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"SOLAR-AIDED COAL FIRED POWER GENERATION: A SYNERGISTIC APPROACH FOR SUSTAINABLE ENERGY"

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Goals of the Study

- Reduction in coal consumption in existing thermal power plant in India
- Reduction in CO2, NOx, SOx emission/Pollution
- Efficiency Improvement of existing coal-based power plants

Abstract:
The goal of this project is to develop a more sustainable and effective energy production system by investigating the integration of solar energy technologies with traditional coal-fired power generation. The synergistic combination of coal and solar power reduces carbon emissions, improves overall efficiency, and tackles the environmental issues related to conventional fossil fuel-based facilities. This study presents a thorough investigation of solar-aided coal-fired power generation, covering its technical features, economic feasibility, and environmental impact. It is a hybrid energy solution.

The research involves conducting a comprehensive literature survey on the integration of coal and solar power generation and assessing the potential scope of such integration in the context of India. Following this, the focus shifts to the identification of a coal-fired thermal power plant in the Konkan region for a detailed case study. The analysis encompasses evaluating coal consumption, carbon footprints, cost per unit of electricity generation, and the efficiency of the selected power plant. These findings will be meticulously incorporated into simulation software's "MATLAB" to design a model of the existing power plant and "System Advisory Model". A Heat and Mass Balance (HMB) system is a crucial tool used in thermal power plants to analyze and optimize the overall energy and material flows within the system. It provides a comprehensive overview of how heat is generated, distributed, and utilized within the plant.

In Stage II, the research will shift towards the calculation of solar energy availability in the Konkan region across different months of the year. Various techniques for integrating solar power with the existing coal-fired plant will be compared to identify the most efficient method. This selected method will be further simulated in the chosen software platform. The research will culminate in the generation of graphs depicting parameters such as coal consumption, carbon footprint, and

efficiency. A comparative analysis will then be undertaken, contrasting the integrated system with solar power against the existing coal-fired system. This comparative assessment aims to clearly articulate the benefits of integrating solar energy into existing coal-fired power plants in India.

Keywords: Thermal Power Plant, parabolic trough collectors, system advisory model, NOx, SOx, SACPG

Introduction

A comprehensive strategy is advised in order to significantly reduce the amount of coal used in India's thermal power plants. In order to improve combustion efficiency, this entails implementing cutting-edge combustion technology including supercritical systems and fluidized bed combustion in addition to enhanced operational procedures and coal blending techniques. The use of renewable biomass in cofiring as an additional fuel lessens the need for coal. Furthermore, by harnessing waste heat, combined heat and power (CHP) systems increase plant efficiency. All of these actions are intended to reduce the total amount of coal used in thermal power plants that are currently in operation throughout India and to encourage the adoption of a more sustainable energy production paradigm.

A pragmatic solution to mitigate the environmental impact of existing non-renewable thermal power plants, specifically coal-fired ones, involves the integration of solar energy. The prevalent use of coal, natural gas, and petroleum for power generation has significantly contributed to elevated levels of hazardous gases, adversely affecting both human health and the environment. Global energy-related carbon dioxide emissions rose by 6% in 2021 to 36.3 billion tonnes, their highest ever level, as the world economy rebounded strongly from the Covid-19 crisis and relied heavily on coal to power that growth. Emission rates per unit of electricity generated, particularly for CO2, SO2, and NO, have been associated with various health issues.

The integration of solar energy emerges as a viable strategy to address these challenges. India, with its abundant solar insolation averaging around 200MW/km² and approximately 250–300 sunny days annually, presents a significant opportunity. Rather than replacing existing thermal power plants entirely with solar facilities, a more feasible and economical approach involves integrating solar energy into the existing coal-fired power plants. This integration can be achieved through various methods, such as solar pre-heating of boiler feedwater, solar-assisted steam generation, and combined solar-coal systems. By adopting these hybrid solutions, the carbon footprint of existing thermal power plants can be substantially reduced without disrupting their operation, offering a sustainable pathway towards cleaner energy production in India.

In solar-rich regions where coal plants are prevalent, the integration of parabolic trough plants offers a promising solution. This integration can serve the dual purpose of reducing coal consumption and facilitating solar peaking, akin to the Integrated Solar Combined Cycle System

(ISCCS) configuration. Modern coal plants operate under higher temperature and pressure steam conditions, necessitating careful consideration in integrating solar steam. In this context, the solar-generated steam may be introduced into the feed-water preheating, instead extracting bleed steam from HP heater. This strategic integration enables a harmonious synergy between conventional coal-based power generation and solar energy, maximizing the efficiency and sustainability of the overall power production system.

Solar Aided Power Generation

The term Solar Aided Power Generation (SAPG), first introduced by, originated in informal usage since 1997. SAPG technology represents a solar hybrid power system designed to enhance the efficiency of conventional Rankine Cycle (RRC) power plants. In this innovative approach, low-grade solar thermal energy is utilized to displace the high-grade heat of the extraction steam within the power plant, specifically for feedwater preheating. The distinctive feature of SAPG lies in the fact that solar heat, carried by a heat transfer fluid (HTF) It is THERMINOL VP-1 or steam, does not directly enter the turbine for power generation. Instead, it is employed solely to displace extraction steam, preheating the feedwater entering the boiler. The crucial aspect here is that the solar thermal input indirectly contributes to power generation by displacing the extraction steam, which, in turn, continues to expand in the turbine, generating power.

