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An Overview on Solar Energy: Indian Scenario

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Abstract: The Sun has been worshiped as a life-giver to our planet since ancient times. The industrial ages gave us the understanding of sunlight as an energy source. India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar photovoltaic power can effectively be harnessed providing huge scalability in India. Solar also provides the ability to generate power on a distributed basis and enables rapid capacity addition with short lead times. Off-grid decentralized and low-temperature applications will be advantageous from a rural application perspective and meeting other energy needs for power, heating and cooling in both rural and urban areas. From an energy security perspective, solar is the most secure of all sources, since it is abundantly available. Theoretically, a small fraction of the total incident solar energy (if captured effectively) can meet the entire country's power requirements.

There has been a visible impact of solar energy in the Indian energy scenario during the last few years. Solar energy based decentralized and distributed applications have benefited millions of people in Indian villages by meeting their cooking, lighting and other energy needs in an environment friendly manner. The social and economic benefits include reduction in drudgery among rural women and girls engaged in the collection of fuel wood from long distances and cooking in smoky kitchens, minimization of the risks of contracting lung and eye ailments, employment generation at village level, and ultimately, the improvement in the standard of living and creation of opportunity for economic activities at village level. Further, solar energy sector in India has emerged as a significant player in the grid connected power generation capacity over the years. It supports the government agenda of sustainable growth, while, emerging as an integral part of the solution to meet the nation's energy needs and an essential player for energy security.

Key Words: Solar energy, Solar collector, Solar parks, Suryamitra, Synegry.

Introduction: Solar energy is the most readily available source of energy. It does not belong to anybody and is, therefore, free. It is also the most important of the non-conventional sources of energy because it is non-polluting and, therefore, helps in reducing the greenhouse effect [1].

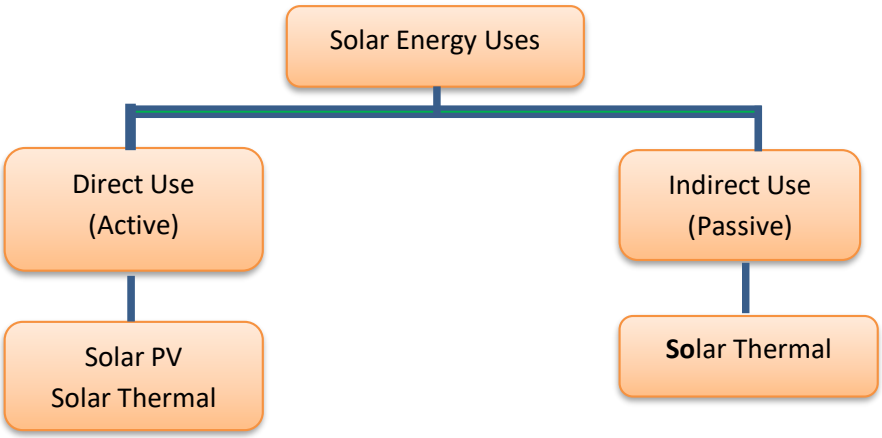
Solar energy has been used since ancient times, but in a most primitive manner. Before 1970, some research and development was carried out in a few countries to exploit solar energy more efficiently, but most of this work remained mainly academic. After the dramatic rise in oil prices in the 1970s, several countries began to formulate extensive research and development programmes to exploit solar energy. India is one of the few countries with long days and plenty of sunshine. Solar energy could be easily harnessed. Solar thermal energy is being used in India for heating water for both industrial and domestic purposes [2].

Solar Energy Uses

India receives solar energy equivalent to over 5000 trillion kWh/ year, which is far more than the total energy consumption of the country. In principle solar energy can also be used to meet all our energy needs, both thermal as well as electricity. The solar energy canbe broadly classified in two categories on the basis of its use.

1. Solar Active Applications i.e. direct use of solar energy to produceelectricity
2. Solar Passive Applications i.e. indirect use of solar energy usuallycalled solar thermal applications.

