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Potential Applications of Renewable Energy Sources Exergetic Analysis of Solar Thermal Energy as a Primary Source of India

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Abstract: Solar energy is a clean, abundant and easily accessible renewable energies. Use of solar energy in various types of systems provides space for several studies on exergy analysis. In the present study, a comprehensive literature search was conducted on exergy analysis of different solar systems. the systems under study are as photovoltaic, solar thermal devices, solar water desalination system, solar air conditioner and refrigerator, solar drying process and solar power generation. the summary of exergy analysis and exergy efficiency along with the exergy destruction presented sources. This study of solar thermal power generation sets out the main evaluate existing collection technologies with the framework of the Analytical Hierarchy Process (AHP). It comprises a parabolic trough, heliostatfields linear Fresnel reflectors, parabolic dishes, compound parabolic and linear Fresnel lenses. These technologies are compared on the basis of technical, economic and environmental criteria. Within these three categories a number of sub-criteria are identified as sub-variants are for than any technology.

Key words: Non Conventional · Wind Energy · Hydro Energy · Solar photovoltaic and solar thermal energy

INTRODUCTION

Since independence in 1947, India has its power generation capacity from 1.4 to increased 148 GW, but largely neglected its solar resource. The current grid connected fuel mix 63% fossil-thermal, 3% nuclear, 25% hydroelectric and 9% from other renewable resources; whereas grid connected solar generation capacity is only a MW[1]. Recently, However, the Indian government has announceda new political direction through its National Action Plan on Climate Change, whose eight national missions, namely the National Solar Mission proposes significant investment in R & D and infrastructure to increase the Share of solar energy in the total energy mix. India benefits from a sunny climate, especially in its northwestern region, which receives around 5.5 kWh / m^2 the solar energy every day. To take advantage of this resource is an option to take, currently of great interest isConcentrating Solar Thermal Power (CSP). This technology has successfully implemented in California and is strongly encouraged for the systems deliver to Europe with power from the Sahara [2]. Detailed feasibility studies for such systems are prepared. In India, the uptake of solar power has been Demonstrations limited, although solar thermal concentrators currentlyused in at least two locations to heat milk for pasteurization offer processing and cooking. This study was developed within a project, construct and test a solar power plant in Gujarat. During the early stages ofthe project it became clear that a critical factor to the success of the system would be the right choice of solar collector technology for use in its India [3]. Alternatives are being actively pursued, but such kind asheliostat concentrators with central tower receiver and satellite dishes coupled toStirling engines. How often it is the case with energy technologies a variety of options, each with their pros and cons. Moreover, the best solution for India can not be the same as for the USA or Europe, such as the economic and technological environment is different. The aim of this work is to review and evaluate the competing solar thermal collection technology for electricity generation in India through a structured process. In particular, the aim is to give a recommendation on which technologies pursue as part of the current project in Gujarat and other did to follow. Analytical Hierarchy Process (AHP) was adopted because it suited

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a decision-making tool well to a variety of problems that require a simple cost-benefit analysis is too simplistic [4]. It is a process that facilitates the discussion among designers and other stakeholders. In addition, they thus generating the lending documentation transparency in the decision-making reasoning[5]. The process is based on both mathematics and psychology answer to provide an overall and differs both certain and uncertain data of other decision models. The essence of the method is that an assessment be used to assess the problem as well as factual information and expert opinions. This is particularly useful in the case of evaluating solar concentrator technologies, where the different scale and nature of the prototype some of these systems are uncertainties in drawing a direct comparison between the operating characteristics. Saaty, AHP arose in the 1970s, described by transport applicationsranging planning to choosing a school for his son. More recently, AHP and other multi-criteria decision making (MCDM) methods, many problems have to be applied in the energy planning, as reviewed by Pohekar and Ramachandran along with other energy selection decisions, including the assessment of the oil pipeline inspections and energy resource allocation for households. To help a paper from Mart tuning and Hamalainenuses the AHP process, the environmental impact of hydropower. Bhattacharya and Dey use the AHP for electricity sector market selection in southern India. Kaya and Kahraman use a combined AHP and fuzzy approach for renewable energy planning in Istanbul. AHP is a tool that consistently for the implementation and growth of technology total energy sector.In this sector, it is common to find a wide range of technologies, surrounded by controversial themes and variations in opinion [6].