The significance of SAPG in conventional coal power plants becomes evident as it offers a means to enhance overall efficiency, reduce CO2 emissions, and lower coal consumption. By optimizing the use of solar thermal energy for feedwater preheating, SAPG introduces a sustainable approach within existing power plants, contributing to cleaner and more efficient energy generation.

Integrating existing Coal-fired power plants with Solar

Solar energy offers various avenues for power generation, with Solar Thermal Power Generation (STPG) being one option. However, STPG comes with inherent disadvantages such as high costs, lower efficiency, substantial land requirements, and the need for new infrastructure. Addressing these challenges, a viable alternative is the adoption of "Solar Aided Coal Fired Power Generation (SACFPG)" in India. This innovative approach involves modifying existing coal-fired power plants to integrate solar energy effectively. By employing parabolic trough collectors, solar power can efficiently contribute to feedwater pre-heating in fuel-fired thermal power plants (FFTPP). The system operates in either power booster mode or coal-saving mode, providing flexibility in power generation. This integration has the potential to reduce CO2 emissions significantly and achieve a notable decrease in coal consumption, estimated at 8-10% according to global research. Leveraging existing infrastructure, SACFPG presents a practical and sustainable solution to enhance the efficiency and environmental performance of coal-fired power plants in India.

Key Points:

- Challenges of STPG: High cost, low efficiency, large land requirements, and the need for new infrastructure.

- SACFPG Concept: Modification of existing coal-fired power plants to incorporate solar energy effectively.
- Technology Utilized: Parabolic trough collectors for efficient solar power collection.
- Integration with FFTPP: Solar power utilized for feedwater pre-heating in fuel-fired thermal power plants.
- Operational Modes: Power booster mode and coal-saving mode provide flexibility in power generation.
- Environmental Impact: Significant reduction in CO2 emissions and notable decrease in coal consumption.
- Practicality and Sustainability: Utilizing existing infrastructure makes SACFPG a practical and sustainable solution for enhancing coal-fired power plants in India.

Review of Paper

Exergetic utilization of solar energy for feed water preheating in a conventional thermal power plant, M. K. Gupta and S. C. Kaushik, International Journal of Energy Research, 9 February 2009

This paper, Flat plate or concentrated collectors are used in the production of solar thermal power; flat plate systems are less efficient overall because of the small temperature differential between the heat source and sink. More effective options are provided by concentrating collector systems, such as central receiver, paraboloidal dish-based, and parabolic trough systems. The successful operation of the 354MW Solar Electricity Generation Scheme (SEGS) in California, USA, has proved the techno-economic feasibility of parabolic trough-based megawatt-scale Solar Thermal Power Plants (STPPs). Since 1990, no new plants have been built, despite improvements in collector and plant design made by SEGS operators, the parabolic trough industry, and international solar research labs.

An option for solar thermal repowering of fossil fuel fired power plants, Kliment Ohridski, Sofia, Bulgaria, Solar Energy, 21 December 2010

In this Article, the urgent reduction of greenhouse gas emissions, especially from fossil fuel-fired power plants, is imperative in light of global climate change. In this case, a workable substitute for the heat that fossil fuels have historically produced is the integration of solar thermal energy into already-existing power plants. This integration can be achieved in a number of ways, including by installing solar-assisted systems, enhancing current heat sources, or preheating feedwater using solar energy. It is feasible to lessen carbon emissions, lessen dependency on fossil fuels, and contribute to a more sustainable and ecologically friendly energy landscape by integrating solar thermal energy into the operational procedures of conventional power plants.

Evaluation of solar aided thermal power generation with various power plants, Qin Yan, Eric Hu, Yongping Yang, and Rongrong Zhai, International Journal of Energy Research, 27 July 2010,

This article, Solar energy, despite being clean and sustainable, faces challenges like intermittency leading to low efficiency and higher costs. Conventional coal or gas-fired power plants, criticized for pollution and resource depletion, still dominate global base load electricity generation. Ultra-supercritical coal-fired plants, with efficiency around 50%, fall short of truly "green" electricity. Governments' carbon taxes and renewable energy goals are pressuring the conventional power sector to undergo a technological revolution for cleaner energy. Globally, interest is growing in solar energy-assisted power systems and equipment, with ongoing research aiming to contribute to a cleaner and more sustainable power sector.

