

# Status of solar photovoltaic systems in India

*India is marching forward to achieve solar power generation, with a target of 100 GW by the year 2022. This paper reports the recent progress and developments in solar power sector in India. It also supports the prevailing progressive path for solar power projects and recommends future course of actions.*

**Keywords:** India; initiatives; solar photovoltaics

## 1.0 Introduction

Government of India (GoI) has set a target of setting up renewable power generation of capacity 1,75,000 MW by 2022, in which solar power have a share of 1,00,000 MW. As on 31 October 2017, 14751.07 MW of grid interactive (ground mounted) and 823.64 MW (roof top) solar photovoltaic (SPV) power was generated and 539.13 MWEQ off grid SPV system was put in service [1]. However the country's estimated solar power potential is about 7,48,000 MW.

Some of the renowned global agencies also support the growth of solar power deployment in India, which are detailed here. International Renewable Energy Agency (IRENA) predicts solar PV deployment in India will be 2, 09,000 MW by 2030. India's green bond market is expanding quickly, with more than USD 1.1 billion issued during 2015 and a total of USD 800 million in the first eight months of 2016 [2]. Global investment in renewables rose from USD 50 billion in 2004 to more than USD 286 billion in 2015, especially the solar sector records USD 161 billion in 2015. In India, renewable energy's investment is increased from USD 2.7 billion (year 2004) to USD 9.7 billion (year 2016) [3]. Utility scale PV power from plants commissioned in the year 2016 typically costs between USD 0.06-0.10 per kilowatt hour (kWh) in Europe, China, India, South Africa and United States. India stands 5th position in the world in terms of annual investments for solar

photovoltaic and renewable power generation [4]. With respect to the above datas, international technology roadmap for photovoltaic (ITRPV) report [5] suggests that global PV capacity to grow from 303 GWp in 2016 to 1700 GWp in 2030.

In India, green climate fund in line with India's intended nationally determined contributions (INDCs) under the UN framework convention on climate change (UNFCCC) supplements domestic resources allocation for accelerating development and deployment of renewable energy. India had made substantial progress in establishing policies to promote investment in renewable energy through national clean energy fund especially for solar photovoltaic systems. Creation of international solar alliance with various countries and organizing many investor meets/summits augments the work done in the process [6]. This paper presents the recent growth and developments of solar photovoltaic systems in India as documented from electric utilities, government sectors/agencies reports and publications. Also contributions by international organizations, government commitments, public-private-partnerships and investments are also presented.

## 2.0 India's energy scenario

As of 30 November 2017, India had 330860.58 MW of utility based installed electricity generating capacity, mostly from thermal based systems (218959.51 MW) and renewable power generation accounts for 60157.66MW [7]. Indian brand equity foundation [8] states that electricity production in India stood at 1,160.1 billion units (BU) in the financial year (FY) 17, having a growth of around 4.72 % over the previous financial year. Over FY10–17, electricity production expanded at a compound annual growth rate (CAGR) of 7.03%. With a production of 1,423 TWh, India is third largest producer and third largest consumer of electricity in the world. The government targets capacity addition of 88.5 GW under the 12th five year plan (2012–17) and around 100 GW under the 13th five year plan (2017–22). Investments of around USD 250 billion are planned for the power sector during 12th five year plan. GoI had approved the raising of bonds worth of USD 351.03 million for renewable energy through Indian renewable energy development agency (IREDA). These funds will be then used by Ministry of new and renewable energy for the

*Blind peer reviews carried out*

Messrs. V. Saravanan and M. Arumugam, Department of Electrical and Electronics Engineering, Arunai Engineering College, Tiruvannamalai 606603, M. Aravindan, Research Scholar, SCSVMV University, Kancheepuram and Assistant Executive Engineer/O and M/, Mambakkam, Tamilnadu Generation and Distribution Corporation, Tamilnadu, India, and V. Balaji, School of Electrical Engineering, Bahir Dar University, Ethiopia. Email: vsaranaec@yahoo.co.in / pударavindam@gmail.com / drmarumugam@yahoo.com

approved schemes for green corridor, central public sectors units, defence solar projects, solar parks, generation based incentives for wind projects, etc.

