Impact of PV-CSP Intergrated System for Power Generation

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Abstract

Solar and Wind energy is available in plenty in the country like India.Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Wind is the indirect form of solar energy and is always being replenished by the sun. Wind energy is the kinetic energy of air in motion also called wind.Technical potential of onshore wind energy is large. CSP technology with thermal storage having potential to replace the conventional thermal power plant.Advantage of CSP technology is that thermal storage technology is easily integrated with the CSP technology in compare with the photovoltaic and wind power technology. When the PV is hybridized with Wind it does not meet the satisfactory performance. PV and Wind power generation technologies not suitable at grid level due to intermittency in the availability of sun and wind. Hybridization of PV with CSP is the option to sole the intermittency problem and provide the energy at grid level. The research status of PV-CSP hybrid technology for its performance is summarized from the study made in this paper to provide a current global scenario, but it is observed that for economic and efficient power generation with the effective proportions of integrated PV-CSP hybrid systems that are yet to be researched.

1. INTRODUCTION

World's energy demand is increasing day by day due to population explosion and technological advancements. So, clean energy is the need for the future which is reliable and cost effective. Renewable energy is the promising option. Solar and wind energy is the best option for future world because of several reason: Firstly, both are abundant energy source of renewable energy. Secondly, both are non-exhaustible. Lastly, the environmental risk are negligible. Photovoltaic and wind both energies are not dispatchable and power is also not consistent due to the cloudiness and intermittency in wind speed. To fulfil the gap between energy demand and supply, there is a need for the energy which is dispatchable, available at grid level and provide consistent power generation. Wind energy is the best option for onshore location and solar power generation system can be built anywhere where there is availability of sun. PV-WIND and CSP-WIND hybridization is not the promising option for these demand. So these demand are only fulfilled by the hybridization of PV-CSP power generation. Electricity produced by the PV is used at day time and energy produced by the CSP technology is store by thermal storage technology and used at night and when the radiation is low at daytime. In this paper study of benefits and problems of photovoltaic, concentrated solar

power and wind power generation have been made and problem identification for various renewable energy system are also studied. From the study it is observed that the hybridization of PV-CSP system is best suited for providing energy at grid level and consistent power supply. It has also been observed that levelized cost of energy (LCOE) for the PV-CSP hybrid system is 0.524 USD/kWh, only 2% higher than the LCOE for the PV-Battery, 0.51 USD/kWh. If demand exceeds to 500 kW, the LCOE of the PV-CSP would be 26% (0.26 USD/kWh) lower.

2. PHOTOVOLATIC POWER GENERATION

2.1 Benefits of Photovolatic

Hjothman et al. [1] presented their paper on performance analysis of a double-pass photovoltaic/ thermal (PV/T) solar collector with CPC and fins. Hybrid PV/T, CPC and fins have a potential to increase the power production and reduce the cost of photovoltaic electricity. Fig.1 shows the schematic model of a double pass photovoltaic thermal solar collector with CPC and fins.

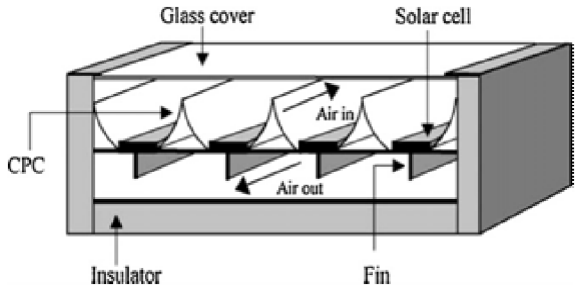

Fig.1: The schematic model of a double pass photovoltaic thermal solar collector with CPC and fins

T.T Chow et al. [2] have presented an experimental study of facade-integrated PV/T water-heating system. Different operating modes were performed with measurements in different seasons. Natural water circulation was found more preferable than forced circulation in this hybrid solar collector system. The thermal efficiency was found 38.9% at zero reduced temperature, and the corresponding electricity conversion efficiency was 8.56%, during the late summer of Hong Kong. V.V. Tyagi et.al [3] presented their paper on progress in solar PV technology. Presently, extensive research work is going for efficiency improvement of solar cells for commercial use. The efficiency of monocrystalline silicon solar cell has showed very good improvement year by year. It starts with only 15% in 1950s and then increase to 17% in 1970s and continuously increases up to 28% nowadays.