This AHP to help a particularly valuable tool that canbe used to reach a consensus. The essence of the AHP is that it is a complex decision facilitated by decomposing the problem into a hierarchy of "criteria" or sub-problems are analyzed individually [7]. In this study, we have categorized the evaluation criteria such as technical, economic and environmental related. the method is described as follows (i). A comparative literature reviewof solar collector technologieshas performed. the output is a shortlist of technology alternatives and evaluation criteria. (ii). The technology alternatives were based on the criteria has a pairwise comparison of the actual data from the literature. In addition, a thermal analysis is used to provide numerical values of certain criteria. (iii). A workshop was convened by solar energy experts in India, with presentation of technological alternatives and criteria. The expert panel was invited to review the criteria and weight them for four case studies, a number of producing recommendations. The last three were included to broaden the scope to include ofreference locations CSP plants are already operating or where advanced stages of planning were carried out. The result is a recommendation of a solar collection technology in any case [8].

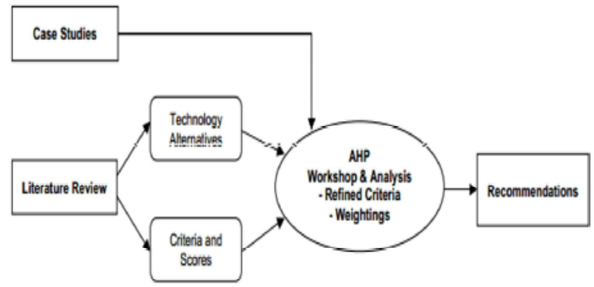

Fig. 1: Flow chart showing the methodology for technology evaluation and selection based on AHP.

Literature Survey: The purpose of this review, it is the most important technology alternatives in terms of solar collectors identify the criteria (technical, economic and environmental) to define research and technical data for use in the AHP study[9]. Some new or little studied technologies are deliberately neglected by the lack of relevant information. For reviews of more general scope of the reader referred to elsewhere. Parabolic trough collectors (PTC) will generally follow from highly reflective glass made with a single-axis tracking mechanism of the ecliptic, so that the sun's energy onto a linear receiver at the focal axis. Typically, the receiver is an evacuated glass tube and the absorber tube, carrying transferred synthetic oil for the heat to a heat exchanger for operating a conventional steam power plant. Can concentrate Such PTCs direct sunlight to generate operating temperatures up to 400°C [10] and achieve concentration ratios in the range 30-100. The world's largest solar thermal plant is currently the nine Solar energy systems generate (SEGS) of Luz Industries in the Mojave Desert built in California providing a total installed capacity of 354 MW. collector fields generally follow a north-south orientation with caution in consideration to the distance between collector rows, as to determine the distance of the height of the surfaces and pipelines used and therefore affect costs. It alsoaffects fluid transport and optical shadowing losses, which in turn impact on the efficiency ofthe system. Optical efficiencies of 80% have been obtained at the SEGS, with a land use of 3.2 m 2 / MWh / year [11]. The online parasitic load on the system varies SEGS VI monthly, but on average about 10% of the gross solar power. The recent SEGS VI - VII increased the outlet temperature from the solar field from 320 to 390°C to increase the vapor generated in the heat exchanger at a pressure of 100 bar. Are typical for parabolic trough collector stagnation temperatures in the range of 600°C. The half acceptance angle for a PTC is approximately 0.5°. For the standard PTC, the projected total cost of ownership and maintenance isapproximately $ 0.02 / kWhe and a total capital cost of3972 $ / kW or $ 424 / m^2. Although synthetic oil has been is used in the intake pipes of most PTCs so far, this transmission medium limits the operating temperature to about 400°C. molten salt has been proposed, but only prototype systems have been built due to the problems of the higher viscosity and high melting temperatures tracing required is. Analternative that was investigated, in that water and steam directlyin the absorber tubes is prepared[12]. In these systems, steam is generated directly in the solar field, thereby avoiding the cost of the heat transfer fluid and the central oil-fired steam generator. The pumping requirements and heat losses are smaller than the field temperature, the steam temperature can be reducedwithout influence and the heat transfer liquid is not present. The system is not without challenges itstechnical, with the risk of overheating and potential tube flow instabilities. Sophisticated controls are required ofwater vapor and absorb the use of two-phase flow[13]. Luz Industries, the plan to commercialize the technology, have projected that the efficiency would be improved, with $ 2,300 / kW - reduced capital costs to around 2100[14]. Ithas also that directly designed steam generation (DSG) systems, the solar field canact as evaporation stage, with turbine exhaust is used for superheating and preheating in a conventional gas turbine combined cycle power plant. The total cycle efficienciesare again expected to reach higher steam temperatures increase work for the same level of heat utilization. The two-phase flow and the load of the receiver for various operation and process conditions are of particular interest[15]. In direct steam generation There are three methods, procedures. Each have their advantages and disadvantages They are once through the fuel injection and the feedback process. With respect to the process conditions, a feedback mode, a continuous mode has been shown to be more useful in terms of stability and stress on the absorber. This is one of the biggest problems in the direct evaporation. The deformation and bending at the receivers during stratified two-phase flow through the thermal stresses is difficult to overcome. during the insertion of copper could reduce these tensions and greater heat transfer, the efficiency of this solution is doubtful. Bimetallic copper-steel receiver have been proven to be superior to steel receiver, especially in low power applications (1-60 kWe), where stratification is inevitable [29]. Where inclined troughs were used have proved unsuccessful and unnecessary to achieve direct steam generation [16].