Ministry of Power, Government of India has set a target of 1,229.4 BU of electricity to be generated in the financial year 2017-18. The annual growth rate in renewable energy generation in India has been estimated to be 27 per cent and 18 per cent for conventional energy. Around 293 global and domestic companies have committed to generate 266 GW of solar, wind, mini hydel and biomass based power in India over the next 5-10 years with an investment of about USD 310–350 billion. Also, the installed capacity of solar cells and modules of India by the year 2017 is 3164 MW and 8398 MW respectively.

NITI Aayog, India initiated India Energy Portal and suggested the need for global information systems based mapping of renewable energy in consultation with NREL, USA. It strongly recommends for solar power growth through action measures beyond 13th five year plan of India [9].

As reported in the user guide for renewable energy sectors, India energy security scenarios, 2047, solar PV capacity addition is expected to achieve any of the levels, where level 1 corresponds to least effort scenario with a capacity addition of 37 GW and level 4 corresponds to heroic effort scenario to add 479 GW.

More impetus is shown for the growth of photovoltaic systems in India through policies such as generation based incentives, public private partnership, liberalized foreign direct investment policy, low interest funds provided from National Clean Energy Fund (NCEF) to Indian Renewable Energy Development Agency Ltd. (IREDA) for on-lending to viable renewable energy projects and tax benefits. Three key regulatory instruments played a major role in the solar photovoltaic promotion in India are preferential feed in tariffs (FiT), renewable purchase obligation (RPO) and renewable energy certificates (REC) over the years. The growth of solar power generation is found to be more promising as shown in Fig. 1.

The bench mark capital cost for solar PV projects for FY 2016-2017 shall be INR 530.02 lakhs/MW, with the assumptions like module prices to be USD 0.48/W, PCU cost to be INR 35 lakhs/MW. The detailed breakup of utility based PV systems is given in Table 1.

Following are the terms and conditions for tariff determination obtained from Central Electricity Regulatory Commission [10], for renewable energy sources, Regulations 2017 as shown in Table 2. Under this, the solar PV plant should have capacity utilization factor (CUF) of 19%, auxiliary consumption factor shall be 0.25% of gross generation and useful life of the system to be 25 years with total power generation of about 41.6 million units.

The Ministry of New and Renewable Energy (MNRE), GoI has revised the benchmark cost for off-grid and decentralized

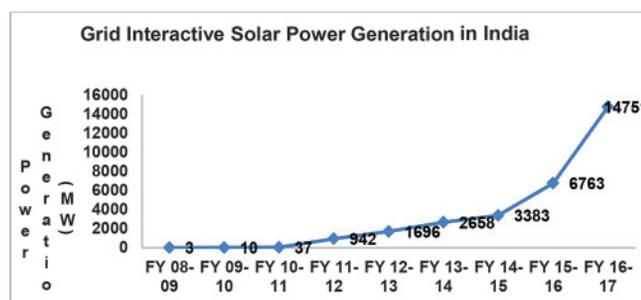


Fig.1: Growth of grid interactive solar power generation in India

TABLE 1: BENCH MARK COST FOR SOLAR PV PROJECTS (1 MW) FOR FY 2016–17

Particulars	Capital cost (INR lakhs/MW)	% of total cost
PV modules	328.39	61.96%
Land cost	25	4.7%
Civil and general works	35	6.6%
Mounting structures	35	6.6%
Power conditioning unit (PCU)	35	6.6%
Evacuation cost up to interconnection (cables and transformers)	44	8.3%
Preliminary and pre-operative expenses including IDC and contingency	27.63	5.21%
Total capital cost	530.02	100%

TABLE 2: CERC TARIFF PARAMETERS FOR SOLAR PV (1 MW) FOR FY 2016–17

CERC tariff parameters	Values
Tariff period	25 years
Capital cost (INR lakhs)	530.02
Debt/equity ratio	70:30
Total debt amount (INR lakhs)	371.02
Debt cost (12 years of repayment period including moratorium)	12.76%
Total equity amount (INR lakhs)	159.01
Return on equity (weighted average)	22.40%
Discount rate	10.70%
Income tax	33.99%
Depreciation values	5.28%
O&M cost (INR lakhs)	7.00
Levelized total cost of generation, (INR/kWh)	5.68
Accelerated depreciation (INR/kWh)	0.59
Net levelized cost of generation, (INR/kWh)	5.09

solar PV applications programme for the year 2017-2018 is given in Table 3. Also the bench mark cost for grid connected rooftop and small solar power plants programme for the year 2017-2018 is given in Table 4. Table 5 gives the details of subsidy revision for solar water pumping systems under off-grid and decentralized solar applications programme for the year 2017-2018.

