**International Journal of Emerging Engineering Research and Technology**
**Volume 2, Issue 6, September 2014, PP 24-31**
**ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)**

# Public Participation in Power Generation - An Assessment through SPV in India

**Anwar Shahzad Siddiqui[1], Abrar Ahmad[1]**

[1]Department of Electrical Engineering, JMI, New Delhi, India

**Abstract:** *Production of power traditionally has been seen as 'Bulk commodity' something that has been a 'beyond individuals' in India. The recent developments and maturing Solar Photovoltaic generation along with 'good solar profile' of India and intersection of cost with per capita income is now letting way for people to participate in this mode of power generation. Here the feasibility of an individual to generate electricity by Solar Photo Voltaic (SPV) has been studied. We propose a new generation policy that has the potential enough to match the current consumption of whole India and even beyond. We conclude that if proper policy decisions and awareness is propagated, India is well capable of generating enough through this distributed generation approach (DGA) to fulfill all its electrical demand without significant transmission loss, GTD infrastructure, and allied services that are conventionally indispensable today*.

**Keywords:** *SPV, Distributed Generation, Grid Parity, Renewable energy, per capita generation*

## 1. Introduction

Solar power as compared to wind is still seen as an inferior renewable source mainly due to its incapability to generate bulk power. But if we change this traditional approach of generation at bulk, even more so because the consumption after all is distributed in nature; the solar energy takes a big leap because even two units per day power generation by every individual will be able to meet all the electricity requirement of India i.e. 220GW [1] that includes TD losses, theft, faults, and reserve capacity. Additionally, as the prices of silicon based panels are deteriorating with consistent rate and the efficiency of thin film plates are rising in consonance, while grid electricity is becoming costlier due to rise of fossil fuel prices and inflation. Thus the equation of achieving grid parity through this approach doesn't seem a distant reality.

India is second largest populated country after china. Although it is the 4th largest producer of electricity in the world but due to its population its position in per capita consumption index falls beyond 100th position. Figure 1 shows a comparative per capita consumption of India with some other significant countries in 2010.

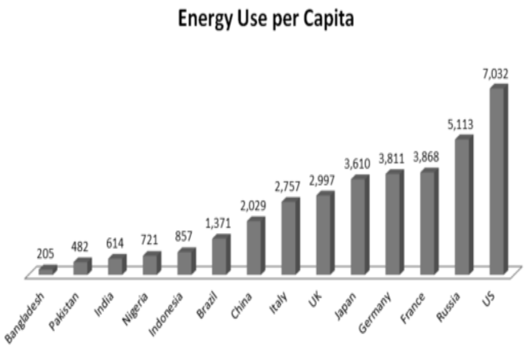


**Figure 1**. *Per capita energy consumption in countries*

Solar energy in India has theoretical potential of 5 trillion kWh/year [2], where most of the country falls under tropical range and has high solar radiation i.e. more than 4kWh/m2/day and more than 300 sunny days as demonstrated in Figure 2 [3]. With these geographical facts the solar energy in India would be always cheaper as compared to western as well as European nations were the sunny days as well as solar intensity is inferior.

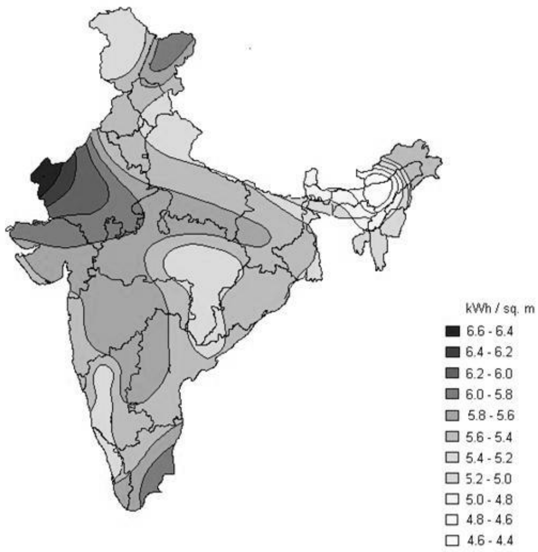


**Figure 2.** *Solar Insolation in India*

This is also quite appropriate for the case of India as it faces frequent blackouts leading to huge economic loss due to chasm between demand and supply. According to an estimate roughly 2/3rd of electrified India, do not get more than 8 hours of power per day. These interruptions and blackouts are directly connected to the economic loss to the country. It has been reported at least 9% of production loss in attributed to the power interruption as shown in Table 1.

