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Solar photo voltaic power generation: An Indian perspective

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Abstract— **Solar energy is a clean, renewable way to provide electrical power available abundant and it is , inexhaustible among all of renewable energy resources. Photo voltaic power (PV) system (direct conversion of solar energy to electricity by means of solar cells) appears more flexible to meet the wide range of small scale energy needs of rural villages, particularly in the agricultural sector in developing countries like India. To make PV systems more economical to the rural users, many works in the areas of research, technological growth, manufacture field . This paper reviews the availability, present status, strategies, major realizations, existing performance models and future predictions of solar options in India. Efforts have been made to summarize the photovoltaic technology, capability, solar cell materials, environmental aspect, system performance and reliability, and present and future predictable costs. This review would be useful for Photo voltaic system producers, researchers and academicians for developing new technologies, comparing cell materials, cost comparisons to give better services to users over a wide range of applications and from the available research works it is also concluded that PV technology provide a better option for energy needs in the near and long term for our country**.

Keywords— PV power, cell, renewable energy

I. Introduction

As per 2001 census data, only 43.5% of Indian rural households have access to electricity. Villages in remote areas are not connected by the electric grid because of high cost of installation of electric lines. In India, there are about 94,000 unelectrified villages, out of which around 25,000 villages are located in remote areas. Small isolated conventional diesel plants fulfill the demand of electricity in some of the remote villages but the scarcity of fossil fuels and continuous increase of its prices makes it a poor choice.

The National Electricity Policy 2005 aims at achieving a minimum consumption of one unit per household per day in the near future .Indian Electricity Act 2003 provides the requisite framework for expediting electrification in rural areas Hourly solar energy for four Indian cities New Delhi, Mumbai, Pune and Jaipur Reflects almost all climatic conditions in India is estimated by Rizwan[1] and he used high performance tool "reference evaluation of solar transmittance" for this estimation.

Atul Sharma [2] made a comprehensive study on need and importance of the renewable energy sources such as solar, wind and bio-energy and concluded that photovoltaic power generation is the best option in our country with cost consideration also. In our country there are plenty of locations where these plants can be erected for the production of power.

Photovoltaic technology is one of the best ways to exploit the solar power. Photovoltaic conversion is the direct conversion of sunlight into electricity without any heat engine . Photovoltaic devices are rugged and simple in design requiring very little maintenance and their biggest advantage being their construction as stand-alone systems to give outputs from microwatts to megawatts.

Naveen Kumar Sharma et al. [3] viewed on solar thermal plants, concentrating power plants (CSP) and the present status of solar energy generation in India. There are many competing technologies, including at least fourteen types of photovoltaic cells, such as thin film, mono-crystalline silicon, polycrystalline silicon, and amorphous cells, as well as multiple types of concentrating solar power[33] and conversion efficiencies are based on technical barriers from one type to other.

K. Mukhopadhyay et al .[4] made a detailed analysis on available resources, current situation with already available proven, undiscovered estimated sources and projection for the rural development in Nigeria. Muneer et al. [2005] described solar PV electricity as the solution of future energy challenges and the modular approach adopted to meet the year 2025 energy demand of six major cities in India: Chennai, Delhi, Jodhpur, Kolkata, Mumbai and Trivandrum. He suggested solar hydrogen based energy network has the capability of providing the future energy requirements [5]. T.K.Bhattacharya [6] exploited the situation in India and recognize the need of research works on many areas to make PV power economically .

II. PV Solar cell materials

Solar cells require a light absorbing material to absorb photons and generate free electrons via the photovoltaic effect. Various silicon technologies , usage of multi-crystalline silicon and mono crystalline silicon for high-efficiency, and advances in chemical and metallurgical ways for photovoltaic (PV) silicon production are assessed in RobertG. Prattworks [7].Goetzberger et al. concise the history of photovoltaic materials[8]. And Keogh et al. briefed about silicon solar cells testing [9].Adamian et al.

examined the usage of porous silicon layers as anti reflection coatings

No.of works on amorphous silicon about their new technologies ,stable efficiencies and production technologies are reviewed[10,11]. Crystalline silicon technologies [12,13],Cadmium telluride and cadmium sulphide materials on PV technologies [14]and organic cells and their usage is best explained in[15,16].Hybrid photo cells development and construction are evidently given by various works[17,18] . Barnett et al. , Aberle, Solanki et al Powalla et al. worked on thin film technologies and suggested the possibilities to improve efficiency[19,20]

III. Performance and reliability with case studies

Li et al. investigated the operational performance and efficiency characteristic of a small PV system installed at the City University of Hong Kong and the amount of solar irradiance data falling on the PV panel was determined using the luminous efficacy approach [21].Ravindra M. et al.[22] made the performance analysis of solar photovoltaic (SPV) system installed at Sagardeep Island in West Bengal state of India and estimated solar radiation by the equations proposed by Sukhatme [23]

Shrestha and Goel [24] discussed the issues in optimizing the use of isolated small PV power generation in remote areas and demonstrated the procedure to evaluate the different PV schemes considering the stochastic nature of the insolation and the load requirement.Bansal et al. developed an integration of solar photovoltaics of 25kWp capacity in an existing building of the cafeteria on the campus of the Indian Institute of Technology, Delhi by creating a solar roof covering with the photovoltaic array inclined at an angle of 15◦ from the horizontal and faces due south [25].