TABLE 3: BENCHMARK COST FOR OFF GRID AND DECENTRALIZED SOLAR PV APPLICATIONS PROGRAMME FOR THE YEAR 2017-2018

Category	Benchmark cost (Rs/Wp)
Upto 10 kWp	70
>10-100 kWp	65
>100-500 kWp	60

TABLE 4: BENCHMARK COST FOR GRID CONNECTED ROOF TOP AND SMALL PLANTS PROGRAMME FOR THE YEAR 2017-2018

Capacity	Central financial assistance at certain percentage of the benchmark cost
Up to 1 hp	30 %
>1 hp and up to 3 hp	25 %
>3 hp and up to 5 hp	20 %

TABLE 5: STANDARDS TO BE ADOPTED FOR GRID CONNECTED SOLAR PHOTOVOLTAIC POWER PROJECTS

Components	Standards to be followed
Solar photovoltaic modules	Crystalline silicon solar cell modules - IEC 61215, thin film modules - IEC 61646, concentrator PV modules - IEC 62108
Power conditioners/ inverters	Efficiency measurements - IEC 61683, Environmental testing - IEC 60068-2/IEC 62093, EM compatibility -IEC 61000-6-2, IEC 61000-6-4 and other relevant parts of IEC 61000, electrical safety - IEC 62103/IEC 62109-1&2, anti-islanding protection-IEEE 1547/IEC 62116/UL 1741

Table 5 indicates subsidy revision for solar water pumping systems under off-grid and decentralized solar applications programme for the year 2017-2018

GoI have waived the inter-state transmission charges and losses on transmission of electricity generated from solar and wind sources of energy under para 6.4(6) of the revised tariff policy 2016 for a period of 25 years [11]. Following are the technical measures required to ensure quality of equipment used in grid connected solar photovoltaic power projects as given in Table 6.

### 3.0 Initiatives and announcements made for solar power development in India

MNRE has planned to set up 50 solar parks each with a capacity of 500 MW and above by 2019-2020, with enhancement of capacity from 20,000 MW to 40,000 MW for development of solar parks and ultra mega solar power projects with an estimated central financial assistance of Rs.8100 crores under national solar mission. Solar Energy Corporation of India Limited, nodal agency of MNRE is committed to develop and monitor solar projects in various parts of India. [12]

Despite challenges and barriers to the adoption of solar photovoltaic systems, huge employment opportunities nearly

1,03,000 are estimated in India (IRENA, renewable energy and jobs, annual review 2016). Many recent initiatives supported by various stake holders such as international organizations, governments and public/private sectors are listed to boost solar photovoltaic power generation in India [8, 13].

#### 3.1 INDO-US INITIATIVES

A joint Indo-US PACE setter fund has been established, with a contribution of USD 7.9 million to enhance clean energy cooperation. US federal agencies have committed a total of USD 4 billion for projects and equipment sourcing for the growing renewable energy sector in India.

#### 3.2 GoI INITIATIVES

(a) Goods and service tax council, GoI levy 5% on solar panels. (b) GoI has recently announced the formation of international solar alliance of 121 tropical countries to develop and promote solar energy. Recently, memorandum of understanding is signed with other countries like France, United Kingdom and Portugal to strengthen renewable energy cooperation. (c) GoI approved 15,000 MW of grid-connected solar power projects of National Thermal Power Corp Ltd. (d) Development of grid connected solar PV power plants on canal banks (50 MW) and canal tops (50 MW) by providing capital subsidies in the various states of India. (e) MNRE has signed an agreement with Germany-based KfW Development Bank to fund the USD 44.7 million (Rs.300 crores) floating solar project in Maharashtra and Kerala to generate over 310 GW of green energy. (f) Central ministries have pledged to produce 5000 MW rooftop solar power. Their individual breakups are: Ministry of Railways (500 MW), Department of Atomic Energy (500 MW), Department of Food and Public distribution (355.23 MW), Department of Defence Production (232.25 MW), Ministry of Steel (230MW). (g) Ministry of Shipping plans to install 160.64 MW of solar and wind based power systems at all the major ports across the country by 2017 for giving a fillip to government's Green Port Initiative. (h) Creation of Indo-German Solar Energy Partnership: KfW to provide concessional loans of EUR 1 billion for 5 years focusing on solar rooftops, GIZ to provide technical assistance, policy advisory services, pilot project promotion and capacity building and training, PTB to provide skill development and curriculum.