**Table 1**. *Production value losses due to power interruption*

PRODUCTION VALUE LOSSES DUE TO POWER INTERRUPTIONS 1

| Country | Percent of Loss Due to Grid Interruption |
|---|---|
| South Africa | 0.9 |
| Thailand | 1.8 |
| China | 1.9 |
| Vietnam | 1.9 |
| Turkey | 2.3 |
| Brazil | 2.5 |
| **WORLD MEAN** | **3.2** |
| Indonesia | 4.2 |
| Philippines | 7.1 |
| India | 9.0 |

Source: World PICS (2002-2005) & Thailand PICS 2007.

The transmission and distribution infrastructure is not robust enough to tackle the faults in a comfortable time limit. The significant percentage of India remains un-electrified for example top 5 states e.g. Jharkhand, Orissa, Bihar, U.P and Rajasthan comprise 28.77% of un-electrified villages in India. Nationally there are 89808 villages that are un-electrified out of 593732 which amount to be 15% of whole India is still without power [4]. In other words every 6th village of India is un-electrified. The detail of un-electrified villages in India is presented in Table 2.

**Table 2.** *Un-electrified villages in India (MNRE- As on 31.08.2010)*

| S. No. | State | Total Villages | Unelectrified Villages | Unelectrified Villages % |
|---|---|---|---|---|
| 1. | Jharkhand | 29354 | 20235 | 31.1% |
| 2. | Orissa | 47529 | 17794 | 62.6% |
| 3. | Bihar | 39015 | 12216 | 68.7% |
| 4. | Uttar Pradesh | 97942 | 11492 | 88.3% |
| 5. | Rajasthan | 39753 | 11228 | 71.8% |
| 6. | Others | 340139 | 16843 | 4.95% |
| | Total | 593732 | 89808 | 15.12% |

This paper discusses the SPV quotient in the perspective of Indian reality in section 2. In section 3 we have explained the approach of 'Micro Distributed Generation' with model and its components. The technical and economic calculation for this approach has been detailed in section 4 and 5 respectively. A discussion based on different possibilities, policies and future prospects is discussed in section 6 followed by conclusion in section 7.

## 2. SPV Quotient of India

SPV to India should not be considered just as an alternate form of energy as generally viewed by other nations. Rather, considering its distinct demographic, geographic, economic, and political reality, SPV to India is a blessing where people participation in the generation would change the way India generates and consume electricity. The population of India which generally projected as bane and reason for its laggardness can be changed to boon if managed properly. For example the population of Australia – a continent is at par with population of Delhi-NCR, population of USA with bigger geographical area than India is just 3Million, as compared to UP state of India i.e. 200 Million. Europe, Russia, and parts of America do not fall under tropical range of sun which is abundantly available to India.

Under properly framed polices, broader vision, and state support, SPV generation does not just have potential to overtake wind generation but even conventional power generation. With MDSPV conventional energy demand can be reduced to a considerably low level which is presently a compulsive requirement due to pollution check under Kyoto protocol and other world regulatory bodies. Furthermore as economic progress and per capita income of millions of people is dependent on the availability of electricity, It has been a common scene of protests to meet their demand of electricity today, only If they knew that it is in their capacity of generate electricity on their own, their dependence on the grid would not be so pressing and compulsive and people would chose this alternative.

Additionally the way the solar panel prices are coming down similar to electronic gadgets, and the research breakthroughs that is making the panel thin and efficient, it only ensure that the days of SPV generation are shining and per capita generation is all the more going to be affordable.

## 3. Micro Distributed Generation Approach

Micro distributed generation (MDG) is a generation approach where every individual has a capacity to generate power that he may require or even sell or share with their neighbors in case of surplus power. This approach is although available to other non conventional methods such as Wind, Bio-fuel etc, but the investment required to generate at low wattage, their price of installation is extremely high as compared to SPV. This makes SPV stand out in MDG approach. In absence of this approach solar power in India, it is just 979MW as on 31st May 2012 [5]. This in not even 1% of generation share of India although its potential is immense. With the 'per capita generation' approach and synergetic efforts by people of India, the possibility to harness this form of energy is unprecedented.

SPV based MDG do not require infrastructure for the transmission of the power thus making two inherent benefits viz. saving from transmission and distribution losses that is 30% to 40% as per different studies, and the saving on the transmission and distribution infrastructure which contributes dearly to grid tariff. Thus levelised cost of generation through this approach would be cheaper as compared to grid cost. This approach of micro distributed generation is more suited to hilly areas or those areas where the grid infrastructure would be extremely costly and dangerous.