Research on solar aided coal-fired power generation systems and performance analysis, Yang YongPing, CUI YingHong, HOU HongJuan, GUO XiYan, YANG ZhiPing & WANG NinLing, Science in China Series E: Technological Sciences, May 5, 2008

Approach to use solar energy on a wide scale and saving energy in thermal power units is Solar Aided Coal-Fired Power Generation, or SACPG. Parabolic trough solar collectors are used in the integration process to gather solar energy, and the system's energy and working fluid flows are carefully matched. An integration and optimization model for system structure and parameters was developed based on extensive research on the thermodynamic properties of solar thermal power generation and their influence on thermal power unit performance. SACPG systems have great promise when integration rules and coupling mechanisms are summarized based on simulation results. When taking CO2 avoidance into account, economic study showed that the solar Levelized Energy Cost (LEC) was 0.098 $/kW·h, which is less than that of SEGS, which is 0.14 $/kW·h.

Solar thermal aided power generation, Eric Hua, YongPing Yang, Akira Nishimura, Ferdi Yilmaz, Abbas Kouzani, ELSEVIER, 25 November 2009

In this paper, author says, Fossil fuel-based power generation remains crucial for the world economy despite contributing significantly to global CO2 emissions. While solar photovoltaic electricity generation is clean, it's impractical for large-scale commercial use due to cost and high-tech complexities. Solar thermal power offers an alternative, but existing solo solar thermal systems have limitations in efficiency and cost. This paper proposes the concept of Solar Aided Power Generation (SAPG) in conventional coal-fired power stations. SAPG integrates solar thermal energy into traditional fossil fuel power generation cycles, combining the strengths of both technologies. This approach not only enhances the efficiency of conventional power stations and reduces greenhouse gas emissions but also provides an effective means of utilizing solar heat for power generation. The conceptual advantages of SAPG make it a promising avenue for cleaner and more efficient power generation.

Goals of Study

As feed water reaches the boiler, solar heat is gathered using solar trough collectors to warm it up. By carefully utilizing the solar thermal energy that has been collected, the temperature of the feed water is optimized, improving boiler efficiency overall. Moreover, turbine exhaust steam—which is often used to pre-heat feed water—is diverted to expand around the turbines, increasing power output or decreasing coal usage. This integrated strategy shows how to use solar energy in a synergistic way to increase the sustainability and efficiency of the power generation process.

Aim of the Project: To integrate solar energy with the country's current coal-fired thermal power facilities in order to lower carbon emissions and usage.

System Design and Modelling

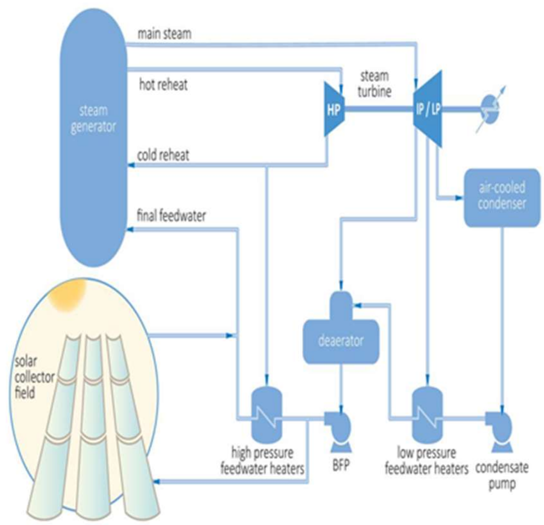


Figure1.1: Power plant feedwater heating using solar thermal power

Power plant feedwater heating through solar thermal power, particularly with the incorporation of a turbine system, is a method that enhances the overall efficiency of electricity generation. The process initiates with the deployment of solar collectors, such as parabolic troughs, designed to concentrate sunlight onto a receiver tube. This tube contains a heat transfer fluid, typically oil, which absorbs the concentrated Therminol VP-1, attaining high temperatures.

The heated heat transfer fluid is then directed to a heat exchanger integrated into the power plant's feedwater system. In this heat exchanger, the thermal energy from the solar fluid is transferred to the cold water destined for the boiler. The preheated feedwater is transferred to boiler for further heating and finally superheated steam is expanded in turbines for power generation. The expansion of steam through the turbine converts thermal energy into mechanical energy, causing the turbine blades to rotate.

As the turbine rotates, it drives an electric generator connected to it, converting the mechanical energy into electricity. The integration of solar thermal power in this system reduces the workload on the boiler, as the feedwater is already preheated before entering the boiler. This leads to more efficient steam generation and, consequently, improved turbine performance.

The benefits of this approach are multifaceted. Firstly, the solar thermal power integration enhances the overall efficiency of the power plant by reducing the demand for additional fuel in the boiler. Secondly, by utilizing solar energy, this method contributes to a reduction in greenhouse gas emissions and lessens the environmental impact associated with conventional power generation. Additionally, the use of a turbine system further optimizes the conversion of thermal energy into electricity, enhancing the overall energy output of the power plant. In conclusion, power plant feedwater heating using solar thermal power with a turbine system stands as a technologically advanced and sustainable solution for efficient and eco-friendly electricity generation.