Thermal energy can be used for Cooking/Heating, Drying/ Timber seasoning, Distillation, Electricity/Power generation, Cooling, Refrigeration, Cold storage, etc. Some of the gadgets and other devices for exploiting thermal energy are: Solar cooker, flat plate solar cookers, concentrating collectors, solar hot water systems (domestic and industrial), solar pond, solar hot air systems, solar dryers, solar timber kilns, solar stills, solar pond, concentrating collectors, air conditioning, solar collectors coupled to absorption and refrigeration systems, etc [3,4]. Although solar photovoltaic systems are used to convert solar energy directly into electricity, the heat generated during the process can be used for solar thermal applications. The solar energy is directly converted in the desired application form. It is usually divided into following two forms:



1. Solar thermal for heating applications
2. Solar Photovoltaic for electricity generation

The use of solar energy for thermal applications is called Solar Thermal Applications. Here solar energy is collected and then converted to heat energy for applications such as water and air heating, cooking and drying, steam generation, distillation by making use of an appropriate solar energy device. Basically a solar thermal device consists of the following:

(a) A solar energy collector called absorber
(b) A heat transferring medium
(c) A heat storage or heat tank

Direct Use of Solar Energy

The solar energy is directly converted in the desired application form by using Solar Cell technology. Solar photovoltaic technologyis now gaining importance because we are running out fossil fuel in the times to come.

Through Solar Photovoltaic (SPV) cells, solar radiation gets converted into DC electricity directly. This electricity can either be used as it is or can be stored in the battery. This stored electrical energy then can be used at night. SPV can be used for a number of applications such as: domestic lighting.

- street lighting
- village electrification
- water pumping
- railway signals.

If all the means to make efficient use of solar energy are implemented, it would reduce our dependence on non-renewable sources of energy and make our environment cleaner.

Solar Collectors

When solar energy comes into contact with matter, one of three things will happen to it:

- It may be reflected off of the matter, or
- It may be transmitted through the matter, or
- It may be absorbed by the matter and turned into heat.

These three phenomena have much to do with the design and use of solar collectors [5]. There are three main types of thermal solar collectors:

- low temperature solar collectors
- medium temperature solar collectors
- high temperature solar collectors

Low Temperature Solar Collectors

The low temperature solar collector operates at relatively low temperature. Solar swimming pool collector is a good example. The heat transfer or loss takes place by the following three processes:

Conduction: When the molecules of one material come in contact with the molecules of another, heat is transferred from the warmer one to the colder one by kinetic energy of the molecules.

Convection: A warm surface heats the fluid (water or air) that comes in contact with it, and the fluid flows away by gravity.

Radiation: All matter gives off long wave infrared radiation in proportion to its temperature. If the object gives off more radiation than it receives from the environment, it will lose heat. Because the low temperature solar collector does not control any of these heat lossfactors, performance falls off very rapidly as collector temperature rises above the ambient temperature [6].

Medium Temperature Solar Collectors

Many of our heating requirements occur at temperatures well above the ambient air temperature. At these higher temperatures, simple collectors rapidly reach the point where they are losing as much heat as they are receiving, and the efficiency drops to almost zero. What we need to do is construct a heat trap; something that will let the sun's energy in, but not let it out again. With respect tothe three heat loss parameters identified above, here are some of the things that we can do to reduce heat losses [7].

Conduction: We can put the absorber plate inside an insulated box. In that way, heat energy will be less able to escape by conductionprocess.

Convection: We can put a cover over the absorber plate. In that way, when the absorber plate heats the air above it by conduction,the heated air is not able to float away and escape. Of course, we will be looking for a cover that lets the sun's energy in.

Radiation: We want our cover material to transmit short wave solar energy coming in, but block long wave infrared radiation going out. There are only a few materials that will meet these requirements.Some plastic will work, but they are not stable enough at higher temperatures. The most commonly used material is glass.

High Temperature Solar Collectors

There are several ways by which we can conserve more of the energy that comes into the collector. We can add thicker insulation, orwe can add additional cover sheets, or we can evacuate the air from the solar collector. All of these measures will result in a collector that can operate at a higher temperature. Such measures that conserve more energy may prevent even more solar energy from striking the absorber plate. We have to make a balance amongst all the relevant parameters so as to maximize the collector efficiency [8].

Advantages and Disadvantages of Solar Energy

Solar energy is available in the most natural and attractive form. It has wide-spread distribution, it is time-specific and definite, it has virtually inexhaustible supply, it has antibacterial and disinfecting qualities, and with proper exposure to human body, it can provide Vitamin-D, helpful for building of bones. It is environment-friendly and has now emerged as an effective alternative source of power. Solar power is supposed to be better than nuclear power. We will now discuss advantages and disadvantages of solar energy.