Solar based MDG model as shown in Figure 3 would necessarily have a set of PV modules made up of number of solar cells that receives solar energy and converts it into electricity by photoelectric phenomenon at Silicon based PN junction platform.

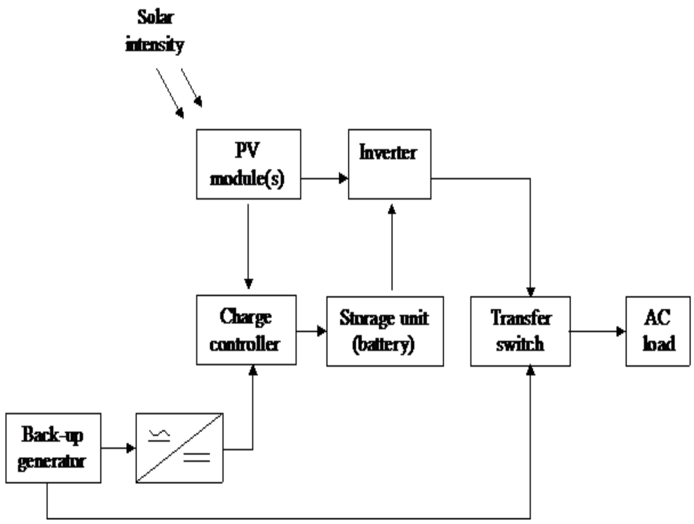


**Figure 3**. *Micro Distributed generation through SPV*

There are different types of SPV cells available with different characteristics and efficiency. Mono-crystalline silicon is the most efficient type of solar panels. But due to their high silicon content, they are also more expensive, but it takes less in number of panels to get required amount of wattage. They are ideal for roofs, street lights, parking spaces etc. Polycrystalline silicon has lower silicon levels than “mono” panels. In general, that makes them less expensive to produce, but they are also slightly less efficient. Their overall construction design can often make up for the efficiency loss, so they are also good for roofs.

Thin film (amorphous silicon, cadmium telluride, copper indium gallium di selenide) are less expensive but less efficient as compared to mono and polycrystalline panels. Recently BIPV (building integrated photovoltaic) are also introduced; they look like real roofing tiles (solar shingles for example). But they are way less efficient than conventional PV, which means lots of space requirement, but it is good for rural roofs where space is not a constraint. SPV based micro distributed generation model must also have a charge controller which is a power electronics circuit based generally based PWM (pulse width modulation) that controls the magnitude of battery charging. It also makes sure that battery is not over charged. In a situation where battery is fully charged, the energy generated through sun is directly given to the load.

The solar inverter is the one of the most important component of a solar PV system. It converts DC solar power that is produced by solar panels into the AC. Another indispensable part of this model is a battery due to necessity of storing power generation through SPV. It can be used in the night or during cloudy weather or even at the same time the solar energy is being generated. Lead Acid batteries are commonly used today.

## 4. TECHNICAL CALCULATIONS

As per report published by Press Beuro of India in May 2012, shows the data of power consumption per capita as in 2011 in India is to be 778.63kWh/Year [6]. Based on this, per day consumption can be calculated as per capita consumption per days is equal to Per capita consumption per year divided by number of days in a year. Per capita consumption in per day terms would be therefore 778 divided by 365 days that means 2.13kWh/day. The wattage requirement for 2.13kWh/day would be 2130Wh/24 or 88.81Watts system.

So if all the individuals of India on an average generate at 88.81 Watts SPV system, with the population 1.21 billion, this means equal to 107.46GW generation. Now assuming Solar Irradiance availability on an average per day over the year in India to be 8 hours, the system wattage required working for 8 hours i.e. 1/3rd of the day would be 3 times of the system that would produce in 24 hours. Thus the equivalent wattage required for 8 hours working time would be three times 88.81 i.e. 266.3W. Energy production from a solar electric (PV) system is a function of several factors, including the following

**Table 3**. *Factors affecting solar energy output*

| S.No. | Factor | Assumption |
|---|---|---|
| 1. | Solar resources | Assumed solar availability: As per PV Watts |
| 2. | Soiling contamination of the PV panels | Clean, washed frequently: 98% design sunlight transmission |
| 3. | Temperature | 25C, calm wind |
| 4. | System configuration (battery or non-battery) | Non-battery |
| 5. | Orientation to the sun | Tilted at latitude, South |
| 6. | Shading | None |
| 7. | PV Energy delivered as % of rating | 95% |
| 8. | Wiring & power point tracking losses | 9% (91% delivered) |
| 9 | Inverter Efficiency | 90% |
| | Total Energy Output | 0.95x 0.91x 0.90 =78% |

