A Review Article of Solar and Thermal Power Plants

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Abstract— Solar thermal energy is a ground-breaking technology for harnessing solar energy to produce heat energy. Solar thermal collectors can be classified as low or high-temperature collectors. Low-temperature collectors are flat plates typically used to warm swimming pools, heating water or heating air for residential. However, the cost of electricity from contemporary solar thermal power plants remains high, despite several decades of development, and a step-change in technology is needed to drive down costs. Solar gas-turbine power plants are a promising new alternative, allowing increased conversion efficiencies and a significant reduction in water consumption. Hybrid operation is a further attractive feature of solar gas-turbine technology, facilitating control and ensuring the power plant is available to meet demand whenever it occurs. The objective of this research is to develop a new type of hybrid concentrated Photovoltaic/Thermal (CPV/T) solar collector system that could partially fulfill a typical four people family's heat and electricity demands in many parts of the world and industrial use.

Keywords: Solar Thermal Power, Hybrid Gas-Turbine, Thermoeconomics

I. INTRODUCTION

High-temperature collectors center sunlight using mirrors or lenses and is usually used for electricity power production. Solar Thermal Energy for electricity generation is totally different from the popular P.V, which converts solar power directly into electricity. Solar thermal power plants convert the sunlight's energy to heat first and then to electricity through a series of processes. They are also referred to as concentrating solar power plants (CSPs). Solar tower, which is also a form of CSP captures and focus the sun's thermal energy with numerous tracking mirrors placed in a very large field. A tower is placed at the center of the heliostat field. The heliostats then focus concentrated sunlight onto the receiver which sits on prime of the tall tower. Within the receiver, the focused sunlight heats molten salt to above temperatures of 1,000°F (Kumar & Kumawat, 2013). The intense heated molten salt will then flow into a thermal storage vessel where it's then stored, sustaining 98 percent thermal potency, and then it's finally pumped to a steam generator. The steam spins a typical rotary engine to get electric power. This method, also called the " Rankin cycle " is comparable to a normal coal power station that uses coal as its fuel source, but in this case, been fueled by clean and free energy from the sun.

The inadequate supply of fossil fuels and also the negative effect of carbon dioxide emissions from the burning of fossil fuels on our environment give the increasing use and the need of renewable energy. Solar tower is one of the presumably technology for providing the bulk of this renewable/inexhaustible energy, because it is among the most cost-effective renewable energy technologies available.

II. ISSUES OF ARTICLE

A. Olalekan Oladiran, "Solar thermal with Solar Tower":

Concentrating solar power technologies have continued to develop and are being deployed globally. The Power towers will likely play a vital part in the future spread of concentrating solar power owing to their potential to produce dispatch able solar electricity at a low price.

This work focuses on the study of Solar Tower and continuing technology development, history of solar tower development, evolution from Solar I to Solar II. Inventions, Research and Development in Solar Tower technology over the last ten years is also discussed. Different advancements have been developed during this era, as the subject of Solar Tower is becoming more mainstream. Improvements are carried out on heliostat, the collector design and also materials, heat absorption and transport, power production and thermal storage.

Many applications that can be combined with Solar Tower Technology to supply power are recommended. The economics of solar tower is also mentioned in this paper.

B. Sambeet Mishra, "Solar Thermal Electricity Generating System":

A Solar Thermal Electricity generating system also known as Solar Thermal Power plant is an emerging renewable energy technology, where we generate the thermal energy by concentrating and converting the direct solar radiation at medium/high temperature (300ºC – 800ºC). The resulting thermal energy is then used in a thermodynamic cycle to produce electricity, by running a heat engine, which turns a generator to make electricity. Solar thermal power is currently paving the way for the most cost-effective solar technology on a large scale and is heading to establish a cleaner, pollution free and secured future. Photovoltaic (PV) and solar thermal technologies are two main ways of generating energy from the sun, which is considered the inexhaustible source of energy. PV converts sunlight directly into electricity whereas in solar thermal technology, heat from the sun's rays is concentrated to heat a fluid, whose steam powers a generator that produces electricity. It is similar to the way fossil fuel-burning power plants work except that the steam is produced by the collected heat rather than from the combustion of fossil fuels. In order to generate electricity, five major varieties of solar thermal technologies used are:

- Parabolic Trough Solar Electric Generating System (SEGS).
- Central Receiver Power Plant.
- Solar Chimney Power Plant.
- Dish Sterling System.
- Solar Pond Power Plant.

