Advanced Research in Electrical and Electronic Engineering
p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 2, Issue 14 October-December, 2015, pp. 54-58

http://www.krishisanskriti.org/Publication.html

Review of Solar Power Generation in India: A Road Map

D.K Bhalla[1] and Sh. Om Prakash Singh[2]

[1]Bhagwant Institute of Technology, NH -24, Zindal Nagar, Ghazizbad
[2]Department of Electrical Engg, G B Pant Institute of Technology, Okhla Phase III, New Delhi-110020

Abstract—*Solar power is a clean renewable resource with zero emission. Solar energy could be made financially viable with government tax incentives and rebates. Most of the developed countries are switching over to solar energy as one of the prime renewable energy source. Conducive policy environment, regulatory framework, fiscal & financial incentives have accelerated development of renewable energy (RE) in India in the past few years. With such initiatives, large capacity addition through renewable generation shall continue to take place in future also. However, renewable energy is characterized by intermittency &variability in output Power. Therefore, increasing renewable penetration presents numerous challenges to the power grid operator as well as system planner. In this paper identifies challenges in grid integration of large scale renewable as well as suggests suitable measures to address them. Grid integration plan for envisaged renewable capacity by 2012-17 & 2021-22 are formulated through Green Energy Corridors. The requirement of control infrastructure equipped with advanced forecasting tools as well as Real time measurement/monitor schemes through WAMS applications, dynamic reactive compensation, and energy storage to provide balancing services. It also highlights transmission plan that serves as a road map up to 2050.*

Keywords*: Renewable; Integration; Generation Based Incentive Scheme; Solar; National Solar mission; Feed- In -Tariff; Transmission; Balancing; Energy Storage; Intermittency.*

1. INTRODUCTION

The global electrical energy consumption is steadily rising and consequently there is a demand to increase the power generation capacity. A significant percentage of the required capacity increase can be based on renewable energy sources. The need for a cleaner environment and the continuous increase in power demand makes renewable energy production, like solar and wind increasingly interesting energy production and solar energy could be a solution for the ever increasing power demands. One of the major advantages of PV technology is that it has no moving parts therefore, the hardware is very robust, it has long life time and low maintenance requirements and most importantly it is one solution that offers environmentally friendly power generation.

Electricity is a key infrastructure for development of a nation. Fossil fuels are finite in nature as an energy source and millions of years are required to form fossil fuel in the earth. Fossil fuels like coal, oil, natural gas etc, are depleted at a rate 100,000 times faster than they are being formed. Under this backdrop, there is a pressing need to accelerate the development of renewable energy technologies in order to address the global challenges of energy security, climate change and sustainable development. Solar power and solar energy resources on earth are enormous, non-polluting, and virtually inexhaustible and has proved to be an economical source of energy in many applications. Ministry of New Renewable Energy (MNRE) has envisaged about 165GW renewable capacity through solar (100GW) & non solar (65) by 2020.

Power is the most vital input for the growth of any economy. Therefore, it is considered as a base industry as it promotes development across various sectors, Such as manufacturing industries, education, railways, commercial etc. to achieve economic growth. Power demand need of the country is growing at a very fast pace to meet high GDP growth rate. At Present peak electricity demand of the country is 135 GW which is expected to grow to 200 GW & 283 GW by the end of 2016-2017 (12^{th} plan) & 2021-22 (13^{th} plan) respectively as envisaged in the 18^{th} EPS report of CEA. To meet the growing demand and to reduce the supply demand gap, there is a need of large capacity addition through conventional as well as renewable energy capacity.

Considering envisaged large scale renewable penetration level by 12^{th} plan period (2016-17) and need of identifying challenges & infrastructure requirement to facilitate RE grid integration, POWERGRID carried out comprehensive studies and identified “GREEN ENERGY CORRIDOR”. It includes transmission infrastructure for penetration of large RE power in the network. Strong grid interconnection shall also help in enlarging power balancing areas, Intermittent/variable nature of RE sources results in large variation in quantum and direction of power flow on the interstate high capacity transmission corridors. There is a need of placing Dynamic reactive compensation in the form of STATCOM/SVC at

strategic locations to provide dynamic voltage support for smooth operation and maintaining grid security.