Thus actual energy production is reduced to 78% of converted energy from the sun. Incorporating this reduction, actual system wattage requirement would be increase by the inverse of the same factor i.e. 0.78. So actual System wattage we require would be increased to 266.44W divided by 0.78 that means 341.5W. As far floor area requirement, it is estimated that 300W can be generated per square meter as per current standards. Thus the area requirement for a system of 341.5W solar system would be 341.5W divided by 300W that equals to 1.138 square meters. In Summary per capita generation equivalent to per capita consumption can be matched by generation through an SPV system of 341.5Watt spread over the area of 1.138 square meters.

## 5. SOLAR ENERGY ECONOMICS

The price of silicon based solar panels is depreciating at a steady and steep rate. Following bar graph demonstrates the steep decrease in the prices of installed solar PV over two decades. In 1980 per watt Installed price for SPV was close to $12 per watt which has now come down to $4 per watt in 2011 as shown in Figure 4 [7]. In the current year this price has even come down to $2 per watt as on July 2012. As per the green economics research the efficiency of solar panel has reached to 300Watt per square meter and panel cost has reduced to as low as $1 per watt in some thin film category [8]

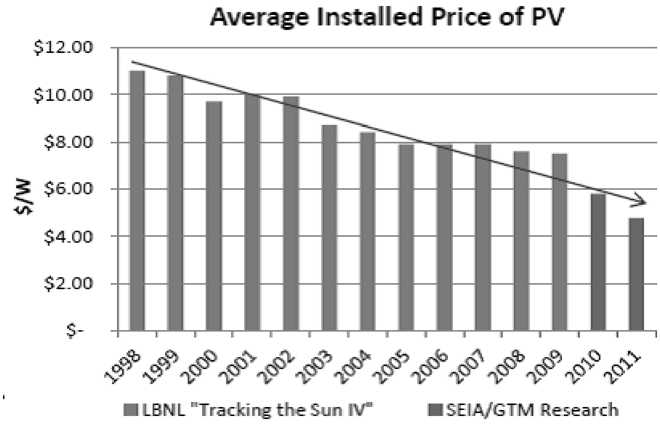


**Figure 4**. *Average Installed Price of SPV*

Here we assume $2.5/Watt levelised cost (including panels, battery, inverter, and installation) as of July 2012 for the case of India where import cost is on the higher side. At the rate of $2.5 per watt, the cost of electricity generation per day or 2.13kWh consumption per day would be $2.5 multiplied by 341.5W that is equal to $853.75 or Rs. 46956 in INR taking the exchange rate of Rs.55 equals to $1.

This amount is very much affordable considering the ease of generation and independence of fluctuating, unpredictable, and largely blackout grid as of today in India. For a capacity of 1kW SPV, the cost would be around Rs.137500. So with an investment of less than Rs.50000 every individual is capable to match the electricity one is getting from grid for around two decades with zero operating cost and negligible maintenance. However with Rs.137500 one can generate 1kW.

Breakeven point: Considering the unit price of residential energy to Rs.5 per unit with 2.13 unit of consumption per day, time required to reach the bill of Rs. 46956 would be divided by 5 divided by 2.13 divided by 365 which equals to 12 Years. Thus breakeven point is achieved in 12 years and rest of around 1 decade one can generate equivalent electricity free of cost with MDSPV. This is also need to be seen in the context where SPV prices are coming down at a very fast pace and grid electricity is getting costly day by day. Therefore the breakeven point can shift to as low as 5 years in near future.

## 6. THE POSSIBILITIES AND DISCUSSIONS

Although we considered per capita generation for whole India to be same, but there is a significant difference in the consumption pattern of rural and urban loads. In rural areas per capita consumption is less however the availability of solar radiation and space for installation is abundant as compared to cities. Therefore this approach is ‘take home’ for the rural areas. Therefore instead of repeating the same conventional rhetoric of electrification through grid, government should implement this MDG approach along with proper awareness drive, subsidies to people and promoting SPV accessories vendors.