Kivaisi presented the installation, working and reliability of a 3kWp photovoltaic (PV) plant at Umbuji village, in Zanzibar, Tanzania which intendes to provide power supply for a village school, health centre, school staff quarters, and mosques [26]. Ubertini and Desideri [K] studied a 15 kWp photovoltaic plant and the performance of solar air collectors coupled with a sun breaker structure which was installed on the roof of a scientific high school [27].

Amorphous silicon 4 kw PV system was installed with high durability and reliability by ROBERT G.PRATT in 1987 without any operation failure of components over 2 years of testing period. Efficiency and fill factors are estimated from the data collected for four occasions and are quite economical for small scale PV systems [8].

IV. Environmental aspect

Environemntal pollutions will greatly reduced by the usage of solar energy for power generation and it is around 4-5% of total emissions. By installing Concentrating PV systems we can eliminate to maximum CO2, SO2, and NOx contents in addition to reduction of noise and air pollution.

To reduce carbon emissions from India, the government at present spends over 2.6% of the gross domestic product (GDP) with the considerations of climate variability, specific agricultural areas , forests, water resources, health and cleanliness, coastal zone infrastructure and severe events. On average, every 1 GW of extra renewable energy capacity decreases CO_2 emissions by 3.3 million tonnes in a year. So there is a great need to promote the Solar power systems in Indian power sector to reach future energy requirements and for environment protection [17].

Large-scale solar power plants are increasingly placed in desert and dry areas across the India. Dust is one of the main problem as it forms as layers and decreases the solar power conversion of 40% by 4 g/ m^2 and these plants can lose nearly 30% energy output within short period after installation. It is therefore necessary to maintain them with frequent cleaning at least every other day either manually or with the installation of automatic cleaning systems like solar wash and others. Cleaning three times in a week and washing once a month is vital for many of the Indian locations.these are addressed and follow up remidies are explained in detail by Deodhar et al. [28].

Transparent screens infused with indium tin oxide electrodes are used to cover the solar panels .this material is electrically sensitive and electronic sensors will monitor the dust levels and send the signals when it is sufficient thick and cleaning will be done. This may be the best option to take away dust in solar panels, especially for Indian localities which will greatly affect the and reliability of the system[30].

V. Sizing, distribution and control

Abbas a. salim et al. [31] prepared a comprehensive report on the performance of a 350 kW concentrator solar photovoltaic power system (PVPS) is briefly summarizes the system design, fabrication and installation phases, performance and the problems faced over a span of 7 years . They also mentioned the problems arised from the plant for the last 5 years such as Cell-ceramic substrate bonding, thermal adhesive etc. Now it was connected to the utility grid and also expecting to produce hydrogen with this plant by directly coupled to a 350 kW electrolyzer.

H. Saha [32] made a critical analysis on the usage of solar photo voltaic power in an Indian village through centralized and decentralized power generation and discussed about the suitability according to requirement. Village energy centre and roof-top approaches are analyzed based on the requirements of the village including its domestic, agricultural, community and street lighting needs and its techno economic aspects to make it

most cost effective.Regression equation developed by NASA Lewis Research Centre is used to estimate the load for the two approaches and was applied to a typical village. A comparison is made between the economics of village energy centre model and the highly decentralized, roof-top model and concluded that former one is more cost-effective five times than the roof top approach apart from other benefits like better maintenance, superior load management and greater security. He suggested a detailed experimentation for obtaining a reliable and realistic data which is suitable for Indian conditions.

Katti and Khedkar[33] investigated the application of wind-alone, solar-alone, and integrated wind- PV generation as stand-alone generating systems to use at the remote areas based on the site matching and an energy flow strategy for optimum unit sizing .

Ladakh Ecological Development Group, Leh released a report[34] on 100Kw solar power plant to meet the energy needs of Lehdistrict.here the presnt needs are met with minor,majorhydro power plants and with diesel generators but transmission and distribution and investments are major hurdles which leads to the installation of 100Kw plant .in this report a 100kw SPV power plant.Installation procedure, array details, battery banks, charge controllers, inverters, A.C.Feeder panels and minimum and maximum loadsare given.Implementation methodology from the erection state to power generation, distribution and sources of assistance for the problem rectification were clearly explained .This report concludes SPV generation is effective and suggested transmission improvements. Report contains financial, environmental, social impacts along with sustainability and problems.

