Proceedings of Second Shri Chhatrapati Shivaji Maharaj QIP Conference on Engineering Innovations
Organized by Shri Chhatrapati Shivaji Maharaj College of Engineering, Ahmednagar
In Association with Novateur Publications JournalNX-ISSN No: 2581-4230
February, 22nd and 23rd, 2019

Review of India's Solar Energy

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***Abstract*—*Energy demand is increasing day by day. It is not possible to get energy from limited fossil fuels we have to move towards renewable energy sources to meet this demand. In this paper the focus is given on solar energy, types and its review in India. Many solar projects are working in India but whether these are enough efficient to fulfill the future energy demand of our country.*

Keywords—solar energy; elecricity demand; renewable energy

I. INTRODUCTION

India is developing nation and GDP growth rate for the year 2018 is 7.3%. In this development stage role of energy sector is important because the nation has to meet the increasing energy demand from all the important sectors. Energy development systems in India have evolved over the last six decades which has ensured country's economic development. This increasing demand of energy has posed tremendous pressure on its limited existing resources. India pursued a reformed development agenda since 1991.[1] To meet this energy demand significant efforts have taken by the country towards the use of renewable energy sources. As Sun is the main source of energy we must focus on development of solar energy which is inexhaustible and clean. In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global.[4].

II. OVERVIEW OF INDIAS ENGERY SECTOR

A. *Energy Demand of the country*

The energy consumption in India is the third biggest after China and USA with 5.6% global share in 2017.[10] The total primary energy consumption from crude oil (221.1 Mtoe; 29.34%), natural gas (46.6 Mtoe; 6.18%), coal (424 Mtoe; 56.26%), nuclear energy (8.7 Mtoe; 1.15%), hydro electricity (30.7 Mtoe; 4.07%) and renewable power (21.8 Mtoe; 2.89%) is 753.7 Mtoe (excluding traditional biomass use) in the calendar year 2017.[5] In 2017, India's net imports are nearly 198.8 million tons of crude oil and its products, 25.7 Mtoe of LNG and 129.8 Mtoe coal totaling to 354.3 Mtoe of primary energy which is equal to 47% of total primary energy consumption. About 75% of India's electricity generation is from fossil fuels. India is surplus in electricity generation and also marginal exporter of electricity in 2017.[11] India is largely dependent on fossil fuel imports to meet its energy demands – by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption.[12] In 2009-10, the country imported 159.26 million tonnes of crude oil which amounts to 80% of its domestic crude oil consumption and 31% of the country's total imports were oil imports.[12] India ranks second after China in renewables production with 208.7 Mtoe in 2016. But near about 136 million Indians (11%) use traditional fuels like wood, agricultural waste and biomass cakes are used for cooking and general heating needs in most of the rural parts of India.[2]

The utility electricity sector in India has one National Grid with an installed capacity of 349.288 GW as on 31 December 2018.[3] Renewable power plants constituted 33.60% of total installed capacity. During the fiscal year 2017-18, the gross electricity generated by utilities in India was 1,303.49 TWh and the total electricity generation (utilities and non utilities) in the country was 1,486.5 TWh.[5] The gross electricity consumption was 1,149 kWh per capita in the year 2017-18.[5] India is the world's third largest producer and third largest consumer of electricity.[7][8] Electric energy consumption in agriculture was recorded highest (17.89%) in 2015-16 among all countries.[5] The per capita electricity consumption is low compared to many countries despite cheaper electricity tariff in India.[9].

B. *Solar Energy Potential in India*

In renewable energy sources solar energy is the most trustworthy source because in most parts of India, in a year clear sunny weather is experienced of an about 250 to 300 days. The annual global radiation in the country varies from 1600 to 2200 kWh/m^2, which is comparable with radiation received in the tropical and sub-tropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year. Figure 1 shows map of India with solar radiation levels in different parts of the country. [3]

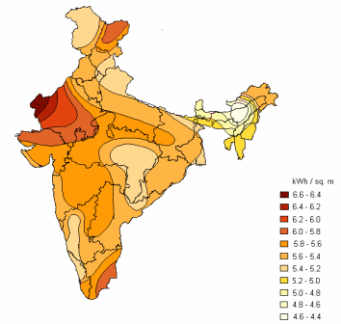


Fig.1. *Solar Radiation across India* [3].

III. SOLAR ENERGY

Solar energy is the conversion of energy from sunlight into electricity. The early development of solar technologies starting in the 1860s was driven by an expectation that coal would soon become scarce. Charles Fritts installed the world's first rooftop photovoltaic solar array, using 1%-efficient selenium cells, on a New York City roof in 1884.[5] In the

mid-1990s, development of both, residential and commercial rooftop solar as well as utility-scale photovoltaic power stations, began to accelerate again due to supply issues with oil and natural gas, global warming concerns, and the improving economic position of PV relative to other energy technologies.[6] Thereafter up to present many new techniques have evolved in the solar power methods.