Methodology: Heliostat field collectors (HFCs), also known as power towers, use to direct the sun's rays onto a central receiver a series of heliostat mirrors. These mirrors are flat or slightly concave. Typically, water vapor is used in the receiver, but some of the newer system using a molten nitrate salt. The advantage of the salt melt, that the radiation receiver can be started. As HFC systems are usually at about 10MWas they benefit from economies of scale in size. The use of a central receiver means that minimum heat transport is needed, resulting in higher optimum temperature of about 500°C and stagnation temperature in the range of 1750 °C [17]. This can be a technical challenge with thermal fatigue filters limiting the level of solar power that can be maintained. The Solar Tower 1 operated at 516 °C with an outlet pressure of 105 bar, the typical design parameters for all HFCs. typical concentration ratios are between 300 - 1500 With the higher temperatures, the result is that these systems have the capacity for greater efficiency, so that more power than the parabolic trough most commonly used. The parasitic loads are estimated at around 10% for a full scale system, with values. In is not significantly higher commercial solar power system 2, due to the lower capacity factor of over 20% From an ecological perspective, the nature of a heliostat is array layout requires a large space and thus HFC Moreland use than any other CSP technologies at about 4.6 m 2 / MWh / year [18]. Depending on the arrangement and location of such factors as the optical efficiency, trapping efficiency and acceptance angle is variable [19] The type of terrain available is also variable, while leveled ground is the most common choice, slopes were also used. A number of other types of receivers were also designed. In 1987, the CESA-1 tower at the Plataforma Solar de Almería in Spain usedan air tank with operating temperatures up to 1000 °C at 10 bar with the use of ceramic recipients [20]. Problems arose from the ceramic receiver to be 20-25 times greater than with a molten salt receiver, so that the system is very expensive and with high heat loss. A newer idea is to create a three dimensional volume, which came to be known as the volumetric air receiver. Despite their theoretical advantages have technical limitations, as yet limited in large scale developments of technology. Solgate, built in the CESA-1 tower, is one of the few air volume receiver pilot projects in existence and has reached operating temperatures above 1000 º C with a direct drive a gas turbine presented a comprehensive description of all the power tower projects and receiver types[21]. For the large-scale implementation adopted in this case study, the technical capabilities of the system as the most important criteria were weighted, so the PDR favored because of its superior technical efficiency. Surprisingly, the PTC is with synthetic oil receives an unfavorable rating of only 5.9%. Another factor favoring the PDR is the water consumption, which is crucial for a system in a large deserts of the Sahara; the PDR with a Stirling engine has a very low water consumption, while the PTC with steam turbine has a high usage. The heliostat field collectors and PDR are high for both the Mojave Desert and Southern Spain favors. In the Mojave desert in the volume of air receiver power tower is heavily favored at 14.2%, with the PDR is a close Secondat 13.9%. A similar result profile found for southern Spain exceptwith respect to the PTC favored is Less. The advantages of the CPCs is that they reach a concentration without any tracking with half acceptanceangles of about 20°; However, this allows only a very low concentration ratio of about 3, the destination using solar thermal systems, a device that have to operate at higher temperatures and efficiencies, which requires much higher concentration ratios than this. Due to the size impractically large ofa conventional CPC concentration ratios of about 10, is analternative approach to a lens before using collector opening entrance. These are then referred to as primary and secondary concentrators. The size and weight of the lens, to reduce a Fresnel lens, either linear or circular, would be selected as a rule. The advantage of refractive materials, such as polymethyl methacrylate is often used to make the Fresnel lenses is that they are generally cheaper and have a longer service life can be used as a mirror for reflecting materials. For the secondary concentrator again relatively inexpensive materials such as aluminum or glass can be used. Furthermore, if a material ischosen that a degree of flexibility, a less rigid frame is required to withstand wind loads without risk of breakage [22].