MATLAB model of A typical 300MW power plant thermal power plant

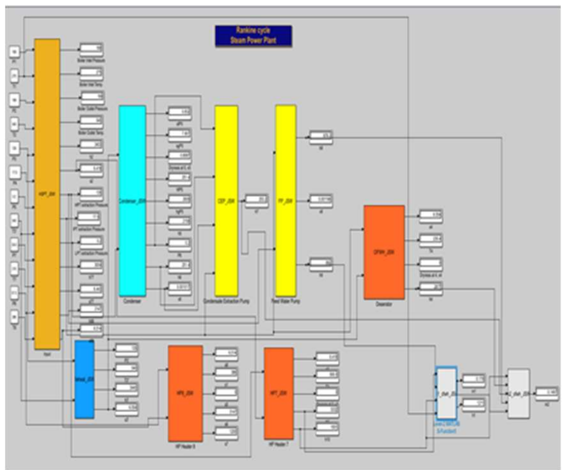


Figure1.2: MATLAB model of A typical 300MW power plant thermal power plant

The Heat and Mass Balance Equations for HP Heaters and Turbine are mentioned below:
Heat Balance HP Heater 8:

$$FW * (h_{8o} - h_{8i}) = Ex_8 * (h_{ex8} - h_{d8})$$

Heat Balance HP Heater 7:

$$FW * (h_{7o} - h_{7i}) = Ex_7 * (h_{ex8} - h_{d8}) + Ex_8 * (h_{d8} - h_{d7})$$

Heat Balance HP Heater 6:

$$FW * (h_{6o} - h_{6i}) = Ex_6 * (h_{ex7} - h_{d7}) + Ex_7 * (h_{d7} - h_{d6})$$

De-aerator Heat Balance:

$$Ex_7 * (h_{d8}) + Ex_8 * (h_{d7}) + Ex_6 * (h_{ex6}) + CD * (h_{cd}) = FW * (h_{bfp_{in}})$$

De-aerator Mass Balance:

$$FW = Ex_7 + Ex_8 + Ex_6 + CD$$

Once the Extractions and MS flow is calculated, the Heat Rate is calculated considering this MS flow, Extraction Flows, Design Leakages and enthalpies as calculated from the Pressure and Temperature Readings as taken from DCS.

The Heat Rate Formulae is as mentioned below:

$$H.R = (Heat\ Input)/(Power\ Generated)$$

$$Heat\ Input = MS\ FLOW\ (h_{ms} - h_{8o}) + CRH\ Flow\ (h_{hrh} - h_{cr}\ ) + RH * (h_{hrh} - h_{8o})$$

$$MS\ FLOW = FW\ Flow - Boiler\ Leakages - RH\ Flow$$

$$CRH\ Flow = MS\ Flow - (HP\ Turbine\ Leakages) - Extraction\_8\_flow$$

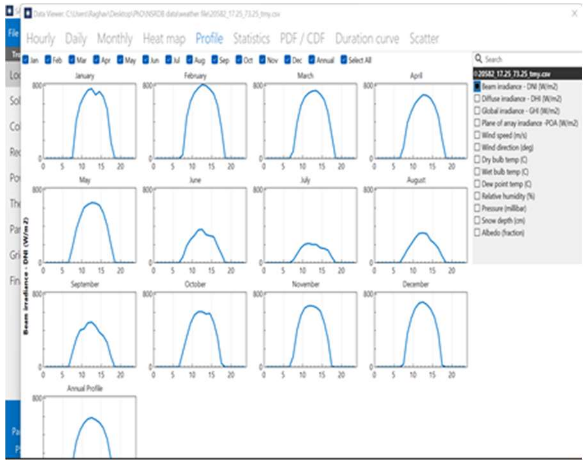
Coal Handling Plant (CHP):

- Coal is received at the power plant and processed in the coal handling plant.
- The coal is crushed, sized, and then transported to the boiler for combustion.

- Boiler:
  - The boiler is a crucial component where coal is burned to produce high-pressure steam.
  - This steam is used to turn a turbine connected to a generator.
- Turbine:
  - The high-pressure steam from the boiler drives the turbine blades, causing the turbine to rotate.
  - Turbines are typically classified into high-pressure and low-pressure sections to optimize efficiency.
- Generator:
  - The rotating turbine shaft is connected to a generator.
  - As the turbine rotates, it generates electricity in the generator through electromagnetic induction.
- Condenser:
  - Steam exiting the turbine is condensed back into water in the condenser.
  - This water is then returned to the boiler to complete the cycle.
- Cooling System:
  - A cooling system is essential to condense the steam and maintain the efficiency of the power plant.
  - Cooling can be achieved using water from rivers, lakes, or cooling towers.
- Ash Handling System:
  - Residues from the combustion process, such as ash, are collected and handled to prevent environmental pollution.
  - Modern plants often use advanced ash handling systems for efficient disposal.
- Control Room and Automation:
  - The entire power plant is monitored and controlled from a central control room.
  - Automation systems help optimize the plant's performance and ensure safety.
- Environmental Control Systems:
  - Measures like electrostatic precipitators and flue gas desulfurization systems are implemented to control emissions and reduce environmental impact.