Most parts of India, Asia experiences a clear sunny weather for about 250 to 300 days a year, because of its location in the equatorial Sun Belt of the earth, receiving fairly large amount of radiation as compared to many parts of the world especially Japan, Europe and the US where development and deployment of solar technologies is maximum. Whether accompanied with this benefit or not, usually we have to concentrate the solar radiation in order to compensate for the attenuation of solar radiation in its way to earth's surface, which results in from 63,2 GW/m^2 at the Sun to 1 kW/m^2 at Earth´s surface. The higher the concentration, the higher the temperatures we can achieve when converting solar radiation into thermal energy.

C. Mohamed Rashad, "A comparative Study on Photovoltaic and Concentrated Solar Thermal Power Plants":

Recently solar energy receives a great attention as an important source of renewable energy. Solar energy is converted to electrical energy directly through photovoltaic (PV) or indirectly through concentrated solar power (CSP) system which converts solar energy to heat energy which in turn can be used by thermal power station to generate electricity. This paper present a comparative study between the two types of solar power (PV & amp;CSP). This study includes types, components, initial and running costs, efficiency, advantages, disadvantages and storage systems.

D. Peter Meisen, "Solar Electric and Solar Thermal Energy":

Energy is the most valuable resource and foundation of civilization. It is also our heritage for future generations. Preserving this resource for future requires a thorough understanding of energy resources, optimal operation and sustainable usage. Solutions that previously seemed impossible or too expensive, today, are technically and economically achievable. Application of new capacity generated by renewable energy sources, new management systems, advanced technologies and improving productivity can contribute to economic growth. Solar energy is one of the most important sources of energy as it is free and no other country can charge for the use of the sun. Solar energy, on the other hand can be important because this energy is infinite. Solar energy received by the earth in one hour is more than the energy used by world's population in one year. World attention to solar energy has risen recently due to technology development and lower cost of installation and operation along with environmental concerns about fossil fuels.

According to experts, solar energy will soon become the favorite energy used. Increasing the efficiency of photovoltaic systems and reduced costs of associated equipment has impacts on this explosive growth. Addressing the issues related to solar energy and renewable energy is important for everyone. This report investigates the nature of solar energy; various ways of exploiting it; and examining the state of the art technologies used to provide power from this profitable energy.

E. Britt; Jeffery s. (tucswon.AZ) Wiedeman; Scott (Tucson.AZ) 2012:

They have presented an experimental investigation to study a semiconductor material used in a PV cell and its importance in determining the efficiency of the solar cell at various parameters such as regards to behavior with respect to temperature, weight and as well as other parameters with which it is used and all those contribute to the deciding factor of efficiency of the PV cell

The inventor has conducted many experimental researchers to devise improvised methods and apparatus for forming thin film layers of semiconductor materials. The field of photovoltaics generally relates to multi-layer materials, converts sun light directly into DC Electrical Power.

The basic mechanism for this conversion is "The Photovoltaic Effect". Solar cells are typically configured as a co-operating sandwich of P-Type and N-Type semiconductors, in which the N-Type semiconductor material (on one side of the sandwich) exhibits an excess of electrons and the P-Type semiconductor material (on the other side of the sandwich) exhibits an excess of holes each of which signifies the absence of the an electron.

F. Zhao; Xiaofeng (Guangdong, CN) 2011:

The authors have conducted a study on solar collecting and utilizing device and have concluded that the efficacy of a solar energy conversion system depends on the various parameter such as the quantum of radiation, intensity, direction, the tilt angle of the collector, temperature etc. In case of solar collector and utilizing device the sun tracking and beam focused radiation are of paramount importance. This device consist of paraboloidal mirror, a sun light collector, a solar storage and conversion device and a solar tracking equipment wherein said sun light collector compresses a light guide which convert factual into substantially parallel light beam and deflect them in a desired direction and a curved surface condenser mirror which receive the substantially parallel light beams reflected from the light guider and converting them into a solar storage and conversion.