A. Solar Power Technology

Solar energy is either directly harvested by using photovoltaic (PV) or indirectly by using concentrated solar power or combination of both. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect. The Solar Power technologies are classified as,

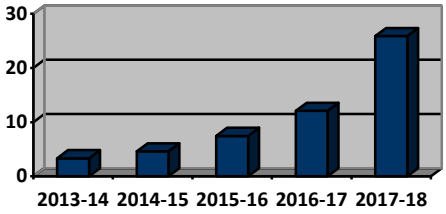
i) Photovoltaic - A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photovoltaic effect. The array of a photovoltaic power system, or PV system, produces direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or alternating current (AC), through the use of inverters. Multiple solar cells are connected inside modules. Modules are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase. [7]

ii) Concentrated solar power - Concentrated solar power (CSP), also called "concentrated solar thermal", uses lenses or mirrors and tracking systems to concentrate sunlight, then use the resulting heat to generate electricity from conventional steam-driven turbines.[4]

iii) Hybrid systems - A hybrid system combines (C)PV and CSP with one another or with other forms of generation such as diesel, wind and biogas. The combined form of generation may enable the system to modulate power output as a function of demand or at least reduce the fluctuating nature of solar power and the consumption of non-renewable fuel. Hybrid systems are most often found on islands.[4]

B. Solar Power Projects in India

The daily average solar-power-plant generation capacity in India is 0.20 kWh per m^2 of used land area, equivalent to 1400–1800 peak capacity operating hours in a year with available, commercially-proven technology. Grid-connected solar electricity generation has reached nearly 2% of total utility electricity generation.[8] Solar generation meets the daytime peak load in non-monsoon months when electricity spot prices exceed the daily average price.



Graph.1. *Annual Solar Power Generation in (TWh)* [3].

Above graph shows that in the year 2013-14 the solar power generation was 3.35TWh but it has been increased up to 25.87TWh up to year 2017-18.

TABLE I. MONTHLY SOLAR POWER GENERATION IN INDIA, APRIL 2017 - MARCH 2018

Month	Regional solar power generation (GWh)					Total (GWh)
	North	West	South	East	North-East	
April 2017	458.76	419.26	833.47	40.16	0.99	1,752.74
August 2017	504.42	363.99	765.21	30.43	1.17	1,660.26
December 2017	483.35	465.63	1242.36	31.49	3.35	2,242.64
February 2018	548.61	546.80	1,530.38	35.23	0.98	2,677.10
January 2018	-	-	-	-	-	2,547.77
July 2017	461.40	282.92	886.69	27.17	0.98	1,661.29
June 2017	489.02	399.95	871.08	36.36	0.92	1,803.35
March 2018	685.27	703.39	1,872.31	49.26	1.29	3,311.53
May 2017	528.92	426.05	935.51	39.72	1.17	1,931.30
November 2017	518.77	489.30	1,083.92	19.27	1.32	2,094.59
October 2017	608.61	456.16	1,069.60	33.31	1.11	2,186.00
September 2017	547.08	438.70	974.52	32.84	0.94	2,002.51
Total (GWh)	-	-	-	-	-	**25,871.08**

In India many solar power projects are installed and generated 25871.8 GWh solar power. In that most of the plants are photovoltaic (PV), some are Concentrated solar tower.

TABLE II. MAJOR PHOTOVOLTAIC (PV) POWER PLANTS

Plant	State	DC Peak Power (MW)	Commissioned
Kamuthi Solar Power Project	Tamil Nadu	648	21 September 2016
Gujarat Solar Park-1	Gujarat	221	April 2012
Welspun Solar MP project	Madhya Pradesh	151	February 2014
ReNew Power, Nizamabad	Telangana	143	15 April 2017
Sakri solar plant	Maharashtra	125	March 2013
NTPC solar plants		110	2015
Maharashtra I	Maharashtra	67	2017
Tata Power Solar Systems (TPS), Rajgarh	Madhya Pradesh	50	March 2014
Green Energy Development Corporation (GEDCOL)	Odisha	50	2014
Welspun Energy, Phalodhi	Rajasthan	50	March 2013

Jalaun Solar Power Project	Uttar Pradesh	50	27 January 2016
Kamuthi Solar Power Project	Tamil Nadu	648	21 September 2016