Advantages of solar energy:

- Solar energy is free.
- Solar energy does not produce waste and pollution.
- In sunny areas having no grid power, solar power can be used.
- Low power areas are very handy like solar powered batteries,lights, etc.

Disadvantages of solar energy

- Solar energy is not available in the night.
- Solar power stations are relatively expensive.

India is densely populated and has high solar insolation, an ideal combination for using solar power in India. The Government of India proposed to launch its Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change, it was announced in November2009, The program was inaugurated by former Prime Minister Manmohan Singh on 11 January 2010 with a target of 20GW grid capacity by 2022 as well as 2GW off-grid installations, this target was later increased to 100 GW by the same date under the Narendra Modi government in the 2015 Union budget of India. Achieving this National Solar Mission target would establish India in its ambitionto be a global leader in solar power generation. The Mission aims to achieve grid parity (electricity delivered at the same cost and quality as that delivered on the grid) by 2022. The National Solar Missionis also promoted and known by its more colloquial name of "Solar India " [9]. The earlier objectives of the mission were to install 1,000 MW of power by 2013 and cover 20×10^6 m^2 (220×10^6 sq ft) with collectors by the end of the final phase of the mission in 2022. On 30 November 2015, the Prime Minister of India Narendra Modi and the President of France Francois Hollande launched the International Solar Alliance. The ISA is an alliance of 121 solar rich countries lying partially or fully between the Tropic of Cancer and the Tropic of Capricorn, several countries outside of this area are also involved with the organization. The ISA aims to promote and develop solar power amongst its members and has the objective of mobilizing $1 trillion of investment by 2030 [10].

The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022. This is line with India's Intended Nationally Determined Contributions(INDCs) target to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources and to reduce the emission intensity of its GDP by 33 to 35 percent from 2005 level by 2030.

In order to achieve the above target, Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc [11].

Various policy measures undertaken included declaration of trajectory for Renewable Purchase Obligation (RPO) including Solar, Waiver of Inter State Transmission System (ISTS) charges and losses for inter-state sale of solar and wind

power for projects to be commissioned up to March 2022, Must run status, Guidelines for procurement of solar power though tariff based competitive bidding process, Standards for deployment of Solar Photovoltaic systems and devices, Provision of roof top solar and Guidelines for developmentof smart cities, Amendments in building bye-laws for mandatory provision of roof top solar for new construction or higher Floor Area Ratio, Infrastructure status for solar projects, Raising tax free solar bonds, Providing long tenor loans from multi-lateral agencies, etc.

Recently, India stands 4th in solar PV deployment across the globe as on end of 2021. Solar power installed capacity has reached around 61.97 GW as on 30th November, 2022. Presently, solar tariff in Indiais very competitive and has achieved grid parity.The various policies launched by the Government to promote solar energy program in India are as follows:

Suryamitra Programme

To create skilled manpower in the field of solar energy particularly in view of huge demand of trained persons to install, operate & maintain the SPV system under the National Solar Mission, Ministry launched Suryamitra Skill Development Programme in 2015 and assigned the task of coordination of the trainings to National Institute of Solar Energy (NISE) for creating skilled manpower for employmentin Solar Power Projects with a target to develop 50,000 Suryamitrasby 2019-2020 for the country. The programme follows the M/o Skill Development & Entrepreneurship norms. So far 31,092 no. of Suryamitras have been trained upto 31st March, 2019 [12].

The Suryamitra Skill Development Programme is designed with the objective to develop skilled and employable workforce (Suryamitras) catering to the needs of Solar PV industries. The duration of the Suryamitra Skill Development Programme is three months consisting of 600 hours including classroom training, lab practical, SPV plant exposure, On The Job Training (OJT), soft skills and entrepreneurship skills. Min.10thPass+ITIin Electrician/ Wireman/Electronics Mechanic/Fitter/Sheet Metal. Each batch containsaround 30 seats. At the end of the Suryamitra programme, the host institute facilitate the trainees for placement [13].

