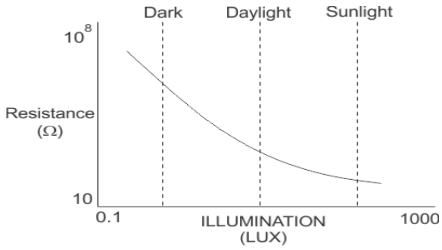


Fig.5 LDRSensor with LM393 IC **Fig.6 Resistance vs Illumination curve of LDR with LM393 IC**

In heliostat reflector, there are 2 LDR Sensors mounted on two diametrically oppositepointsofthereflector.Since,thereismovementofsun,thelightintensityononesensor gradually increases and decreases on the other sensor. This leads to one LDR becoming aconductor whereastheother LDRbecominganinsulator.Theconductor LDRgives output as 1, Whereas,theinsulatorLDRgivesoutputas0[4].Thusthereisadifferenceintheoutputfromboth theLDRs. LDR is connected to a Microcontroller(Arduino NANO) and so, the output from each LDR isfedtotheMicrocontrollerwhichdirectstheMotorDrivertorotatetheGearMotorinaspecificdirection[5][6]. There is LM393 IC integrated with the LDR Sensors which converts the analog output of the LDR sensors into digital.

5.2.2.MICROCONTROLLER (Arduino Nano)

Arduino Nano is a small , cheap microcontroller. It is used to take the input from LDR sensors and rotate the heliostats in the direction of moving sun just like a sunflower. In order to rotate the heliostat, it gives output to the motor driver to rotate, so that optimal focus of sun beams are maintained while catching up to the movement of sun from time to time[5][6].

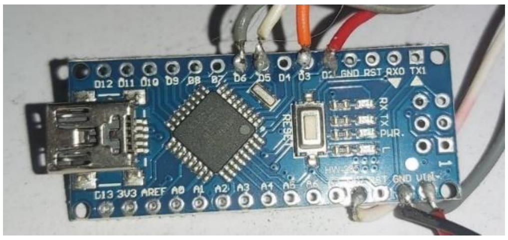


Fig.7 Arduino Nano

5.2.3.MOTORDRIVER

The motor driver IC is an integrated circuit chip used as a motor controlling device inAutomatic Solar Tracker. L293D isthe oneusedmotor DriverICinAutonomousSolarTracker.Amotordriverisundoubtedlysomethingthatmakesthemotormoveasperthegiveninstructionsortheinputs(highandlow).Itlistenstothelowvoltagefromthecontroller/processor and control an actual motor which needs high input voltage. In simplewords, a motor driver IC controls the direction of the motor based on the commands orinstructions it receives from the controller. Many motor drivers follow different topology, inthisarticlewewillfocusonthepopular**H-bridgetopology** whichisusedintheL293Dmotordriver IC[6].
WeuseMotorDrivers/MotorICsbecauseMicroprocessorsoperateonlow-levelvoltage/current, unlike motors. For example the popular Arduino microcontrollers or PICmicrocontrollerhasanoperatingvoltageof5Vor3.3V,buta decentDCmotorrequires5Vor12Vto operate.

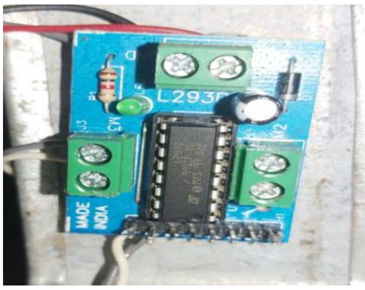


Fig.8 Motor Driver L293D

Motordriverreceivessignalsfromthemicroprocessorandeventually,ittransmitstheconverted signal to the motors. It has two voltage pins (VCC1 and VCC2), and one of them isused to turn on the motor driver, and another pin is used to apply the voltage to the motorthrough this motor IC[5]. This motor IC will continuously toggle the output signal according totheinput waveit is receiving from themicroprocessor.

The small IC transmits the signal it receives, but it will not change the value of the signal. Forexample, if the microprocessor sends a high input (1) to the Driver IC then, driver IC will passthe same High (1) though it's an output pin. The **H-bridge circuit** will look like this in thepicture below. Four switches will form an **''H'' shape**, and these four switches are used toenable/disable thesupply.