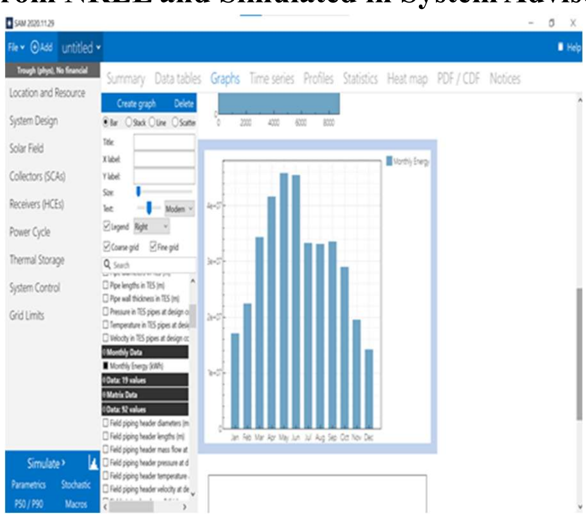
It's important to note that the specifics A typical 300MW thermal power plant, including technological advancements, efficiency measures, and environmental controls, may vary. Detailed information about JSW's thermal power plant would be available in their project documentation, annual reports, or through direct communication with the company.

Direct Normal Irradiance (DNI)

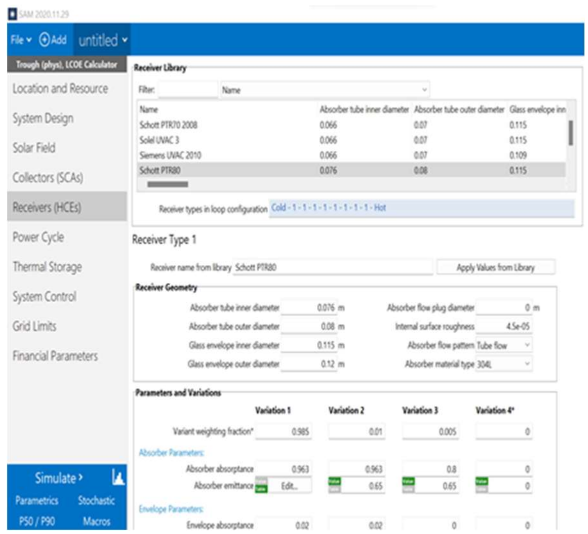


The accurate measurement of direct normal irradiance (DNI) is of major significance since this value presents the heat input into the system and is, therefore, analogous to the fuel input in a conventional thermal power plant. Generally, there are two different ways to measure the DNI.

Weather data collected from NREL and Simulated in System Advisory Model



Parameters of the PTC to be used-Receivers



The PTC provides standard procedures and guidelines for conducting performance tests on various types of equipment, including power plants.

A site selected for the project is simulated in System advisory model software. All the weather data is collected from NSRDB.

For said system a Luz solars LUZ3 PTC is considered which is having around 545m2 area with length of 100 meters. Receiver used is Schott PTR 80. Heat transfer fluide used is Therminol VP-1considering is low freezing point and good higher temperature range.

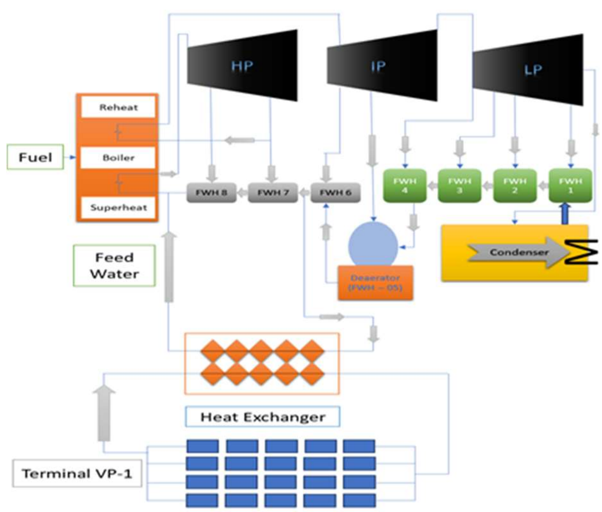


Figure1.3: Schematic diagram of the solar-coal hybrid power plant.

Following is the brief outline of MATLAB blocks for a solar-aided coal-fired power plant using actual values and values calculated using SAM (System Advisor Model), this is a high-level overview, and specific details would depend on the components and parameters relevant to your particular power plant and SAM simulations.

Define Parameters:
Set up MATLAB variables for key parameters such as solar irradiance, coal characteristics, and plant specifications (boiler efficiency, turbine efficiency, etc.).

Solar Collector Model:
Implement a MATLAB block to model the solar collector. Utilize SAM or other solar modeling tools to calculate the solar thermal energy input based on location-specific solar irradiance data, collector efficiency, and area.

Coal Combustion Model:
Create a MATLAB block to simulate the coal combustion process. Use SAM or coal combustion models to determine the heat input from the coal, taking into account coal properties, combustion efficiency, and boiler performance.

Feedwater Heating Model:
Implement a block to model the feedwater heating process. Combine the solar thermal energy and coal-derived heat to preheat the feedwater before it enters the boiler.