BJØRNAR SANDNES and JOHN REKSTAD [35] worked on Photovoltaic and thermal hybrid systems. They tested the interactive mechanism between PV & thermal system and the performance of the system. The observations are made on three different collector configurations, thermal efficiency data and average efficiency curves are drawn. An analytical model for PV/T system was developed with the consideration of the effect of integrated solar cells and different designs of absorber plates.

Wissem et al developed a mathematical model to estimate the optimum characteristics of a PV system for a specific location.This model represents an estimated study of the sun position at any location,calculating recovered solar energy,electric energy produced by a PV generator and finallythe capacity of the storage unit and can be applied for any location by knowing the meteorological data and consumer's demands of that particular location.[36]

Orhan et al. [37] paper aims to give the use of the "response surface methodology" (RSM) in size optimization of an independent PV/wind incorporated energy system with battery storage.RSM is a set of statistical and mathematical methods which relies on optimization of response surface with design constraints.

SnigdhaChakrabarti et al. [38] made an attempt on developing a decentralized photovoltaic power system from socio-economic and environmental point of view in sagarDweeo,an island in westbengal,India.they observed a noticeable development and significant impact on education, trade and commerce, entertainment, health etc. as a result of supply of power from SPV power plants in a short span and are more effective in rural areas especially. productivity in agriculture sector and women economic standards are also improved.

VI. Applications

Photo voltaic materials are incorporated in roofing, sides, glasses and other possible areas to minimize the space, cost in addition to appearance. Various works are available on BIVP systems installation, possibility, system efficiency and power out puts .
Desalination applications with photo voltaic power are briefed by Lamei , Kershrnan et al.[39] in their works.Hasnain et al. [40] proposed a solar still plant , Girish [41] discusses about space applications with PV power .Pump for drip irrigation with photo voltaic power is designed and developed by Pande et al. under different operating conditions and several issues involved in solar PV pumps were observed by Short et al. and proposed a newer model for future sustainability .Badescu thoroughly examined the operation of a time dependent solar water pumping system consisting PV array, battery, DC motor, and a centrifugal pump [42]. Chow et al. described an experimental study of solar thermal systems [43] and He et al. proposed the hybrid photovoltaic and thermal (PVT) collector technology for cooling system as water as the working substance [44].Vokas et al. studied and concluded that PV thermal system can cover wide range of domestic heating and cooling needs [45].same authors are also developed a thermo syphon collector system and discussed the performance of the system [46].Othman et al. studied a system which generates electricity and heat energy simultaneously with improved efficiency by using fins and double collector system [47].

In addition to the above, photovoltaic power systems can also be used in Commercial Lighting, Consumer electronics, Telecommunications. The increasing efficiency, reducing cost and minimal pollution are the encouraging factors to led PV systems for a wide range of applications.

VII. Problems associated with photovoltaic technology

Solar PV systems exactly cannot integrate the rapid fluctuations in output and the normal consumer requirement as in conventional generators. This basic imbalance of supply and

demand likely shows the crucial limit on share of intermittent renewables and conventional power generation in hybrid systems. Rapid changes in output can also enforce burdens on generators and limit their use[48]

To overcome the problems associated with the PV power during cloudy conditions, Nelson et al [49] proposed the following modifications after a thorough investigation such as orienting the solar modules toward the zenith to capture the maximum solar energy than simple tracking system. A simple isotropic diffuse model is developed for measurement of diffuse radiation both qualitatively and quantitatively as it is beneficial to absorb diffuse radiation to minimize the storage capacity and to meet the fluctuations. Denholm et al. [50]observed some of the limits to large-scale applications and Lund et al. explained the problems associated with hybrid power systems[51].

VIII..COST

LOUIS ROSENBLUM et al (52) focused on photo voltaic power systems for rural areas of developing countries. Energy cost comparisons are made for PV power generation versus other renewable sources and concluded that PV system make available a reasonable energy production option for developing countries like India in the near and long term.Bhuiyan et al. studied the economics of stand-alone photovoltaic power system to test its feasibility in remote and rural areas of Bangladesh and compared renewable generators with nonrenewable generators by determining their life cycle cost using the method of net present value analysis. They showed that life cycle cost of PV energy is lower than the cost of energy from diesel or petrol generators in Bangladesh and thus is economically feasible in remote and rural areas of Bangladesh [8]

IX. Conclusions

In this work some of the existing methods are analyzed and based on the limitations, innovative methods are suggested which will produce better results. As a case study the present photovoltaic power development and different analysis methods will be applied to meet the present day energy requirements.A review of different works regarding the need of PV power systems, SPV technologies comprising of PV power generation, Hybrid PV generation, Solar cell materials, performance and reliability of PV systems with case studies and sizing & distribution is presented. The different applications of solar PV systems, problems associated with, environmental considerations and costs are thoroughly discussed. This paper might be useful for the solar PV system manufactures, designers, academicians, researchers, and decision makers

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