In addition, the study involves requirement of other control infrastructure like establishment of Renewable Energy Management Centers (REMC) equipped with advanced forecasting tools, Real time measurement/monitoring schemes through WAMS applications, energy Storage facilities to provide balancing services etc.

2. PRESENT SCENERIO OF INDIAN MARKET

The Indian grid is most important and diversified network in the world. The Indian power sector has been progressing in generation capacity addition through conventional viz. Coal, lignite, gas, hydro, and nuclear as well as non conventional/ renewable sources viz. wind, solar, small hydro, biomass etc. Presently total generation capacity is about 263.8 GW which constitute capacity from conventional sources (87% share) viz. coal (158.5GW), Gas (23GW), Nuclear (5.8GW) and large hydro (40.9GW).Balance 34.4 GW (13%) contribution is from wind (22.7 GW), solar (3.4GW), SHP (4GW) and Biomass/ biogases (4.3GW) generation.

India has made continuous progress in conventional as well as renewable capacity addition. Since during 9^{th} plan period, share of renewable capacity has increased from 2% to 13% as on by the end of year 2014.Electricity generation due to renewable has also increased about 6% in overall electricity generation mix as on today. During 12^{th} year plan, renewable capacity penetration &energy penetration shall increase to 18% &10% respectively. The trend of increasing renewable penetration from present to 2030 is shown in table 1.

Table 1: Renewable Capacity Penetration in India (present &envisaged)

S. No.	Plan Period since 9^{th} five year	% Energy Penetration	% Renewable Penetration
1.	2014	6	13
2.	12^{th} Plan (2012-2017)	10	18
3.	2030	16	31

3. ASPECTS OF SOLAR GENERATION FOR INDIAN POWER MARKET:

The world's energy market relies heavily on fossil fuels like coal, petroleum, crude oil, and natural gas as source of energy or fuels. They are finite to depletion at a rate that is 100000 time faster than they are being formed. There is a pressing need to accelerate the development of renewable energy technologies in order to address the global challenges of energy, security, climate and sustainable development. In India the aspects of soar generation are bright due to the following reasons.

3.1 SOLAR POTENTIAL IN INDIA:

India is located on the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. There are about 300 clear sunny days in a year in most part of the country. The average solar radiation incident over India varies from 4-7 kwh per sqm per day. The total radiation received over the Indian land area is estimated to be 5,000 trillion kwh per year – more than India's total energy consumption per year. Solar potential in India is about 20-30 MW per sq km. About 66 MW of aggregate capacity is installed for various applications comprising one million industrial PV systems – 80% of which is solar lanterns, home & street lighting systems and solar water pumps, etc. The estimated potential envisaged by the Ministry for the solar PV program, i.e. solar street & home lighting systems, solar lanterns is 20 MW per sq.km.

3.2 STATE PROVISION FOR SOLAR GENERATION:

Rural Electrification Program in 2006 was the first step by the Indian government in recognizing the importance of solar power. It gave guidelines for the implementation off-grid solar applications. However, through this only 33.8 MW was installed. This primarily included solar lanterns, home lighting systems, solar pumps, street lighting systems and solar home systems. In 2007, as a next step, Indian Government introduced the Semiconductor Policy to encourage the electronics and IT industries. This included the silicon and PV manufacturing industry as well.

The Generation Based Incentive (GBI) scheme, announced in January 2008 was the first step by the government to promote grid connected solar power plants. The scheme for the first time defined a feed-in tariff (FIT) for solar power (a maximum of Rs. 15/kWh). Since the generation cost of solar power was then still around Rs.18/kWh, the tariff offered was unviable. Also, under the GBI scheme, In June 2008, the Indian government announced the National Action Plan for Climate Change (NAPCC). A part of that plan was the National Solar Mission (NSM). The NSM guidelines indicated that the government had improved on the shortcomings of the GBI scheme. It aimed to develop a solar industry, which was commercially driven and based on a strong domestic industry. The extra cost of generation of solar power was being borne by the federal government under the GBI scheme.