Boiler and Steam Generation Model:
Develop MATLAB blocks for the boiler and steam generation process. Consider SAM results for boiler efficiency, and model the production of high-pressure steam from the preheated feedwater.
Turbine and Generator Model:

Create blocks for the turbine and generator system. Consider SAM or other performance models for the turbine and generator efficiency. Calculate electricity generation based on the mechanical power output of the turbine.

Overall System Integration:
Integrate the individual MATLAB blocks to represent the entire solar-aided coal-fired power plant. Ensure that the energy balances and efficiencies are accounted for throughout the system.

Performance Analysis:
Use MATLAB to analyze the overall performance of the integrated system. Compare actual values with those obtained from SAM simulations to validate the model.

Sensitivity Analysis:
Conduct sensitivity analyses within MATLAB to assess the impact of variations in key parameters on the overall system performance.

Optimization (if applicable):
Implement optimization algorithms within MATLAB to find the optimal values for certain parameters that maximize efficiency or minimize environmental impact.

Remember that the specifics of each block would depend on the unique characteristics of your power plant and the details provided by SAM simulations. Additionally, proper validation and calibration with real-world data are essential for accurate representation of the power plant's performance.

Matlab Simulink Model

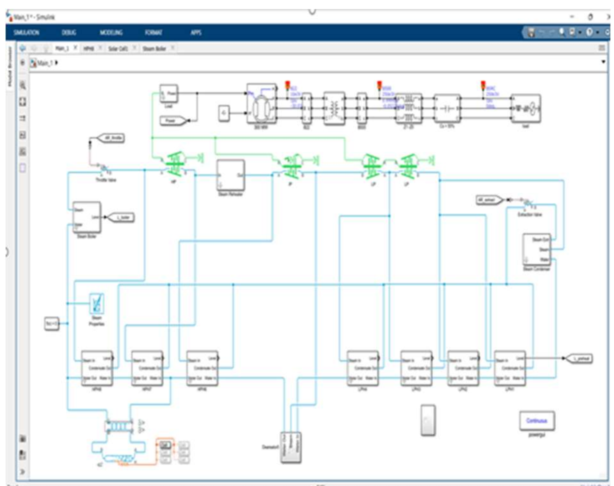


Figure1.4: Matlab Simulink Model

this is a simplified representation, and the actual implementation would require more detailed modeling based on the specific characteristics of your solar-aided coal-fired power generation system. Additionally, calibration and validation against real-world data or validated simulation results are crucial for the accuracy of the Simulink model.

Boiler Simulink Model

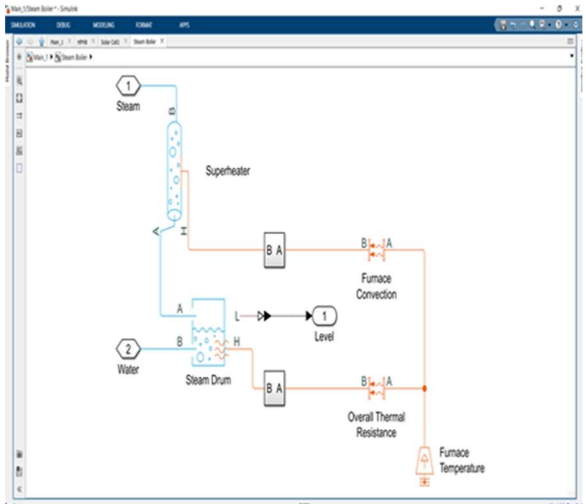


Figure1.5: Boiler Simulink Model

This fundamental design presupposes a simple energy balance in which high-pressure steam is produced by using the heat released during burning. You may need to include more intricate models for heat transfer characteristics, combustion efficiency, and other parameters, depending of your particular system.

To ensure that your Simulink model accurately captures the performance of your system, always check it against real-world data or validated simulation results. Furthermore, think about including this boiler model into the larger Simulink model for solar-assisted coal-fired power generation.

Condenser Simulink Model

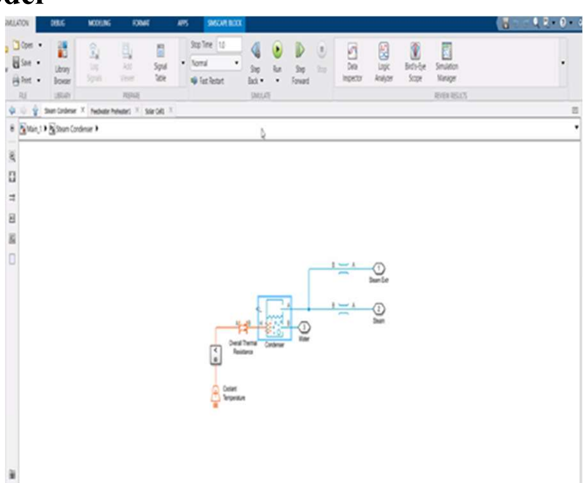


Figure1.6: Condenser Simulink Model

Maintain in aware that the precise specifications of your condenser, cooling system, and other features particular to your solar-assisted coal-fired power generation system will determine the model's exact details.