#### 3.3 FINANCIAL SECTOR INITIATIVES

- (a) World Bank Group has committed to provide USD 1 billion for India's solar energy projects and plans to work with multilateral development banks and financial institutions to develop financing instruments to support solar energy development
- (b) International Finance Corporation, investment arm of World Bank, plans to invest USD125.3 million in Hero Future Energies Limited, to fund the construction of solar and wind power plants.
- (c) Reserve Bank of India has notified to include renewable

energy under priority sector lending. So, banks can provide loans up to a limit of USD 2.36 million to borrowers for renewable energy projects.

- (d) State Bank of India has signed an agreement with World Bank for USD 626.3 million credit facility, aimed at financing grid connected rooftop solar photovoltaic projects in India.

#### 3.4 ANNOUNCEMENTS AND SERVICES

(a) Adani group has announced new investments exceeding INR 23,000 crores by 2021 in solar and wind development at 8th Vibrant Gujarat Global Summit, 2017. (b) Abraaj has committed to invest nearly 500 MW of utility scale solar projects with Aditya Birla Group in December 2015. (c) Tamilnadu Energy Development Agency, a Government of Tamilnadu enterprise established for promoting renewable energy, invites the national/international companies for the establishment of 500 MW solar parks in Tamilnadu. [14]. (d) CLP India has acquired a 49 per cent stake in SE Solar, Suzlon Group for building a 100 MW solar energy plant at Veltloor in Telangana, with USD 11.02 million (Rs.73.5 crores). (e) Andhra Pradesh government plans to establish an Energy University, focusing on research orientation and development of energy efficiency, energy conservation, and renewable sources. (f) MNRE has developed a list of web/mobile services for the promotion of photovoltaic systems in India: (i) SPIN-to enroll all empanelled agencies (private/government sector) under grid connected rooftop and small solar power plants programme. [15] (ii) Solar Guidelines – for encouraging rapid development of solar power sector by facilitating information dissemination about latest solar energy projects, policy frameworks. (iii) Web portal of Green Energy Corridor for monitoring. (g) ARUN (Atal Rooftop solar User Navigator) - mobile app for promoting and installation of solar rooftop power system in the home/consumer premises [16].

#### 4.0 Recommendations suggested for further growth of solar power in India

The suggestions recommended for solar photovoltaic project developments in India are: (i)strengthening of policy commitments, (ii) incorporating latest technology insights and planning techniques, (iii) integrated framework for standards and quality assurance/infrastructure, (iv) solar resource planning and grid operating protocols, (v) National solar energy financing mechanisms, private/public funding schemes and low cost financing, (vi) Attraction of foreign direct investments, (vii) no collateral security for development of solar energy parks, (viii) single window clearance for solar projects, (ix) must run status for PV systems, (x) support to PV manufacturing, supply chain and cross cutting power electronic technologies, (xi) proactive planning through National Smart Grid Mission, (xii) quicker implementation of advanced metering system, (xiii) upgradation of power evacuation/transmission infrastructure

for green energy transmission corridor, (xiv) availability of solar radiation data through GIS based stations, (xv) organizing more consumer awareness campaigns and demonstration activities, (xvi) creation of new training institutes and build institutional, technical and human capacity, (xvii) support to R&D programmes with industry association and (xviii) integration of solar technology with energy storage mechanisms.

#### 5.0 Conclusions

India has made substantial progress in establishing policies and actions to promote investments in renewable energy especially solar photovoltaic systems. It also set targets and timeframes to achieve clean power generation through various mechanisms and collaborations with all stakeholders of the world. Besides it needs to develop and strengthen its grid infrastructure, deregulation of energy markets, rural electrification, and skilled employment opportunities. By doing so, India can ensure affordable, reliable and sustainable power.

#### Acknowledgements

This work was supported by Wind Energy Division, Ministry of New and Renewable Energy, Government of India under financial grant (IFD Dy. No. 1429 dated 04/11/2016, Demand No. 61/69, Budget Head: 2810.00.104.04.05.31/35).

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(A Scopus Indexed Journal)

FEBRUARY 2022 ISSUE (VOL.70, No.2)

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