The Jawaharlal Nehru National Solar Mission aims at development and deployment of solar energy technologies in the country to achieve parity with grid power tariff by 2022. The National Solar Mission is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change .The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level.

The main features of the National Solar Mission are:

1. Make India a global leader in solar energy and the mission envisages an installed solar generation capacity of 20,000 MW by 2022, 1, 00,000 MW by 2030 and of 2, 00,000 MW by 2050.
2. The total expected investment required for the 30-year period will run is from Rs. 85,000 crore to Rs. 105,000 crore.
3. Between 2017 and 2020, the target is to achieve tariff parity with conventional grid power and achieve an installed capacity of 20 Giga Watts (GW) by 2020.

3.3 DECREASING INVESTMENT COST OF SOLAR IN INDIA

The worldwide market for PV has grown exponentially over the last ten years as PV costs decreased significantly (Fig 1.). The cost of PV is likely to decrease further over the next ten years; if a large scale rural electrification programmed go ahead. Research shows that grid parity could be reached in Germany in 2019, 2017 and 2015 for PV system with life time of 25, 30 and 40 years respectively In India PV technology has the prospect of cost break-even at such production volumes estimated production of 195 GWP in 2020, with costs approaching those of conventional grid power for residential consumers by 2020.

Encouraging the spread of solar power generation (both CSP and PV) and aiming for grid-parity by 2022 and parity with coal power generation by 2030, is a key element in India's comprehensive, long term energy supply will strategy. Keeping in view the solar annual insolation, solar power could therefore easily address India's long-term power requirements. However, it has to be cost-competitive. As of December 2011, solar power generation in India costs around RS.10/kWh, or over 2.5 times as much as power from coal. Importantly, it is crucial that the industry receives the right policy support to ensure that projects are executed and performed up to the mark.

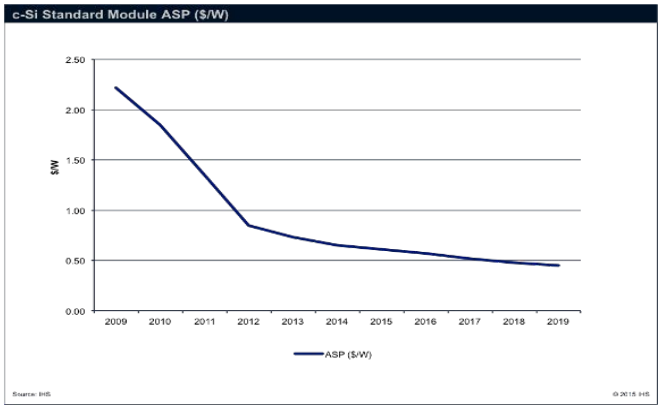

Fig. 1: Declining PV electricity cost

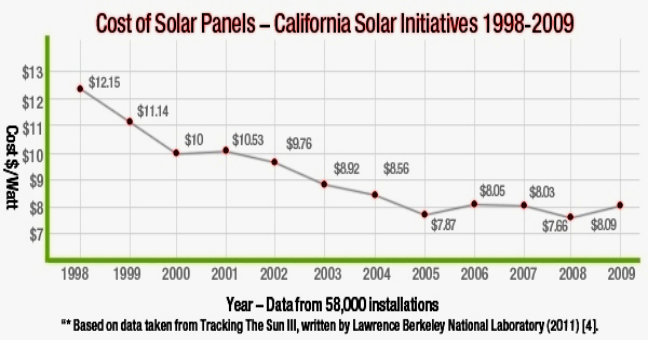

Fig. 2: Data of Cost of solar panel system

4. SOLAR ENERGY DEVELOP-MENT IN INDIAN STATES

The Gujarat solar policy initiated a process of the states formulated their own policy frameworks independent of the federal guidelines. These policies exist independent of each other as well as the NSM. Other states like Karnataka, Andhra Pradesh and Rajasthan have also formulated their own policies for development of solar power programs. Rajasthan has implemented land banks as well to make land acquisition easier. As more states plan to meet their solar power obligations, new policies are expected to be offered, creating as very high market across the subcontinent.