2.2 Problems Associated with Photovoltaic

J. Thongpron et al. [4] discussed the effects of low radiation on the power quality of a distributed PV-grid connected system. This paper is focused on the nature of components of complex power of a PV-grid interactive system due to low radiation, under 400W/m^2. The system being investigated in northern Thailand. It was found that actual power is available at high values of radiation from a PV array. At low radiation level when the array does not provide enough output power, reactive power is drawn from distribution transformer and fed into an inverter and loads. Methods must be devised to capture this low radiation energy and converted into actual power form. V.V. Tyagi et al. [3] discussed the progress in solar PV technology. It was concluded that when photovoltaic technology is compared with the nuclear energy, coal and fuel it shows that PV technology suffers due to low efficiency and its performance depend on weather and location. Nuclear energy, coal and fuel shows the efficiency higher than PV and nuclear, coal and fuel power plant can built any where. G.K. Singh [5] discussed the solar power generation by PV (photovoltaic) technology. This study suggested that the geographical location has a strong impact on the level of reliabilityobtained by utilizing PV in small isolated power systems.

S-JPSET : Vol. 11, Issue 2, ISSN : 2229-7111 (Print) and ISSN : 2454-5767 (Online)

Cost of residential solar PV, electrical energy price, size of the incentive, and solar insolation decide the strength of the solar renewable energy credit policy. Nadarajah Kannan [6] reviewed the solar energy for future world. This paper discussed the barriers to solar industry such as-sunshine intensity, cloudiness and power generation is not consistent all the time so the integration of other energy source is essential to provide consistent supply. Energy generated by solar system is direct current which is not useful to home appliances so for providing alternating current, complex circuits and storage system are required. Lian L. Jiang et al. [7] discussed the computational intelligence techniques for maximum power point tracking in PV systems. Due to the difference in the received irradiance, PV module observe multiple peaks in the power versus voltage (P-V) curve due to the current versus voltage (I–V) PV cell mismatch. Under varying climatic conditions for maximizing the power extraction from photovoltaic (PV) systems maximum power point (MPP) tracking (MPPT) is an important technique. With the help of the study, CI (Computational Intelligence)-based MPPT technique is provide to users to understand and select an appropriate method based on application requirements and system constraints. Dipesh Lamsal et al. [8] discussed the output power smoothing control approaches for wind and photovoltaic generation systems. Photovoltaic generation system provides solar irradiance which needs to be smoothed before supplying power to the grid level. Various power smoothing methods are developed for photovoltaic systems.

3. CONCENTRATED SOLAR POWER GENERATION

3.1 Benefits of Concentrated Solar Power

Xu et al. [9] discussed that the high-temperature TES system is the key element of the CSP systems. It provides the capability of providing dispatchable energy to the CSP plant by extending the generation time beyond sunset and avoiding fluctuations associated with the intermittent solar rays, etc. The thermal storage is easily integrated with CSP plant as compared to the other non-conventional power sources such as wind power and photovoltaic power. Stefan Pfenninger et al. [10] comparing concentrating solar and nuclear power as base load providers using the example of South Africa. They found that under a range of technological learning assumptions, CSP compares favourably against nuclear on costs in the period to 2030, and has lower investment and environmental risks. The results suggest that CSP has lower investment and environmental risks in compare to nuclear power and CSP could be capable of providing a stable base load supply at lower cost than nuclear power, and may have other non-cost benefits.Ben Xu et al. [11] discussed the application of phase change materials for thermal energy storage in concentrated solar thermal power plants. Thermal storage for CSP industry in the form of sensible heat, or latent heat, or a combination of both is considered . Studies conducted to compare latent thermal storage and sensible heat storage which result a significant reduction of storage tank volume can be achieved using PCMs.Rafael Soria et al. [12] discussed the modelling of concentrated solar power (CSP) in the Brazilian energy system. Three energy planning tools, namely MESSAGE Brazil, TIMES-TiPs-B and REMIX-CEM-B, have been combined to analyze the opportunities that CSP plants offer to the power system and to the wider energy system of the country. This work shows that CSP can be a cost-effective option under stringent mitigation scenarios. Their results show synergies between CSP and other power supply technologies with small cost differences between the baseline and CSP-forced scenarios. Xinhai Xu et al. [13] discussed