V. RESULT AND DISCUSSION

The result obtained upon testing the model under the sun during the afternoon time are as discussed below :-

REFLECTORDETAILS

ProjectedRadiusofReflector=40cm

Projected Area Of Reflector = $\pi r^2 = 3.14\times(40)^2 = 1256\ cm^2$NumberofReflectors =4

Totalreflectorarea=4×1256 =5024cm^2

ENERGYCALCULATIONS

SolarInsolationatEarth Surface =1050W/m^2

Totalenergy Incidentonthereflectors=(Areaof Reflector)×1050×10^{-6}Watt

=5024×1050×10^{-6}=5.2752watt

Amount of energy reflected by reflector = ηfield×5.2752 = 4.8532 wattWhereηfieldis the Field EfficiencyOf STPP And, ηfield=0.92

BOILERCALCULATIONS

Amount of water present in Boiler = 50ml = 50g = 0.05kgSensibleHeat Capacity ofWater =4180J/Kg K

NormalWaterTemperature=30 ˚C

Heat input to boiler when it is operated for 2hours = 4.8532x7200= 34943.04 JHeat required to raise water temperature from 30 to 100 = 4180x0.05x70 = 14630 JLatentheat ofwater =334000 J/Kg

Heatneeded tovaporisewater=334000x0.05 =16700 J

TotalHeatrequired tillnow=(14630+16700)J= 31330J

Heatleft forsuper heatingsteam =(34943.04-31330)J =3613.04 J

Heat required for Super Heating of Steam at 1atm pressure by 1 ˚C = 0.48x4.184x50= 100.32J

Temperatureriseofsteamobtained= 36.02˚C

Hence, finaltemperature ofSuperheatedsteam=136.02 ˚C

Saving of coal by integrating solar thermal powerplant

Previously, for generating 1kWh energy we needed 9495.504 kJ but now, for generatingsame amount of energy we will require only 9460.56 kJ. Thus, we are increasing the powerplantefficiency byintegrating conventional power plant with solarenergy.

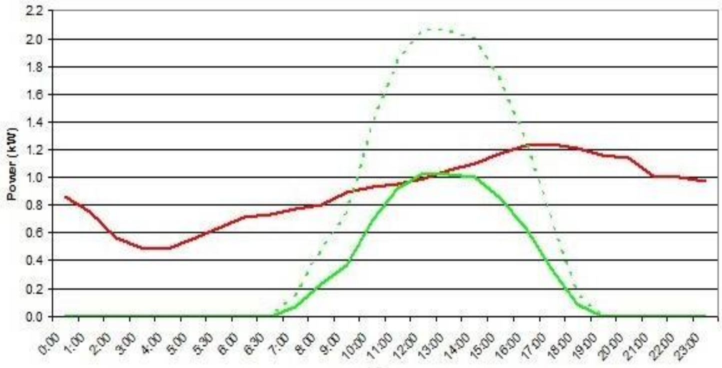


Fig9. ComparisonofPowerOutputbetweenSolarThermal andConventionalPowerPlant

From the above graph, we can observe that for 3KW Solar hybrid thermal power plant , the poweroutputishigherthanthatofequivalentconventionalpowerplant.TheSolarThermalPowerplant is less efficient than the conventional Thermal Power Plant up to 7Hours ofcontinuous Operation, the Solar hybrid thermal power plant proves to be more efficient that theconventional Thermal Power Plants of Equivalent Capacity.The findings obtained from theproject is that it is 5-7% more efficient than the conventional coal-based power plants. Theproject has been done in the workshop with conventional machining process, and not withadvanced machining process e.g., CNC and thereby contains some manufacturing errors ascomparedtoCNCmachining.HaditbeendonewithCNC,itsefficiency wouldhavebeen10-12%morethan theconventional coal based powerplants.

VI. Conclusion

The threat of shortfalls in domestic coal production is constraining the development of coalpower plants in a number of countries. Coal based thermal plants in base load operation consume tremendousamountsofhighlyspecifictypes ofcoalandmake tight coalsupplysituationsforeseeablein thefuture if consumption remains high. If coal power plants can increase the flexibility of theiroperation while increasingly acting as a back-up for renewable generation, coal consumptioncan be reduced. This would extend the longevity of existing coal mines while reducing the needfor new exploration. As de-carbonisation progresses over the long run, coal power plants couldbe gradually phased-out or maintained as a strategic reverse, thus reducing coal consumptionandemissions even further.With the ratification of the Paris agreement, decarbonisation of the power sector has become atop priority for a range of countries. However, enhancing the flexibility of the power sector iscrucialifrenewablegenerationistobeconsiderablyexpanded.Aprimaryoptioninthisregardistooperatepowerplants moreflexibly.Thispaperprovidesabroadanalysisonpossiblehybridisationmeasuresforthermalpowergeneration, incorporating Solar system with advanced Electronic process control measure. In the model proposed in this paper, the efficiency of the Thermal plant shall improve and at the same time coal consumption shall get reduced so also CO_2 emission to the environment.

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