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Solar Energy Potential, Policy and Forecasting- A Review

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***Abstract*— Solar energy is one of the cleanest sources of energy with minimum possible, pollution or harmful emissions and has the potential to minimize dependency conventional energy sources such as coal, oil, gas and other fuels. The quest for energy autonomy, remunerative growth, and environmental sustainability continuously indicates the importance of solar energy sources across the world. Solar energy sources are seen not only as sources of energy, but also as tools to address some other important requirements, such as improving energy security access, minimizing the health, environmental impacts due to emission of harmful gases from fossil fuels. The increasing dependency on imported fuels may create a serious threat to the future energy security of the country. In addition, the India's 272 GW of power generation capacity, around 65% of India's current power generation capacity is based on coal. It exhibiting a lot of pressure from environmental, health and remunerative growth point of view from these high import factors.**

***Index Terms*— Solar Energy Potential, Policy, Physical Growth, Forecasting.**

I. INTRODUCTION

In the today's world the fastest growing thing is the energy requirement by world, with the reduction in the conventional resource. The most challenging thing in front of the world is how fulfill the requirement of energy. Due to the limitation of the conventional resources, the world has to think about the alternate source of energy. Now a day's most of the countries are emphasizing on the development of renewable energy resources. In the renewable energy resources, solar energy plays important role and it is a tremendous source of energy. The sun is the planet's most powerful source of energy and also the most unused source of energy by humans. Solar energy is abundant and offers a solution to fossil fuel emissions and global climate change. The rate of energy received by the earth from solar energy is approximately 120000 TW (1 TW = 10^{12}W or 1 trillion watt). This is much high from both the current annual global energy consumption rate of about 15 TW, and any additional requirement in future [1]. Solar power is a clean, environmental friendly source of energy [2]. There are no toxic byproducts or emissions. Sun Heat is directly utilized for water heating, room heating, vaporization etc. Solar water heating systems are in high demand. Typically 30–40% of a family's electricity bill is devoted to water. Sun Heat's system can save the individual family from 70% to 90% of the total amount spent on the electricity used for heating water. The system generally meets all of the summer time heating needs [1, 2, 3, 4]. During times of decreased sunlight, the system will preheat the water then bring it up to temperature by the conventional water

heating system already in place. The first serious attempts to deploy the technology were made with the formation of Department of Non-Conventional Energy Sources (DNES) in 1982,

though the history of research and pilot-demonstration go back to 1960s. The total installed collector area increased from 119,000 m^2 in 1989 to 525,000 m^2 in 2001 and to estimated 3.1 million m^2 by December 2009 [4, 9, 8, 10].

II. SOLAR POTENTIAL IN INDIA

Power sector is one of the key sectors contributing significantly to the growth of country's economy. Power sector needs a more useful role to be played in defining, formulating and implementing the research projects with close involvement of all utilities such that the benefit reaches the ultimate consumer. In India there is a huge gap between the energy generation and energy consumption. India has a great potential for solar power and it is estimated so many times of the energy requirement which is about 5000 trillion kWh per year. The solar radiation incident over India is equal to 4–7 kWh per square meter per day with an annual radiation ranging from 1200–2300 kWh per square meter. It has an average of 250–300 clear sunny days and 2300–3200 hours of sun shine per year. India's electricity needs can be met on a total land area of 3000 km^2 which is equal to 0.1% of total land in the country [2, 3, 4].

Government of India is trying to improve the share of energy generation from the solar energy and launched Jawaharlal Nehru Solar Mission. Under First Phase of Jawaharlal Nehru National Solar Mission (JNNSM) to be implemented between 1st April 2010 and 31st March 2013 200 MW capacity equivalent off grid solar PV systems and 7 million square meter solar thermal collector area to be installed in the country. Table.1 shows the development progress of JNSM [6, 7, 8]. During first year of first phase (2010-11) a target of 32 MW solar PV off grid systems and 5 lakh square meter solar thermal collector area was set. The targets are to be achieved through various channel partners mentioned in the scheme. As on February 2011, the achievements figures are 38.5 MW for off grid PV systems and 1.2 Lakh square meter solar thermal collector area [1, 3, 5, 7]. The policy visions to install 22,000 MW through grid connected and off grid power plants. As of April 2014, India's total installed capacity through grid connected solar power plants has crossed 2.2 GW with major contribution coming through grid connected solar PV power plants. Table.2 shows the

current status of install urban solar energy status categories wise [11].