 S-JPSET : Vol. 11, Issue 2, ISSN : 2229-7111 (Print) and ISSN : 2454-5767 (Online)

the prospects and problems of concentrating solar power technologies for power generation in the desert regions. Multiple challenges were discussed for concentrating solar power technologies such as water consumption, thermal energy storage, thermocline system, heat transfer fluid, heat receiver, sizing strategies and cost. Sites with relatively high direct normal irradiance is preferable for CSP system.Yu-ting Wu [14] discussed about improving the thermal properties of NaNO3-KNO3 for concentrating solar power by adding additives. Mixed molten salt is a rising medium for both energy storage and heat transfer in solar thermal power because of its many advantages such as low vapour pressure, large heat capacity, low cost, wide range of temperature in application, etc but there are the disadvantages of higher melting point and poor thermal stability with the commonly mixed molten salts, such as Solar salt (60 wt% $NaNO_3$ + 40 wt% KNO_3, melting point (220°C), limit use of temperature (565°C). Based on Solar salt, 14 kinds of mixed molten salts are obtained by adjusting the component ratio and adding carbonates or nitrates to obtain molten salt with lower melting point and better short-term thermal stability. 4 kinds of mixed molten salts are selected having melting points and decomposition temperatures are about 100°C and 600°C respectively. When the 4-days repeated heating-cooling experiments are conducted they show good short thermal stability.

3.2 Problems Associated with Concentrated Solar Power

Jay Prakash Bijarniye et al. [15] presented their paper on concentrated solar power technology in India. Conventional power plants suffer from issues like fuel scarcity, availability of site and other environmental concerns. Renewable energy sources especially solar, wind and bio-mass are utilised to overcome these problems. Among many options available in solar technology, power generation through, CSP (Concentrating Solar Power) could be the most promising one for India in the coming future. They also discussed the SWOT (Strength Weakness Opportunity and Threats) analysis of CSP which is based on the views of various researchers. Strength of CSP are-high efficiency, fully recyclable material used and onsite power generation with less transportation. Weakness of CSP are-high capital cost, handling of high temperature fluid, manufacturing cost of reflector and losses due to heat transfer. Jibran Khan et al. [16] discussed the solar power technologies for sustainable electricity generation. Comparison of PV and CSP technology concluded that higher electricity production is shown by CSP technology and when we compare the PV power plant with CSP plant considering the same area of an occupied land, PV technology shows the better performance for electricity production and land use capability. Advantage of CSP plant is that it provide electricity even in the absence of the sun.Comparative analysis of CSP and PV plant revealed that initial investement cost for CSP is higher than PV but CSP plant yields higher economic returns and incentives than PV. Wang Fuqiang et al. [17] discussed the progress in concentrated solar power technology with parabolic trough collector system. CSP technology is beneficial with parabolic trough collector system include ease of coupling with fossil fuels and other renewable energy and promising cost effective investement. Future prospects of CSP technology with PTC system is discussed and result is that how the operating temperature would be increased and how the amount of heat collected per unit area increases resulting in higher thermodynamic efficiencies and smaller heat losses. Future generation of HTFs for

S-JPSET : Vol. 11, Issue 2, ISSN : 2229-7111 (Print) and ISSN : 2454-5767 (Online)

CSP technology with PTC system will have low cost and without toxins.