Solar Park

Solar power projects can be set up anywhere in the country,however the solar power projects developed in scattered manner leads to higher project cost per MW and higher transmission losses. Individual projects of smaller capacity incur significant expenses in site development, drawing separate transmission lines to nearest substation, procuring water and in creation of other necessary infrastructure. It also takes longer time for project developers to acquire land, get all types of clearances and permissions etc. which ultimately delays the project. To overcome these challenges, the scheme for "Development of Solar Parks and Ultra-Mega Solar PowerProjects" was rolled out in December, 2014 with an objective to facilitate the solar project developers to set up projects expeditiously [14].

- A solar park is large chunk of land developed with common infrastructure facilities like transmission infrastructure, road, water, drainage, communication network etc. with all statutory clearances. Thus, the solar project developers can set up solar projects hassle-free.
- The scheme was rolled out by Ministry of New & Renewable Energy on 12-12-2014. Under the scheme, it was proposed to set up at least 25 Solar Parks and Ultra Mega Solar Power Projects targeting 20,000 MW of solar power installed capacity within a span of 5 years starting from 2014-15.
- The capacity of the Scheme was enhanced from 20,000 MW to 40,000 MW on 21-03-2017. These parks are proposed to be set up by 2023-24.
- The scheme envisages supporting the States/UTs in setting up solar parks at various locations in the country with a view to create required infrastructure for setting up of solar power projects. The solar parks provide suitable developed land with all clearances, transmission system, water access, road connectivity, communication network, etc. The scheme facilitates and speed upinstallation of grid connected solar power projects for electricity generation on a large scale.
- All the States and Union Territories are eligible for getting benefitunder the scheme.
- The capacity of the solar parks shall be 500 MW and above. However, smaller parks are also considered where contiguous land may be difficult to acquire in view of difficult terrain and where there is acute shortage of non-agricultural land.
- The solar parks are developed in collaboration with the State Governments and their agencies, CPSUs, and private entrepreneurs. The implementing agency is termed as Solar PowerPark Developer (SPPD). There are 7 modes for selection of SPPDs.

CFA (Central Financial Assistance) Pattern:

Under the scheme, the Ministry provides Central Financial Assistance (CFA) of up to Rs. 25 lakh per solar park for preparation of Detailed Project Report (DPR). Beside this, CFA of up to Rs. 20.00 lakh per MW or 30% of the project cost, including Grid-connectivity cost, whichever is lower, is also provided on achieving the milestones prescribed in the scheme.

India's solar energy insolation is about 5,000 T kWh per year (i.e. ~600 TW), far more than its current total primary energy consumption.India's long-term solar potential could be unparalleled in the world because it has the ideal combination of both high solar insolationand a big potential consumer base density. Also a major factor influencing a region's energy intensity is the cost of energy consumed for temperature control. Since cooling load requirements are roughly in phase with the sun's intensity, cooling from intense solar radiation could make perfect energy-economic sense in the subcontinent locatedmostly in

the tropics [15].

Installation of solar power PV plants requires nearly 2.0 hectares (5 acres) of land per MW capacity which is similar to coal-fired power plants when life cycle coal mining, consumptive water storage & ash disposal areas are also accounted for, and hydropower plants when submergence area of the water reservoir is also accounted. 1.6 million MW capacity solar plants can be installed in India on its 1% land (32,000 square km). There are vast tracts of land suitable for solar power in all parts of India exceeding 8% of its total area which are unproductive barren and devoid of vegetation. Part of wastelands (32,000 square km) when installed with solar power plants can produce 2400 billion kWh of electricity (two times the total generation in 2013-14) with land productivity/yield of 0.9 million Rs per acre (3 Rs/kWh price) which is at par with many industrial areas and many times more than the best productive irrigated agriculture lands. Moreover, these solar power units are not dependent on the supply of any raw material and are self- productive. There is unlimited scope for solar electricity to replace all fossil fuel energy requirements (natural gas, coal, lignite, and crude oil) if all the marginally productive lands are occupied by solar power plants in the future. The solar power potential of India can meet perennially to cater to per capita energy consumption at par with USA/Japan for the peak population in its demographic transition.