Conducted Studies on Exergy Analysis of Solar Energy: In this section, the review of exergy analysis of solar photovoltaic application. Photovoltaics as a direct conversion of sunlight into electrical energy have been considered in the past decades. As a clean and renewable solar PV cells were grown in different areas of residential, industrial and applied commercially. The review of exergy analysis of solar ponds applications is described in this section. Solar ponds are used to collect and storage of solar energy, to provide the thermal energy required for various processes.

Development of the relationship between the electrical and thermal output of a house style PV/T system was done by Coventry and Lovegrove. The ratio between the thermal energy and the electricity was introduced as a dimensionless factor that can influence the design and the energy cost of the PV/T system. This dimensionless factor as 1.0, based on the first law analysis evaluated and at 17 modified by the application of exergy analysis and second law of thermodynamics. The effect of this ratio on the best design of the system has been shown with an example. The exergetic efficiency of a hybrid PV/T air collector was evaluated in a study by Joshi and Tiwari. In order to analyze the energy and exergy of the optimal inclination, they had determined the maximum condition under which was the sunlight. The exergetic efficiency of PV/T air collector has been calculated on the basis of on Eq. (1)

$$\eta_{exergy\,overall} = \eta_0[1 - \beta\Delta T] + \eta_{th}\left[1 - \frac{T_0 + 273}{293 + \Delta T}\right] \tag{1}$$

The calculated exergy efficiency was varied between 12-15% in January and 13-14% in June. They had also noted that the monthly total amount of exergy varies from 8 to 15 kWh kWh. By studying the effect of flow rate on the annual amount of Exergy has been found that increasing the flow rate leads to exergy increment. The exergy analysis of PV / T integrated with a solar greenhouse was carried out by Nayak and Tiwar. They considered the annual Exergy input as a combination of radiation exergy in the south Roof and the PV module. The exergy input for PV module was with Eq. (2)

$$\dot{E}x_{in} = A_C \times I(t)\left[1 - \frac{4}{3}\left(\frac{T_a + 273}{T_S}\right) + \frac{1}{3}\left(\frac{T_a + 273}{T_S}\right)^4\right] \tag{2}$$