4. WIND POWER GENERATION

4.1 Benefits of Wind Power

Bhatt et al. [18] studied prediction and enhancement of performance of wind farm in India and found that annual plant load factor by 1-3% would be increased by improving the wind farm availability at grid level. G.M. Joselin Herbert et al. [19] presented their paper on a review of wind energy technologies. This paper concluded that to analyse the vibration problem of wind turbine, experimental and theoretical methods are used. Probabilistic models such as selection of site, height, choice of wind generators, wind velocity, wind power potential have been considered to determine the energy output of the wind turbine system. Francisco Díaz-Gonzáleza et al. [20] presented their paper on a review of energy storage technologies for wind power applications. This paper discussed the potential of energy storage system applications in wind power. This paper presented the main characteristics of energy storage technologies suitable for stationary applications. Wind has stochastic nature due to which electric power generated by wind turbines is highly erratic and may affect both the power quality and the planning of power systems. For controlling wind power plant output and providing ancillary services to the power system, energy storage system (ESS) play an important role.

4.2 Problems Associated with Wind Power

Caselitz et al.[21] presented their paper on saving of fuel through load-shedding of diesel generators sets by wind energy converters. This paper concluded that technical constraints must be considered while installation of wind energy generation system in autonomous systems because wind penetration may disturb the operation of the system due to the oscillation of voltage and frequency. If the wind speed is high the output of wind energy conversion may damage conventional units. V.V. Tyagi et al. [22] discussed the progress in solar PV technology. When photovoltaic technology is compared with the solar power it shows that wind power suffers from noise pollution and it may kill birds that pass by. Kody M. Powell et al. [23] discussed the hybrid concentrated solar thermal power systems. This study discussed the hybridization of CSP with various renewable and non-renewable energy sources. Among these hybridization of CSP with wind shows the several advantages and disadvantages. Advantages of hybridization of wind with CSP are potential for purely renewable power generation and different energy availability profiles provides some reliability. Disadvantages are energy sources not dispatchable, little synergy at equipment level as hybridization is generally only at grid level and no capital cost savings from shared equipment. Hybridization of wind with CSP does not show the satisfactory performance due to the discussed disadvantages. DipeshLamsal et al. [24] discussed the output power smoothing control approaches for wind and photovoltaic generation systems. Wind generation system provides fluctuating output power due to intermittency in wind speed which needs to be smoothed before supplying power to grid level. It is observed that the wind power plant generation faces the following problems at the level of power grid-

- Unstable grid frequency.
- Voltage flicker at the buses of the power grid
- Instability in the grid for loads which are sensitive to the voltage and frequency variations.

Result suggested that the combination of PVGS (Photovolatic Genertation System) and

 S-JPSET : Vol. 11, Issue 2, ISSN : 2229-7111 (Print) and ISSN : 2454-5767 (Online)

WPGS (Wind Power Generation System) provide the reduction of power fluctuation but it is not sufficient for a satisfactory performance. Hence for desired smoothing the use of ESS (Energy Storage System) along with a proper smoothing technique is necessary. Among the various smoothing approaches, conventional control and converter control approaches are more frequently used as compared to other approaches.