Table.1 Rural status of solar energy uses

Source	Cumulative capacity
Rural /Semi Urban Biogas Plant	42,77,000 MW
SPV Street Lighting System	1,21,634MW
SPV Home Lighting System	6,19,428 MW
SPV Pump	7,495 MW
Solar Cookers	6,64,000 MW

The amount of solar energy produced in India in 2007 was less than 1% of the total energy demand. The grid-connected solar power as of December 2010 was merely 10 MW. Government-funded solar energy in India only accounted for approximately 6.4 MW-yrs of power as of 2005. However, India is ranked number one in terms of solar energy production per watt installed, with an insolation of 1,700 to 1,900 kilowatt hours per kilowatt peak (kWh/KWp). 25.1 MW was added in 2010 and 468.3 MW in 2011. Table.3 shows the current installed capacity of the solar power state wise [8, 9, 10, 11, 12].

Table.2 Status of solar power in India

State	MW Power	% Power
Andhra Pradesh	127.85	4.00%
Chhattisgarh	4.00	0.30%
Delhi	2.50	0.19%
Gujarat	654.80	49.80%
Haryana	7.8	0.59%
Jharkhand	4.00	0.30%
Karnataka	9.00	0.69%
Madhya Pradesh	132.00	9.15
Maharashtra	20.00	1.38%
Odisha	13.00	0.99%
Punjab	9.00	0.69%
Rajasthan	510.25	38.89%
Tamil Nadu	15.00	1.14%
Uttar Pradesh	12	0.91%
Uttrakhand	5.00	0.38%
West Bengal	2.00	0.15%
Total	**1,442.10**	**100%**

III. FUTURE OF RENEWABLE ENERGY

New project development for 100 MW capacity of grid (below 33 kV) connected solar projects (of 100 kW to 2 MW capacities each) have also been selected. It is expected that 150–200 MW of solar power will be installed in the country by December 2011. By end September 2014, the installed grid connected solar power had increased to 2,766 MW and India expects to install an additional 10,000 MW by 2017 and a total of 20,000 MW by 2022. Table.2 shows a state wise distribution of renewable energy generation, tentative target set by the ministry of new and renewable energy under the12th financial plan. The State Government of Andhra Pradesh is developing a solar farm cluster called solar city on a 10,000 acre land at Kadiri in Anantapur district. Solar city is expected to attract investments worth Rs. 3000 crore in the first phase. Four firms (Sun borne, 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. Karnataka Power Corporation Ltd. has implemented two projects– each of 3 MW power capacities and has awarded a third project of same capacity recently. The solar plants, located in Kola and Chickadee districts, have been implemented under the Arunodaya scheme for ensuring assured power supply to rural areas, especially irrigation pump sets [2, 4, 7 9].

Table 3: Share of Off Grid-interactive RES.

Sector	Capacity (MW)
Waste to Energy	154.47
Biomass(non-bagasse)	591.87
Biomass Rural, Industrial	170
Aero-Genrators /Hybrid s	2.53
SPV Systems	234.35

Table 4: Share of Grid-Interactive RES.

Sector	Capacity (MW)
Wind Power	23444.00
Small Hydro Power	4055.36
Biomass	1410.20
Bagasse Cogeneration	3008.35
Waste to Power	115.08
Solar Power	3743.97
Total	**35776.96**

Table 5: Region wise Installed RES

Region	Capacity (MW)
Northern	6489.77
Western	12975.07
Southern	14884.77
Eastern	862.76
North- East	567.67
Islands	11.06
Total	**35791.04**

IV. DIFFERENT RE POLICIES IN INDIA

(i) National Action Plan of Climate Change (NAPCC-2008)
(ii) Renewable Purchase Obligation (RPO)
(iii) Solar park scheme
(iv) National offshore wind policy
(v)Green energy transmission corridor
(vi) JNNSM
(vii) Solar Scale up Vision
(viii) National Wind Energy Mission

These policies are made time to time by the Indian Government for better development of RE sources to meet the demand of power requirement. Main feature and detailed of few of the above policies are describes below.