4.1 GUJARAT SOLAR POLICY -2009

Gujarat is the first state to make its own solar policy in 2009.The initial target was to achieve 500 MW of the installed capacity by the end of the period. Gujarat Energy Development Agency (GEDA) and Gujarat Power Corporation Limited (GPCL) have been appointed the nodal agencies for the facilitation and implementation of the solar policy. Gujarat solar Policy is the only policy, which has awarded projects with a fixed Feed-In Tariff (FIT), on a first come first basis.

4.2 INDIA FIRST SOLAR PARK

On December 29th 2010, India's first solar park was inaugurated at Charanaka in Patan district of Gujarat. So far, Land has been allotted in the solar park for projects to 16 companies from the first and second phases. The total capacity of the solar park is 500 MW with 30,000 sq. m per MW allotted to thermal and 20,000 sq. m per MW of land allotted to PV projects. The solar park has been financed with over Rs 12 billion by financial institutions. The Park tackles land procurement, water availability and grid connectivity issues and offers a single-window process.

4.3 KARNATKA SOLAR POWER POLICY (2011-16)

Karnataka, announced its solar policy on July 1, 2011. Under the solar policy 2011-16, the Karnataka Government proposes

to promote solar power as part of renewable energy generation policy in the state**.**

1. It targets 350 MW worth of projects till 2016.
2. 200MW is to be developed for direct sale to the distribution companies in the state (40 MW to be added each year)
3. 100MW under mechanism50MW for bundling of power with thermal power from outside the state at rates to be determined by the state Government subject to approval of KERC.

The minimum capacity of solar PV projects is 3 MW. Through the state has come up with its own policy; it will continue to support programs like the NSM. The state has set a combined target of 126 MW of solar power to be developed by 2013-14 through NSM and its own solar policy.

4.4 RAJASTHAN SOLAR POWER POLICY – 2011

On April 19th 2011, Government of Rajasthan issued Rajasthan Solar Energy Policy, 2011 to promote solar energy in the state. The policy aims to help Rajasthan, develop as a global hub of solar power for 10000 -12000 MW capacity over the next 10 to 12 years to meet energy requirements of Rajasthan and other states of India.

1. It targets a minimum of 550MW of grid connected solar power in Phase 1
2. PV projects will be worth 300MW, out of which 100MW are reserved for project developers and 200MW for Panel Manufactures.
3. The minimum and maximum sizes of PV projects are 5MW and 10MW.
4. Module manufactures that set up their manufacturing plant and Rajasthan can bid for either 10MWor 20MW worth of PV projects based on their manufacturing capacity.
5. A further 50MW will be allocated for rooftop PV (1MW each) and other small solar power plants.

5. GROWTH OF SOLAR ENERGY GENERATION IN INDIA

India's government has begun to acknowledge the importance of solar energy to the country's economic growth. The Indian Government launched a National Solar Mission in 2010. From less than 12 MW in 2009, solar-power generation in the country grew to 190 MW in 2011. By March 2013, it grew to fivefold to 1,000 MW. Now at present the solar installed capacity is 3400MW. But the country has a long way to go to reach its goal of increasing solar-power generation to 20 Giga Watts by 2020. Across India, there are still thousands of villages with plenty of sun but not enough power.

6. CHALLENGES IN INTEGRATION OF RENEWABLES INTO GRID & THEIR SOLUTIONS:

Large scale renewable integration presents numerous challenges to power grid operator as well as system planner. Power grid has carried out studies to identify transmission infrastructure and control infrastructure for grid integration of RE capacity. Challenges are described as under.