It is analyzed in the paper [9] that DC based SPV takes 40% less load and is 33% cheaper than AC based SPV. Therefore it is recommended that DC system should be installed for less load requirement for the same application. Especially in the area where AC system is not in existence i.e. in un-electrified villages, DC based SPV should be installed. With DC based SPV the load requirement would be reduced from 341.5W system to 205W system for the same applications. The Cost would also be reduced from Rs. 46956 to approximately Rs. 30000. There is also possibility of micro power trading (MPT) through this approach. An individual can easily aim for higher generation and can sell to his neighbor like any commodity. As there is negligible loss of transmission and distribution we can utilize about all that we generate. Furthermore by this approach, the burden on government would be radically reduced as the load would be reduced to a great extent and only very high industrial load may be requiring grid electricity. This radical approach has even potential to make the grid and grid related expenses redundant. This would even enable people in general to be more electrically literate and better managers of electricity which is noticeably absent today

A series of detailed models may be designed specifying area requirement, investment requirement to suit every individual. This may be advertised at large scale. Once the people will realize its importance all vendors, be it PV modules, batteries vendors, and Installation engineers would surface as market forces itself manages inherently. This however may be criticized for a highly ambitious way of thinking, but witnessing few technological revolutions in recent history it cannot be ruled out. Just in 10 years, mobile technology has penetrated every individual in the villages or in the cities; same is the case of Dish TV, or more importantly the reach of ‘Battery based Inverter’ in Millions of households today. It is only that people have to be convinced that it is beneficial to them and if it is beneficial, people have enough to invest into it.

## 7. CONCLUSION

Per capita generation is not just an option but a pressing need for Indian reality. It is financially viable, technically feasible, and socially affordable. There may be some significant percentage of population incapable to generate even to the parity level, but then there will always be some who would be generating more than what they and consume. Even it can be seen as a business opportunity to Indians to invest, generate and sell electricity at profitable prices.  With as little as Rs.46950 investment and 1.138 squares meter of sunny space an individual can easily generate what one is currently consuming from the grid. However if the investment capacity is raised one can be completely independent from grid. We also conclude that with the trend shown in last 10 years, these prices would come as little as Rs.20,000 and breakeven point would be achievable in a period of as little as 5 years. We propose that government of India should take this MDG approach proactively as it has not just potential to make India, self reliant in energy but it can eliminate transmission and distribution cost to insignificant level.

## REFERENCES

[1] http://www.powermin.nic.in/indian_electricity_scenario/introduction.htm
[2] http://www.enviro-energytechindia.com/energy.html
[3] http://india-reports.com/summary/map-solar.aspx
[4] http://www.indiaenergyportal.org/engstats/stat16.htm
[5] http://www.mnre.gov.in/mission-and-vision-2/achievements/
[6] Renewable Energy Status report 2011 – REN21-Renewable Energy policy Network for 21st Century
[7] http://www.iea.org/publications/freepublications/publication/name,3902,en.html
[8] http://greenecon.net/understanding-the-cost-of-solar-energy/energy_economics.html
[9] Abrar Ahmad, A. S. Siddqiui, A. S. Anees, Majid jamil, “Techno–Economic Analysis of Standalone Solar Fed AC Vs DC System”, Solaris 2012, 7-9 Feb2012, Varanasi, India

## AUTHORS' BIOGRAPHY

**Prof. Anwar Shahzad Siddiqui** obtained his B.Sc. Engg. (Electrical Engineering) and M.Sc. Engg. (Power Systems and Electrical Drives) degrees from AMU, Aligarh, both with Honors in 1992 and 1994 respectively. He earned his Ph.D. degree from Jamia Millia Islamia (Central University) N. Delhi in 2001. He has been teaching and guiding research for about two decades at AMU, Aligarh; JMI, New Delhi and BITS Pilani – Dubai campus. His research interests include Power System operation, control and management and Applications of Artificial Intelligence Techniques in Power System. He has more than 50 research papers published in refereed international and national journals and conferences of repute.

**Mr. Abrar Ahmad** obtained his B.Tech (Electrical Engineering) and M.Tech (Electrical Power System Management) from JMI, New Delhi, both with First division in 2003 and 2009 respectively. He is pursuing his Ph.D. from Jamia Millia Islamia (Central University) New Delhi since 2011. He has been teaching and guiding research for about 10 years at different institutions such as MDU, UPTU and Jamia Millia Islamia at undergraduate and post graduate level. His research interests include Renewable Energy, Power System operation, control and management. He has around 10 research papers published in different international and national journals and conferences of repute