By substituting A_C and I_C with A_{sr} and I_{sr} the exergy south entrance roof was calculated. They evaluated the relative exergy output growth on the study of Syahrul *et al*. that is, by Eq. (3).

$$\dot{E}x_{th,daily} = \sum \left(1 - \frac{T_a + 273}{T_r + 273}\right) \times \dot{Q}\ u_{daily} \quad (3)$$

The defined exergy efficiency is given by Eq. (4).

$$\eta_{Ex} = \left(\frac{\dot{E}x_{out}}{\dot{E}x_{in}}\right) \times 100 \quad (4)$$

The annual total exergy has been reported that 12.8 kWh and be calculated exergetic efficiency of the PV / T integrated greenhouse was to be 4%. The exergetic and economic analysis of hybrid photovoltaic Thermal (HPVT) were carried out by Raman and Tiwari. the Study was carried out for four different cities in India. the annual Exergy output was based on Eq. (5) has been applied.

$$E_{aex} = \dot{Q}_{ii}\left[1 - \frac{25 + 273}{T + 273}\right] \quad (5)$$

The maximum output exergy reported was 157.22 kWh and the maximum exergy efficiency of the considered cities ranged from 11.4% to 14.8%. Compare the thermal efficiency and the exergy efficiency, they found that the exergy efficiency about 40% lower than the thermal efficiency. The performance of PV/T collectors flat water, as had been his pattern in series were evaluated in four different weather conditions of India. The total exergy inflow was based on Eq. (2). The exergy outflow was considered to be a combination of thermal and electrical exergy. Six collectors were connected in series model with constant mass flow investigated. They found that the amount of total exergy maximum in summer. The annual exergy was 1273.7 kWh. A comparison between the exergy efficiency of PV / T collector with and without glass cover was done by Chow *et al*. both cases were modeled numerically and the results validated with data collected one day. The overall exergetic efficiency was the sum of the exergetic efficiency of a thermal collector and the PV cells. It is given by Eq. (6).

$$\varepsilon_{PVT} = \eta_{PV} + \left(1 - \frac{T_a}{T_2}\right)\eta_t \quad (6)$$

where in T2 and Ta is the ambient temperature and the final temperature of the liquid medium. The exergetic efficiency defined as the ratio of the total duration of to the total exergy Exergy inflow. They found that the desired parameters for the exergetic efficiency of PV cells were unfavorable for the thermal exergy efficiency. They also pointed out that the exergy efficiency for unglazed state is better compared with the vitrified state. An analytical expression was derived for the connected PV/T collectors in series. The performances of two different air collectors were completely covered with the PV module compared. an air collector of air through the absorber plate and in another of the air stream flowing beneath the plate. The exergy balance of the two configurations was analyzed. It was that in the case of electricity generation made and hot air production configuration, flow in the air below the absorber panel is much better. Exergy efficiency of a typical PV/T air collector was measured and presented a detailed exergy analysis with computer simulation. They took the general form of exergy balance, which can be expressed as Equation. (7).

$$\dot{E}x_{fin} - \dot{E}x_{ini} = \dot{E}x_Q - \dot{E}x_W + \dot{E}x_{in} - \dot{E}x_{out} - \dot{I}_{c.v} \quad (7)$$

Calculates the exergy rate of inlet mass to adjust the volume using Eq. (8).

$$\dot{E}x_{in} = \dot{m}C_p\left[T_{f,in} - T_{anb} - T_{amb}\ \ln\left(\frac{T_{f,in}}{T_{amb}}\right)\right] + \dot{m}RT_{amb}\ \ln\left(\frac{T_{f,in}}{P_{amb}}\right) \quad (8)$$

The exergy rate of outlet mass was calculated by changing the Parameters of the inlet with the outlet of the parameters in the above equation. The exergy rate of heat transfer was evaluated with Eq. (2). Eq. (9) is used to calculate the speed of operation exergy.

$$\dot{E}x_W = V_{mp}I_{mp} = \dot{E}_{el} \quad (9)$$

The irreversibility rate was assumed that the combination of its external and internal exergy exergy destruction. Finally, the exergetic efficiency of the system was described by Eq. (10).