1. Variability& Intermittency- may lead stress on the system.
2. Solar plants are normally located in remote/concentrated locations and may not lie at the load centre. In case of sudden drop in generation, may cause supply management issues.
3. Solar plants are known to be providing lesser grid support in terms of ancillary services during system disturbances than conventional generation.
4. Renewable may introduce new patterns in the flow of power which may cause congestions in transmission & distribution network in case of conservative planning.
5. Some of the solar power plants consume reactive power from the system, which can adversely impact the system during disturbance/high loading unless suitable measures are taken.
6. Integration of large scale home based PV system to the grid would be other technical challenges such as voltage stability, harmonics, and protection of feeder.

The Challenges described as above accordingly solutions are given below:

1. Presently, the variability and intermittency of solar generation is being addressed by the varying output of hydro plants whereas thermal plants are being operated as meeting base load. But now there is need for Strong Grid interconnection to enlarge power balancing areas.
2. Pocket wise RE generation development should be prioritized in such a manner so that transmission infrastructure available in the pocket can be utilized optimally.
3. Establishment of renewable Energy Management Centers (REMC) equipped with advanced forecasting tools.
4. Flexible generation, Ancillary services etc for supply - balancing.
5. Demand Side management, Demand Response and storage for load balancing.
6. Grid integration plan for envisaged renewable capacity addition is to be formulated through green energy corridor in phase wise by power grid.

7. FUTURE ROAD MAP

In first phase several initiatives have been taken by MOP/MNRE/CEA to expedite the implementation of Green Energy corridors for integration of large scale renewable in 12th five year plan. Capacity addition from renewable is envisaged to be nearly 33 GW in RE resource eight (8) solar rich states viz. Tamil Nadu, Karnataka, A.P, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh and Jammu& Kashmir. Out of 33 GW, about 65% capacity (20.5 GW) is envisaged to be contributed from wind, about 30% (10GW) from solar and balance 2.5GW from small hydro.

In second phase Grid integration plan for envisaged renewable capacity addition by 2021-22 is being formulated through Green Energy Corridors-II. In second phase about 22GW solar capacity addition through ultra-mega solar power parks is be envisaged in 12 states comprising 17,600 MW capacity including 7500MW in Leh/Kargil is proposed to be evacuated on inter- state transmission system and balance 4500 MW through intra state network. Power grid has also carried out studies to identify transmission infrastructure and control infrastructure. Power evacuation arrangement & dynamic reactive compensation as part of Intra-state transmission system (ISTS) network has been evolved in Green Energy Corridors phase 11.A perspective transmission plan which includes high capacity hybrid UHV/EHV AC & HVDC transmission system in phased development approach is also chalked out (2050).

8. CONCLUSION

Large scale grid integration of renewable generation, which is variable and intermittent in nature, is expected to take place in the near future. To address issues on integration of large scale renewable, balancing requirement are the primary needs. Flexible generation & Ancillary services, Demand Side Management Demand Response through Smart Grid technologies, Energy Storage and Establishment Of renewable Energy Management Centers (REMC) along with communication infrastructure is the solution.

Grid integration Plan for 33GW renewable capacity addition envisaged in 12th Plan period (2012-17) is being formulated through Green Energy Corridor in to eight(8) RE resource rich states. And Grid integration Plan for envisaged RE capacity addition by 2021-22 is being formulated through Green Energy Corridor-ii .The Government plan is to set up 100GW solar generation in next five years including 25 solar park with a capacity of 500 to 1000MW as Ultra Mega solar power projects, thereby targeting around 20 GW solar Capacity. 40,000MW Solar capacity addition is envisaged through Roof Top solar PV and 40,000 MW through distributed solar generation. 17.6MW capacity is proposed to be evacuated on interstate transmission system and 4.5M through intra state network.