G. SB Sadati, M.Yazdani – Asrami and others 2010:

The author worked on evaluation of supplying ruler and residential area using photovoltaic systems in I.R. Iran. They have commented on use of sun's energy has the biggest energy supplies and is clean and annexable source which can be utilize by using appropriate technologies. The total solar radiation received by different regions throughout the year the average energy consumption required effect of temperature voltage –current curve characteristics have been conceder for evolving a photo voltaic system to meet the domestics required, economic analysis has been made for justification of the use age of photovoltaic system.

H. Bareis; Bernard F (Plano, TX) and Goei; E Esmond T. (Dublin, CA) 2004:

They have investigated on the concentrating solar energy receivers. In their study they have commented that the solar collectors can be classified into focusing type (concentrating type) and Non – focusing type (non-concentrating type). The inventor has designed the concentrating type solar energy

receiver comprising a primary parabolic reflector having a centre and a high reflective surface on a concave side of the reflector and having a fixed axis extending from the concave side of the reflector and passing through a fixed point of the primary parabolic reflector and a conversion module having a reception surface. Non concentrating type solar collecting devices intercept parallel un-concentrated rays of the sun with an array of photovoltaic cells. The output is the direct function of array.

I. Coc Oko and S.N Nanchi 2012:

They have worked on Optimum Collector Tilt Angle for low latitudes. There are many factors that affect the solar radiations falling on the earth. Some of the factors that affect the intensity of the extra-terrestrial solar radiation on the earth's horizontal and tilted surfaces are clouds, dusts and shades. In designing the solar equipment the designer has to pay more attention towards harnessing the insulation to the optimum level for effective performance of the equipment. Determination of the tilt angle at lower latitudes is one such effort for a country like Nigeria.

J. "Model Identification of Typical Thermal Process in Thermal Power Plant Based on PSO-CS Fusion Algorithm":

Congzhi Huang: The model identification issue of typical thermal process in a thermal power plant is investigated in the paper. It is crucial to further develop the PID controller parameters tuning approach or designing various advanced control laws. A CS-PSO fusion identification algorithm is proposed to identify the optimal model of the thermal process based on the process input and output data. In the algorithm, the conventional particle swarm optimization algorithm is employed to identify the model parameters of the typical thermal process, where the cuckoo searching algorithm is used to optimize its velocity parameters, and thus the identification accuracy is improved. The effectiveness of the proposed approach is validated by the extensive simulation results about the ultra-supercritical unit and the circulating fluidized bed thermoelectric unit. At present, the thermal power is still widely used in the field of power generation, and the study of its typical thermal process is the base of the controller's parameters tuning and advanced control law design, and thus it is crucial to improve the system control performance. As an important part of process control, system identification can effectively identify the mathematical model that can reflect the characteristics of a typical thermal process, which is in favor of optimizing the parameters of the controller and greatly improving the system performance [1][2][3][4][5]. Among them, the offline identification method can obtain an accurate process mathematical model only by inputting and outputting historical data information [6] [7]. The key idea is that an excellent intelligent algorithm can be used to get the process transfer function model that reflects the characteristics of the system.

K. "Priority list and particle swarm optimization based Unit commitment of thermal units including renewable uncertainties" Md. Sajid Alam:

Utilizing thermal generation alone to meet the energy demand leads to adverse effects on environment. So, to minimize the environmental pollution, there is a need to enhance the renewable energy contribution in the grid. In this paper a hybrid Priority List and Particle Swarm Optimization (PL-PSO) approach to solve Unit Commitment (UC) and Economic Load Dispatch (ELD) of thermal units integrated with renewable sources like wind and solar power plant is presented. The on/off decision of thermal units is handled by PL technique, while Particle Swarm Optimization (PSO) solves ELD. Both programs are run simultaneously, fine tuning their solutions in search of a better solution. Wind and solar power output is modeled using MATLAB simulink tool and coding respectively. Wind and Solar uncertainties are handled using scheduling of operating reserve Ancillary service. The problem formulation considers minimum up and down time, startup cost and spinning reserve constraints. The objective is to minimize the fuel cost associated with thermal units while satisfying constraints. Unit commitment (UC) involves turning on/off of thermal units for forecasted load of particular hour, while considering system capacity requirements. The decision on UC also includes few constraints like spinning reserve, minimum up, down time and ramp limits [1]. After UC decision, ELD load dispatch is performed for committed units. ELD is carried out to find out the output power of each committed unit, to find optimal fuel cost while satisfying all constraints associated with thermal units [2] [3] [4] [5]. UC is usually performed by priority list method and can be applied for large power systems. Among all available methods priority list technique is simple to understand and computationally very fast [6]. In this method incremental cost(IC) of each unit is calculated and based on IC value on/off decision of units is considered. Dynamic programming based on IC is flexible but computationally very expensive [7]. [8] Has proposed optimal generating schedule including unit commitment using Dynamic Programming. This study also includes wind uncertainties by weibul PDF method. [9], [10] and [11] proposed UC and ELD using genetic algorithm. MD sajid alam et.al. Have attempted the solution for UC and ELD problem using PL- GA method [12].