To improve accuracy, you could want to take into account the impacts of subcooling, use data from SAM or other modeling tools for your particular power plant, and add more complex heat exchange models. To ensure that your Simulink model accurately captures the performance of your system, always check it against real-world data or validated simulation results.

Mathematical modeling for solar-aided coal-fired power generation involves representing the system's components using mathematical equations. Below is a simplified mathematical model for such a system. Note that this is a generic representation, and you may need to adapt it to your specific system parameters and requirements.
Assumptions:
The system includes a solar collector, coal combustion process, feedwater heating, boiler, turbine, generator, condenser, and cooling water.

Energy and mass balances are considered for each component.

Mathematical Equations:
Solar Collector:
Solar energy absorbed by the collector:
Solar=Collector·Collector·SolarQSolar=ACollector·ηCollector·GSolar

Coal Combustion:
Heat released from coal combustion: Coal=Coal·HHVCoalQCoal=mCoal·HHVCoal

Feedwater Heating:
Feedwater temperature rise due to solar and coal heat: \Delta T_{\text {Feedwater}} = \frac{Q_{\text{Solar}} + Q_{\text{Coal}}}{m_{\text{Feedwater}} \cdot C_{p_{\text{Water}}}}
Boiler and Steam Generation:
High-pressure steam generation: Steam=ΔFeed water mSteam=CpSteamΔTFeedwater

Turbine and Generator:
Mechanical power output from the turbine: Mechanical=Steam·Δ*h*Turbine*P*Mechanical =*m*Steam·Δ*h*Turbine

Electrical power output from the generator: Electrical=Mechanical·Generator*P*Electrical =*P*Mechanical·*η*Generator

Condenser:
Heat extracted by the condenser: Condenser=Steam·Δ*h*Condenser *Q*Condenser=*m*Steam·Δ*h* Condenser

Cooling Water:

Heat absorbed by cooling water: Cooling=Cooling Water·Water·ΔCooling$Q_{\text{Cooling}} = m_{\text{Cooling Water}} \cdot Cp_{\text{Water}} \cdot \Delta T_{\text{Cooling}}$

System Efficiency:

Overall system efficiency: System=ElectricalSolar+Coal$\eta_{\text{System}} = \frac{E_{\text{lectrical}}}{Q_{\text{Solar}} + Q_{\text{Coal}}}$

Notes:

$A_{\text{Collector}}$: Collector area

$\eta_{\text{Collector}}$: Collector efficiency

G_{Solar}: Solar radiation

m_{Coal}: Mass of coal

HHV_{Coal}: Higher Heating Value of coal

$m_{\text{Feedwater}}$: Mass flow rate of feedwater

Cp_{Water}: Specific heat of water

Cp_{Steam}: Specific heat of steam

$\Delta h_{\text{Turbine}}$: Enthalpy drop in the turbine

$\eta_{\text{Generator}}$: Generator efficiency

$\Delta h_{\text{Condenser}}$: Enthalpy rise in the condenser

$m_{\text{Cooling Water}}$: Mass flow rate of cooling water

$\Delta T_{\text{Cooling}}$: Temperature rise of cooling water

This model provides a foundation for analyzing the thermal and electrical performance of a solar-aided coal-fired power generation system. Depending on your specific requirements, you may need to incorporate additional details, such as pressure drops, dynamic behaviours, and more sophisticated heat transfer models.

This paper highlights the critical role of solar collectors in Solar Thermal Power plants (STPs), emphasizing the need for sustainable and efficient technologies in large-scale solar power generation. The focus is on Parabolic Trough Collectors (PTCs) using terminal oil and Linear Fresnel Reflectors (LFRs) with water as the working fluid. A closed-loop controller design is proposed to optimize the performance and lifespan of STPs.

The study employs a first-principal modeling approach to derive linear transfer functions for PTCs and LFRs using step test methods at both continuous and discrete domains within the nominal operating range. A continuous Proportional-Integral (PI) controller is designed, incorporating either Static Feed Forward (SFF) control or Predictive Function Control (PFC). The evaluation of the controller's optimal performance relies on various case studies and performance indicators. This research contributes to advancing solar energy utilization through efficient collector designs and closed-loop control strategies, enhancing the viability and sustainability of Solar Thermal Power plants.

Parabolic Trough Collector (PTC) Technology

- Consists of concentrators (parabolic reflectors) that direct light toward the focal line.
- equipped with a single-axis tracking device that can track from north to south or from east to west.
- Heaters of high temperatures are used to operate conventional steam turbines.
- Benefits: Sturdy, proven in the marketplace, and mature. Its storage, scalability, and modularity enable significant heat generation. less expensive and land-intensive than parabolic dish and central receiver methods.
- Cons: Expensive initial outlay, restricted operating temperature, need for a sturdy structure.