By the year 2012, a total of 4,600,000 solar lanterns and 861,654 solar-powered home lights were installed. Typically replacing kerosene lamps, they can be purchased for the cost of a few months' worth of kerosene with a small loan. The Ministry of New and Renewable Energy is offering a 30- to 40-percent subsidy of the cost of lanterns, home lights and small systems (up to 210 Wp) [13] Solar photovoltaic water-pumping systems are used for irrigation and drinking water.[116] Most pumps are fitted with a 200–3,000 W (0.27–4.02 hp) motor powered with a 1,800 Wp PV array which can deliver about 140,000 litres (37,000 US gal) of water per day from a total hydraulic head of 10 m (33 ft).[14]

IV. FUTURE OF SOLAR POWER IN INDIA

- The objective of the JNNSM 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.
- Fifty-one solar radiation resource assessment stations have been installed across India by the Ministry of New and Renewable Energy (MNRE) to create a database of solar-energy potential. Data is collected and reported to the Centre for Wind Energy Technology (C-WET) to create a solar atlas. In June 2015, India began a 40 crore (US$5.6 million) project to measure solar radiation with a spatial resolution of 3 by 3 kilometres (1.9 mi × 1.9 mi). This solar-radiation measuring network will provide the basis for the Indian solar-radiation atlas. According to National Institute of Wind Energy officials, the Solar Radiation Resource Assessment wing (121 ground stations) would measure solar radiation's three parameters—Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI)—to accurately measure a region's solar radiation.[176] To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To ramp up capacity of grid-connected solar power generation to 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000 MW.
- To create favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programs for off grid applications, reaching 2000 MW by 2022.
- To achieve 20 million m^2 solar thermal collector area by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.
- JNNSM Mission has set a target to provide solar lighting systems to over 10,000 villages and hamlets and also to set up stand alone rural solar power plants in special category States and areas such as Lakshadweep, Andaman & Nicobar Islands and the Ladakh region of Jammu & Kashmir. [9]
- Lance Solar, AES Solar and Titan Energy have signed a memorandum of understanding with the State to set up their units there. These companies will be the anchor units in solar city and have a combined capacity of 2000 MW.
- Indian Government have signed various MoU with the countries. MoU on Cooperation in the field of Energy between The Ministry for the Environment of the Italian Republic and The Ministry of New and Renewable Energy of the Republic of India. MoU between the Ministry of New and Renewable Energy of the Government of the Republic of India and the Ministry of Infrastructure and Transport of the Government of the Republic of Fiji on Co-operation in the field of Renewable Energy.
- MoU between the Ministry of New and Renewable Energy of the Republic of India and the Ministry of Environment and Energy of the Hellenic Republic on Co-operation in the field of New and Renewable Energy. MoU between the Ministry of New and Renewable Energy of the Government of the Republic of India and the Ministry of Energy, Mines and Sustainable Development of the Government of Kingdom of Morocco on Co-operation in the field of Renewable Energy. MoU between the Ministry of New and Renewable Energy of the Republic of India and the Ministry of Public Infrastructure of the Co-operation Republic of Guyana on Cooperation in the field of Renewable Energy.
- MOU between National Institute of Solar Energy Ministry of New and Renewable Energy, INDIA 'NISE' and Commissariat a l'Energie Atomique et aux Energies Alternatives - The National Solar Energy Institute (INES), France 'CEA'.
- MOU between the Ministry of New And Renewable Energy of The Republic of India and The Ministry of Energy and Mining of The Republic of Peru on Cooperation in New and Renewable Energy.
- The Indian government is promoting solar energy. It announced an allocation of 1,000 crore (US$140 million) for the Jawaharlal Nehru National Solar Mission and a clean-energy fund for the 2010-11 fiscal year, an increase of 380 crore (US$53 million) from the previous budget. The budget encouraged private solar companies by reducing the import duty on solar panels by five percent. This is expected to

reduce the cost of a rooftop solar-panel installation by 15 to 20 percent.

V. CONCLUSION

Like other developed and developing nations India is looking with twin difficulties on energy and environment front. It has no choice however needs to continue progress in the direction of expanding the work of renewable sources in the future energy systems. Indian Government has signed various MoU with many countries in order to develop and improve the solar energy potential in the country this will shift the energy dependency from conventional fossil fuel sources.

Acknowledgment

It is an honour for us to thank those who made this research work possible. We feel very profound to apprise you that our research got published in International Journals/conference. We render our deepest sense of gratitude to respected Dr. R. S. Deshpande, Principal, SCSMCOE without whom this would never have come to be today's reality. His constant encouragement, constructive suggestions and guidance has helped me a lot to make this dream come true.

Our unpretentious gratitude to Prof. S. M. Palaskar Sir, Head of Civil Department for the adroit guidance, suggestions, critical evaluation and perceptual encouragement in completing this research. His advice, guidance, ideas, insights and encouragement were instrumental in making this research work possible. We would also like to take this opportunity to express our thanks to all friends and colleagues for their full support, cooperation and kind help provided during this research journey.

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