L. "Design and application of fuzzy immune PID adaptive control based on particle swarm optimization in thermal power plants" R. Bouchebbat, S. Gherbi:

The PID controller is the most used controller in the industry thanks to its simplicity and satisfactory performances, unfortunately there is a class of systems that can't achieve satisfactory performances with a simple PID controller as the nonlinear and the delayed systems. These last years, it appeared a lot of innovative control techniques as the bio-inspired methods, one of the most promising of them is the immune PID controller, it is inspired by the immune system regulating mechanism known by its robustness and self-adaptability.

In this paper, the immune feedback mechanism and fuzzy inference are incorporated to design a fuzzy immune PID adaptive controller while the particle swarm optimization (PSO) algorithm is used to optimize its parameters. The simulation results using a main steam temperature system as Controlled plant, verify that the strategy has strong adaptability to the transformation of the system parameters and has advantages of a good time performances and robustness ability. PID control is the most widely used

control strategy in industrial process control, its algorithm control structure is very simple and can be tuned very easily, but for the time varying, uncertain and nonlinear characteristics, it can't achieve satisfied control performances. Artificial immune system as an intelligent information processing system is an emerging field of researches on control, optimization, pattern recognition, classification and other fields. According to [1, 2] the immune cells role in promoting and inhibiting the immune response in the adjustment process, it can guarantee to obtain fast response and adequate stability. Although this response mechanism needs further exploration, but as a mechanism for biological information processing engineering, the immune regulatory mechanisms can be used to effectively improve the performance of the control system.

M. "Artificial intelligence based optimization algorithm for thermal power generation scheduling incorporating demand response strategy" Oliver Dzobo:

A dynamic combined economic emission dispatch (CEED) problem incorporating demand response strategy is performed. The demand response optimization problem is solved using a nonconvex mixed binary integer programming technique. Fixed and flexible loads connected to the power system network are considered in the analysis. Optimization of the dynamic CEED problem is done using particle swarm optimization (PSO) technique. The algorithm developed is able to take into account the thermal power generation unit ramp rates and power generation constraints. Conventional Lambda iterative method is used to validate the proposed PSO algorithm. The results show that the proposed PSO algorithm performs better than the conventional Lambda iterative method.

III. Conclusions

The VPP can be run on standard workstations to play and simulate major power plant processes in conditions close to the real time with accuracy required for qualitative trend-based prediction and sensitivity analysis. VPPM objectives are to decrease the uncertainty during preliminary power block settings selection, better choice of the starting point in case of power block optimization, identification of the most critical physical and geometry parameters contributed to power block performance, and finally reproduction of operational scenarios contained in the measurement data. As presented in the previous sections the Virtual Power Plant Model (VPPM) structure can be easily maintained and managed, due to introduction of model variants, being model libraries updates. The available models' equations have been implemented and integrated in Matlab/Simulink. It is possible to use several modules creating a combination of simplified transfer function models and extended advanced physics-based models within the single VPPM. Such an approach is important whenever model speed and its flexibility are critical. It is possible to implement in the VPP several submodel versions to customize the model to specific needs of a modeling task, e.g. transient or steady-state. A workshop has been organized together with the involved power plant specialists and academic staff to summarize the status of the VPP and the VPPM development after the first phase of the project. Developed VPP architecture was evaluated as fulfilling the project requirements. However, it is necessary to extend the VPPM to cover broader operating range. The control system must involve more elements necessary for good reproduction of all the system events. The current project results can be divided into software infrastructure and demonstration of the model for the power plant unit. VPP project has included development of powerful software infrastructure, predominantly for data handling, processing and presentation. Further research will be performed in two directions: increase of the computational speed to achieve the real-time operation and further development of the VPPM for better accuracy, especially in transient states.

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