Solar Thermal Power

The installed capacity of commercial solar thermal power plants in India is 227.5 MW with 50 MW in Andhra Pradesh and 177.5 MW in Rajasthan. Solar thermal plants are emerging as cheaper (6 Euro ¢/ kWh) and clean load following power plants compared to fossil fuel power plants. They can cater the load/demand perfectly and work as base load power plants when the extracted solar energy is found excess in a day. Proper mix of solar thermal and solar PV can fully match the load fluctuations without the need of costly battery storage [16].

Synergy with Irrigation Water Pumping and Hydropower Stations

The major disadvantage of solar power (PV type only) is that it can not produce electricity during the nighttime and cloudy daytime also. In India, this disadvantage can be overcome by installing pumped- storage hydroelectricity stations. The ultimate electricity requirement for river water pumping (excluding groundwater pumping) is 570 billion kWh to pump one cubic meter of water for each square meter area by 125 m height on average for irrigating 140 million hectares of net sown area (42% of total land) for three crops in a year. This is achieved by utilising all the usable river waters by interlinking Indian rivers and envisaging coastal reservoirs. These river water pumping stations would also be envisaged with pumped-storage hydroelectricity features to store the surplus electricity available during the daytime and reconvert to electricity during the nighttime. Also, all existing and future hydropower stations can be expanded with additional pumped-storage hydroelectricity units to cater nighttime electricity consumption. Most of the groundwater pumping power can be met directly by solar power during the daytime. To achieve food security, India needs to achieve water security which is possible only by energy security for harnessing its water resources [17].

Electric Vehicles

The retail prices of petrol and diesel are high in India to make electricity driven vehicles more economical as more and more electricity is generated from solar energy in near future without appreciable environmental effects. During the year 2018, many IPPs offered to sell solar power below 3.00 Rs/kWh to feed into the high voltage grid. This price is far below the affordable retail electricity tariff for the solar power to replace petrol and diesel use in transport sector [18].

The retail price of diesel is 53.00 Rs/liter in 2012-13. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power conversion efficiency) to replace diesel (lower heating value 8572 kcal/liter at 40% fuel energy to crankshaft conversion efficiency) is up to 9.97 Rs/kWh. The retail price of petrol is 75.00 Rs/liter in 2012-13. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power conversion efficiency) to replace petrol (lower heating value 7693 kcal/liter at 33% fuel energy to crankshaft conversion efficiency) is up to 19.06 Rs/kWh. In 2012-13, India consumed 15.744 million tons of petrol and 69.179 million tons of diesel which are mainly produced from imported crude oil at huge foreign exchange outgo [19].

V2G is also feasible with electricity-driven vehicles for catering to the peak load in the electricity grid. Electricity-driven vehicles would become popular in the future when the energy storage/battery technology becomes more compact, lesser density, longer lasting, and maintenance-free.

India lies in the sunny regions of the world. India receives solar energy equivalent to over 5000 trillion KWh/year. This is far more than the total energy consumption in the country. Daily average of incident solar energy ranges from 4 to 7 KWh/m^2 depending upon the location. The highest annual radiation energy is received in western Rajasthan while the north-eastern region of the country receives the lowest annual radiation. It has been estimated that we have 250-300 days of clear sunny weather. Annual radiation being 1600 to 2200 KWh/m^2, even if 1% of the nation's land is used, we could have nearly 1000 giga watts (GW) of power.

Conclusions: India's abundant solar potential provides a clean and attainable replacement for the extremely harmful polluting, a rapidly depleting conventional sources of energy. Development of the policies for the viable utilization of solar energy can help India's emerge as a leader in the global arena. India in its nationally intended has set an ambitious target to achieve a capacity of 175 GW worth of renewable energy by the end of 2022, which expands to 500 GW by 2030. This is the world's largest expansion plan in renewable energy.

India was the second largest market in Asia for new solar PV capacity and third globally (13 GW of additions in 2021). It

ranked fourth for total installations (60.4 GW), overtaking Germany (59.2 GW) for the first time. The country's solar installed capacity was 71.61 GW of 31 August 2023. India's planning to issue 40 GB tenders for solar and hybrid projects. India has established nearly 42 solar parks to make land available to the promoters of solar plants. India is also the home to words first and only 100% solar powered Airport located at Cochin Kerala India also have a holy handed percent solar power railway station in Guwahati Assam India's first and largest floating Solar Power Plant was constructed at banasura Sagar Reservoir in Wayanad Kerala. The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.

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