5. IMPACT OF HYBRIDIZING THE PV-CSP SYSTEM

Xing Ju et al. [25] presented their paper on a review on the development of photovoltaic/ concentrated solar power (PV-CSP) hybrid systems. The LCOE of a current-generation molten-salt power tower plant with 10 h of TES is estimated to be 12 $ct/kWh and for utility scale PV the LCOE is estimated about 8 $ct/kWh. Therefore the requirement is to increase the generating efficiency and reduce the LCOE of the CSP technology. Vikas R. Patil et al. [26] presented their paper on techno-economic comparison of solar organic Rankine cycle (ORC) and photovoltaic (PV) systems with energy storage. In this work, they compare the technical and economic performance of a solar organic Rankine cycle (s-ORC) system with thermal energy storage (TES) and a solar photovoltaic (PV) system with battery storage at a capacity of 50 kW. Minimum LCOE estimated for the s-ORC system was 0.19 USD/kWh and 0.26 USD/kWh for the PV with a same CUF (0.56). LCOE of the PV system yields an attractive value of 0.12 USD/kWh with a CUF of 0.27 but it includes no battery storage. Energy storage thus favors s-ORC over PV in terms of CUF and LCOE. Layout of s-ORC power plant and PV power plant is shown in Fig.2 and Fig.3.

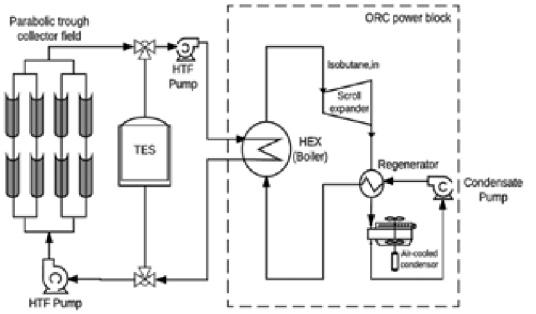

Fig.2: Schematic layout of the s-ORC power plant

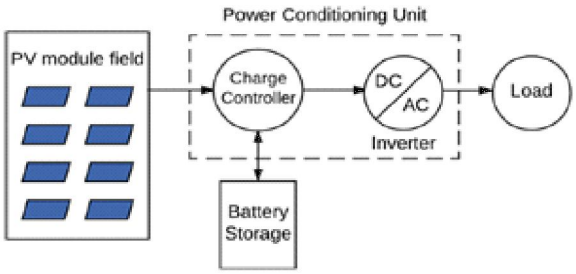

Fig.3: Schematic layout of the PV power plant

J.A. Aguilar-Jiménez et al. [27] presented their analysis on techno-economic analysis of a hybrid PV-CSP system with thermal energy storage applied to isolated microgrids. The results show that, for the case study, the levelized cost of energy (LCOE) for the PV-CSP hybrid system is 0.524 USD/kWh, only 2% higher than the LCOE for the PV-Battery, 0.51 USD/kWh. However if the community's demand exceeds 500 kW, the LCOE of the PV-CSP would be 26% (0.26 USD/kWh) lower. The PV-CSP hybrid system with thermal storage is a better economic option, in terms of the LCOE, than the traditional PV-Battery systems.

6. CONCLUSION

From the above study of various types of renewable energy resources following problems have been identified :

- PV- voltage fluctuations, not available at grid level, low efficiency and power generation is not consistent.
- CSP- high capital cost, handling of high temperature field and losses due to heat transfer.

S-JPSET : Vol. 11, Issue 2, ISSN : 2229-7111 (Print) and ISSN : 2454-5767 (Online)

- WIND- unstable grid frequency, fluctuating output power due to intermittency in wind speed and unstable grid frequency.
- PV+WIND- does not meet the satisfactory performance at grid level, energy storage system (ESS) is necessary.

Keeping in view of above problem, the hybridization for PV-CSP system appears to be beneficial for utilization of renewable energy for the grid system in which levelized cost of energy (LCOE) for the PV-CSP hybrid system is 0.524 USD/kWh, only 2% higher than the LCOE for the PV-Battery, 0.51 USD/kWh. If demand exceeds to 500 kW, the LCOE of the PV-CSP would be 26% (0.26 USD/kWh) lower. The PV-CSP hybrid system with thermal storage is a better economic option, in terms of the LCOE, than the traditional PV-Battery system. The study of improvement of efficiency has not been found for the hybrid PV-CSP system, as to how it can produced electricity during low solar radiation .Thus, this work needs to be studied and extended for the further research.

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