REFERENCES

[1] JA Gow, C.D Manning, " Development of a Photovoltaic array model for use in power- electronics simulation studies" IEE Proc-Electr-Power Appl. Vol,145, No. 2,March 1999. Page No. 193-1999

[2] Masahide Hojo, Tokuo Ohnishi, "Adjustable harmonic mitigation for grid-connected ,photovoltaic system utilizing surplus capacity of utility interactive inverter", 37th IEEE Power Electronics Specialists Conference, 2006, Page No:-. 1-6.

[3] Thomas S. Basso, "High-penetration, grid-connected photovoltaic technology codes and standards", 33rd IEEE Photovoltaic Specialists Conference, 2008, Page No:-. 1-4.

[4] Gyeong-Hun Kim, Hyo-Rong Seo, Seong-Jae Jang, Sang-Soo Park, Sang-Yong Kim, "Performance Analysis of the anti-islanding function of a PV-AF system under multiple PV system connections", International Conference on Electrical Machines and Systems, 2009, Page No:-. 1-5.

[5] Jing Li, Fang Zhuo, Jinjun Liu, Xianwei Wang, Bo Wen, Lin Wang, Song Ni, "Study on unified control of grid-connected generation and harmonic compensation in dual-stage high-capacity PV system", IEEE Energy Conversion Congress and Exposition,2009, Page No:-. 3336-3342.

[6] Seyed Hossein Hosseini, Mitra Sarhangzadeh, Mohammad B. B. Sharifian, Farzad sedaghati, "Using PV in distribution network to supply local loads and power quality enhancement", International Conference on Electrical and Electronics Engineering,2009, Page No:-. 249

[7] Xiaogao Chen, Qing Fu, David Infield, Shijie Yu, "Modeling and control of Zsource grid-connected PV system with APF function", 44th International UniversitiesPower Engineering Conference, 2009, Page No:-. 1-5.

[8] Xiaogao Chen, Qing Fu, Donghai Wang, "Performance analysis of PV gridconnected power conditioning system with UPS", 4th IEEE Conference on Industrial Electronics and Application,2009, Page No:-. 2172-2176.

[9] Chris S. Edrington, Saritha Balathandayuthapani, and Jianwu Cao, "Analysis of integrated storage and grid interfaced photovoltaic system via nine-switch three-level inverter", IECON 2010-36th Annual Conference on IEEE Industrial Electronics Society,Nov 2010, Page No:-. 3258-3262.

[10] Chris S. Edrington, Saritha Balathandayuthapani, and Jianwu Cao, "Analysis andcontrol of a multi string photovoltaic (PV) system interfaced with utility grid " IEEE power and Energy Society General Meeting, 2010, page No. 1-4

[11] T. Ito, H. Miyata, M. Taniguchi, T. Aihara, N. Uchiyama, and H. Konishi, "Harmonic current reduction control for grid-connected PV generation systems",International Power Electronics Conference, 2010, Page No:-. 1695-1700.

[12] M.Sengupta, " Measurement and Modelling of Solar and PV Output Variability'' Conference paper , NREL/CP-5500-51105, April 2011.Page No. 1-5.

[13] Huiying Zheng, Student Member, IEEE Shuhui Li, Senior Member, IEEE and Julio Proano " PV Energy Extraction Characteristics Study Under Shading Conditions for Different Converter Configurations" 978-1-4673-2729-9/12/$31.00@ 2012 IEEE.

[14] M.Makhlouf, F.Messai, H. Benalla " Modeling And Simulation Of Grid Connected Photovoltaic Distributed Generation" Journal of Theoretical and Applied Information Technology, 30th November 2012, Vol. , 45 No. 2 Page, 378-386

[15] M.Chidi,Student member, IEEE,O.Ipinnimo,Student Member, IEEE, S.Chowdhury,Senior Member,IEEE and S.P.Chowdhury, Senior Member,IEEE " Investigation of Impact of Integrating on Grid Home Based Solar Power Systems on Voltage Rise In the Utility" Network" 978-1-4673-2729-9/12/$31.00@ 2012 IEEE.