JNNSM (Jawaharlal Nehru National Solar Mission) [3]:

The JNNSM was launched in January 2010 by the Government of India under the National Action Plan of Climate Change (NAPCC). It is envisaged that as a result of rapid scale up as well as technological developments, the price of solar power will attain parity with grid power by the end of the Mission period, enabling accelerated and large-scale expansion thereafter. The mission includes a major initiative for promoting solar photovoltaic (PV) applications. It had three phases out of which the first phase finished in 2013, and subsequent phases are under way which target a capacity addition of 20,000 MW in India via grid connected solar power plants. Apart from grid connected targets, JNNSM also set up targets for off grid applications and Solar Thermal in India which are shown below in table 6.

Table 6: Solar Target Phase wise under JNNSM

Segment	Phase – I (2010- 13)	Phase – II (2013- 17)	Phase – III (2017- 22)
Grid solar power	1,100 MW	10,000 MW	20,000 MW
Off-grid solar applications	200 MW	1,000 MW	2,000 MW
Solar Thermal Collectors	7 million sq. meters	15 million sq. meters	20 million sq meters

National Wind Energy Mission [3]:

In order to exploit the available wind potential in the country expeditiously, there is a need to address the issues and barriers in a focused manner. The Government therefore proposes to launch the National Wind Energy Mission which aims to achieve 60,000 MW of utility scale wind installations in the country by the end of 13th five year plan (end of 2022). According to Ministry of Statistics and Programme Implementation Government of India report Energy Statistics 2015. The total potential for renewable power generation in the country as on 31.03.14 is estimated at 147615 MW. This includes wind power potential of 102772 MW (69.6%), SHP (small-hydro power) potential of 19749 MW (13.38%), Biomass power potential of 17,538 MW (11.88%) and 5000 MW (3.39%) from bagasse-based cogeneration in sugar mills.

Solar Park [14]:

Ministry of New and renewable Energy (MNRE) has drawn a scheme to set up number of solar parks across various states in the country, each with a capacity of Solar Projects generally above 500 MW. The Scheme proposes to provide financial support by Government of India to establish solar parks with an aim to facilitate creation of infrastructure necessary for setting up new solar power projects in terms of allocation of land, transmission and evacuation lines, access roads, availability of water and others, in a focused manner. Solar Energy Corporation of India (SECI), a central p ublic sector enterprises under MNRE , has been implementing various schemes to develop solar sector in the country. As per the policy, these solar parks will be developed in collaboration with the State Governments. The implementation agency would be Solar Energy Corporation of India (SECI) on behalf of Government of India (GOI). SECI will handle funds to be made available under the scheme on behalf of GOI. The states shall designate a nodal agency for implementation of the solar park.

Table 7: Solar Park details

State	Park Name	Location	Capacity (MW)
Madhya Pradesh	Ultra mega solar park	Rewa	750
Andhra Pradesh	Kurnool solar park	Pinnapuram	1000
Rajasthan	Bhadla solar park	Bhadla	700
Gujarat	Banaskantta Solar Park	Banaskantta	700

V. FORECASTING METHODS OF RES

(a)Weibull probability density function :

Weibull function has been applied widely by researchers in field of wind speed analysis for several decades. The Weibull probability density function (Weibull PDF) for demonstrating the Weibull distribution will be indicated as in equation (1).

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^{k}} \quad \text{.....(1)}$$

where $f(v)$ is the probability of apperceive wind speed, v represents wind speed that is a stochastic.

The Weibull shape and scale parameter are denoted by k and c, respectively. k is dimensionless and it represents how peak the object is, while c has a unit of wind speed (m/s) and it shows how windy the case study is. The weibull probability densities function and the characteristics of the wind speed for c=1 and k= 0.5, 1, 1.5 & 5 are shown in figure 1.