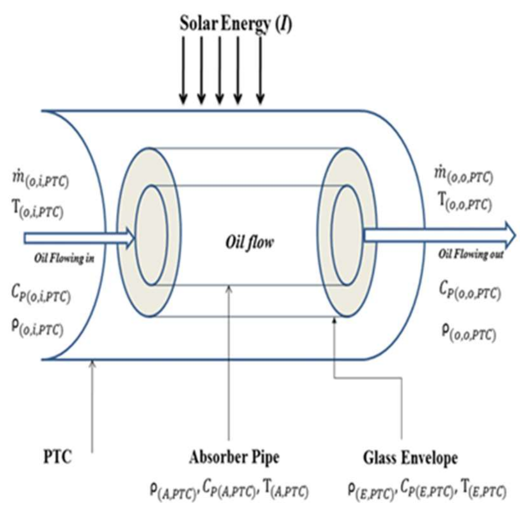


Figure1.7: Schematic of PTC and receiver tube

Created a new serpentine compound parabolic concentrator that combines an at-plate solar collector as a solar collector module with a compound parabolic concentrator. Its features include reduced heat loss for space heating in cold climates and increased thermal efficiencies. As this strategy necessitates the investigation of a more expensive PTC support system, a different strategy for controlling the oil flow rate through PTC has been chosen. In the current work, the optical efficiency is taken to be a constant parameter, however it can be determined online.

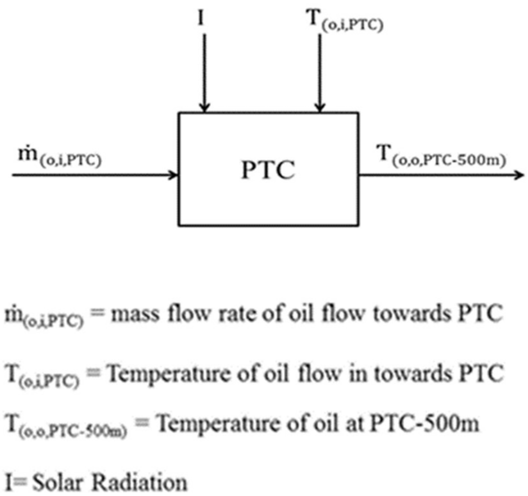


Figure1.8: PTC control parameters

Effective control of these parameters ensures that the PTC operates at its peak efficiency, capturing and converting solar energy into thermal energy effectively. Advanced control strategies, such as predictive control algorithms, may be employed to enhance the overall performance of the solar thermal power plant.

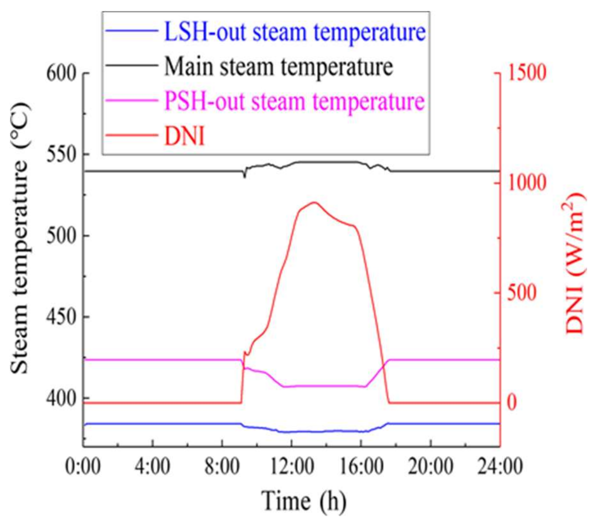


Figure1.9: Dynamic Characteristics of Solar-aided Coal fired Power Generation

Summary:

A 300 MW thermal power plant simulation using PTC and MATLAB software involves intricate modeling and analysis, leveraging the capabilities of MATLAB's Power System Toolbox (PST) for comprehensive simulations. The plant's components, including generators, transformers, transmission lines, and control systems, are represented mathematically in MATLAB scripts or Simulink, allowing for dynamic simulation and analysis. The Power System Toolbox facilitates power flow analysis, enabling the calculation of voltage magnitudes and phase angles to assess steady-state operation and identify potential issues such as overloads or voltage instability.

Additionally, transient stability analysis is performed to simulate the power plant's response to disturbances, evaluating the stability under various fault conditions. Dynamic simulations provide insights into the dynamic behavior during load changes and disturbances, offering a holistic understanding of the system's performance. The software's control system design and tuning capabilities are utilized to ensure stable and efficient plant operation. MATLAB's plotting and visualization tools assist in analyzing simulation results, helping extract valuable information about the system's behavior under different scenarios.

Furthermore, MATLAB's optimization features enable the fine-tuning of the power plant's performance by adjusting control parameters and system configurations. This optimization process aims to enhance overall efficiency and reduce operational costs. The seamless integration of PTC and MATLAB ensures a powerful platform for modeling, simulation, and analysis of the thermal power plant, providing engineers and operators with valuable insights into the plant's behavior, opportunities for improvement, and the ability to implement effective control strategies for optimal performance and reliability. Overall, this combined approach showcases the versatility and efficiency of MATLAB and PTC in addressing the complex challenges associated with the dynamic nature of a 300 MW thermal power plant.

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