$$\eta_{ex} = 1 - \left(\frac{\dot{E}x_{los} + \dot{E}x_{dex}}{\dot{E}x_{Q,sun}}\right) \quad (10)$$

The effect of various parameters, such as inlet air temperature, air velocity, Suns Radiation intensity and wind speed on the exergy efficiency. An evaluation of the performance of the Micro Channel hybrid Photovoltaic Thermal (MCPVT), based on the second law of thermodynamics which was done by Agrawal and Tiwar. The data were collected in four different weather conditions in India. the exergy Components were calculated on the basis of existing formulas in the literature. It was that the maximum monthly total reported

Table 1: Summary of reviewed papers for exergy analysis of solar heating devices.

No.	Heating device	Exergy efficiency	Key results
1	Solar water heating system	16.17%	The highest exergy destruction was related to the solar collector
2	Solar assisted heat pump	23.81%	It was concluded that the maximum exergy losses occurred in compressor, which was followed, by the condenser and solar collector
3	Solar assisted heat pump	30.80%	The exergy losses of solar collector was found to be 1.92 kW
4	Flat plate solar air heaters		It was concluded that the solar air heaters with fins are more efficient than those without fins
5	Flat plate solar heaters	44%	It was found that as the air mass flow rate and time increases the exergetic efficiency also increases

exergy Efficiency of 18% in January. The minimum amount (15.8%) was recorded in June. Compared the exergetic efficiency of Microchannel Thermal solar cell (MCSCT) with the MCPVT. it It has been found that the overall efficiency of the Exergy MCPVT higher as MCSCT.

Exergy Analysis of Solar Power Generation: The performance of the solar aided coal-fired power Plant-based assayed for the energy and exergy analysis. The study also includes environmental and economic analysis. The plant exergy efficiency was defined on the basis on Eq. (11).

$$\varepsilon = \frac{\text{Net electricity output}}{\text{Mass flow rate of coal} \times \text{specific exergy of coal}} \qquad (11)$$

They also Exergy Performance Index (Expi), which is calculated using Eq. (12)

$$\text{ExPI} = \frac{\text{Excess power generated over the design rated capacity}}{\text{Exergy input through solar irradiation}} \qquad (12)$$

where the concept of exergy input of solar radiation was calculated by Application of Eq. (13)

$$\dot{E}x_S = \left[1 - \frac{4T_a}{3T_S}(1 - 0.28\ \ln f\right]\dot{Q}_S \qquad (13)$$

The plant exergy efficiency was in the range of 33.6 to 38.2% reported. By comparing the energy and exergy analysis, they found that the application of solar energy for heating feed water efficiently on the basis of exergy analysis rather than energy analysis. The exergy analysis on the basis of ammonia solar thermal system examined. The overall exergetic efficiency was reported to be 70.7%. The reaction and heat transfer were found to be the two main sources of irriversibilities be.

CONCLUSION

The AHP study shows that the preferred solar panel for the case of Gujarat in northwestern India is the linear Fresnel lens with CPC-type secondary. After the sensitivity analysis in which criteria weights were varied to likely uncertainties in the selection procedures reflect the preferred technologies thresholds are either the Fresnel lens-CPC or the parabolic dish reflector. The initial phase of the growth of renewable energy in India on the capital based grant and grants. In order to obtain renewable energy, it is necessary for capital grant to move the power to the base support. the IEPC also recommends this. A possible solution for grid-connected renewable energy is through the provision of preferential feed-in tariff. In many cases, the effectiveness of the renewable options will depend on implementation strategies and cost recovery mechanism. the challenge can be met by PV, small hydro, wind or hybrid systems access to remote villages. It is necessary to understand the document actual performance of the systems in the area of impact of various interventions and on the economics of renewable system. Systematic potential assessment and goal setting, the establishment of rates of progress and possible prosecution of actual program performance is for the diffusion of renewable energies.

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