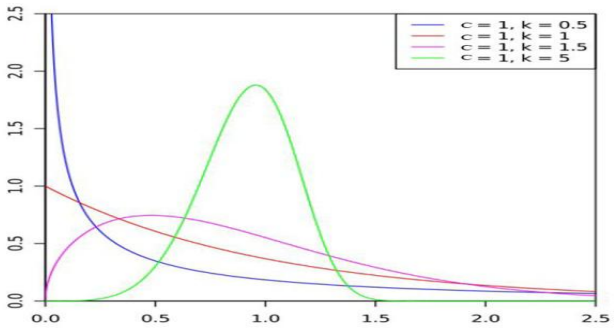

Figure 1: The Weibull PDF for wind speed

(b) Numerical weather Prediction & wind forecasting:

In developing a NWP-based wind power prediction model the selection of the particular NWP model is a critical step [6]. Important selection criteria include the geographical area, the resolution (both spatial and temporal) and the forecast horizon, as well as the accuracy required and the computational time and number of runs. NWP models usually have three main components, the dynamic center, which represents the adiabatic non-viscous flow, the physical equations describing variability of the meteorological processes (e.g. turbulence and radiation) and the information gathering software code.

(c) Physical methods:

Several physical models based on the use of weather data have been developed for wind speed forecasting and wind power predictions. The physical models generally make use of global databases of meteorological measurements or atmospheric mesoscale models, but they require large computational systems in order to achieve accurate results [7]. In the physical approach a detailed description of the lower atmosphere is used to estimate the wind power output.

(d) Statistical and learning approach method:

In the statistical approach a vast amount of data is analyzed and meteorological processes are not explicitly represented. The link between historical power production and weather is determined and then used to forecast the future power output. Unlike physical methods, statistical methods involve only one-step to convert the input variables into power output. Hence, the methods used are described as 'black box'. Generally a statistical relationship is developed between the weather forecast or prediction and the potential power output from the wind farm.

(f) Probabilistic Forecasting:

Probabilistic forecasting consists in providing the future probability of one or more events. In this sense, probabilistic forecasting is generally opposed to deterministic forecasting where a single predicted value is provided for each considered horizon. Probabilistic forecasts can be provided under different forms depending on the nature of the variable being forecast. For discrete variables (i.e. for a finite number of possible events) probabilistic forecasts are called probability forecasts. Various types of forecasts exist when forecasting continuous variables. A quintile forecast is the value such that the observation has a predefined probability to be inferior or equal to this value. Predictive intervals provide a lower and upper bound between which the observed event is expected to fall within a predefined probability.

(g) Neural Network:

Now days it is the most powerful tool for optimization as well as forecasting. In the beginning it was mainly used for the load forecasting. Now it is widely used in the PV generation power forecasting. The artificial neural network (ANN) is rapidly used by the most of the researchers in the field of PV power forecasting because of non-linearity in the weather data. ANN is a great tool and easily understands the complicated and non-linear bonding between the data without any prior assumption. ANNs were implemented to develop models using different input vectors. In the first model it uses historical data of measured PV power as an input data vector, in the second model time series of measured PV power with irradiance and in the third model author uses time series of model, ambient temperature, solar irradiance data and time series data of the PV power [11]. In all above model third model give more appropriate and desired results. So, we see that as we add more weather variables as an input data vector the prediction of the forecasting is going to be more accurate and satisfactory. It uses time series analysis model NARX, feed forward neural network with tapped delay lines. During training process model uses solar radiation as an input data, the hour as exogenous input and PV production data as an endogenous input. Model forecast the PV power generation with less than 5% error [12].

VI. CONCLUSION

Country like India has very much unbalanced in electricity production. Production is less and consumption is very much. Solar power is very good option in India to increase power production. This is also very good for our environment protection and economic development. Solar power is unlimited source of energy and our country also provide suitable climate for this energy but we need some better idea to increase efficiency and decrease production cost. Our government launches some schemes for production of solar power and achieves some successes but we need education and publicity in society for these schemes so that people take some initiative for use renewable energy as much as at a place of conventional energy sources. Currently we are generating 4.59% of solar energy of total produced renewable energy installed capacity in India. It is very low in comparison of total installed capacity of renewable energy and scope is very much for this solar PV.

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