OPERATIONAL ISSUES OF SOLAR POWER GENERATION IN INDIA

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1 ABSTRACT

Renewable Energy is one of the clean substitute of fossil fuel based polluting power plants in India. Solar power generation based on Photo Voltaic (PV) technology is most popularly used technology for generation of solar power as well as renewable energy in India. Though there is no moving parts in Solar PV based power generation plants, the operators of solar PV based power plants are facing numerous operational problems, which are affecting energy generation as well as plant load factor.

This paper identified major operational problems, which are being encountered by operators of numerous solar PV based power generating plants in India and suggested mitigation plans.

The identified operational problems are basically of two categories and related to (i) equipment / component and (ii) system and location / atmosphere.

For any problem in equipment of the component related to generation of power such as solar PV module, inverter, inverter transformer etc., affecting the operation of the plant, the manufacturer may provide mitigation measures based on their experience on their equipment / component.

Indian and international operators are also well aware of the operational issues related with the conventional power equipment of solar PV based power plant such as transformer, cable, low voltage & high voltage switchgears, EHV substations etc. therefore, it is not worth to highlight these issues in this forum.

In view of the above, though this paper addressed few mitigation measures of operational problems related to equipment and component like PV module, more thrust have been given on operational problems related system and location / atmosphere such as soiling & cleaning of modules, soil erosion due to high wind, instruction for backing down (curtailment) of generation etc., which are not common for every site. Experience of operators of other sites who are not facing similar problems are nor useful to solve such typical site specific problems. Much support from the equipment manufacturers are also not expected to solve these issues. Therefore, these site specific operational issues are required to be mitigated by the operators with the help of agencies, who have experience in the specific fields.

In dusty areas, keeping the PV modules as clean as possible to achieve maximum output and efficiency is a real challenge. Mechanized (robotic) cleaning of PV modules have few merits over cleaning by water or other manual cleaning methods from the point of view of cleaning cycle, savings in water, where there is scarcity of water. Mitigation measures of soil erosion due to high wind has also been addressed in this paper.

2 INTRODUCTION

Growing concern for the environmental degradation has led to the world's interest in renewable energy resources. Solar PV based power generation is commercially and operationally, one of the viable renewable

energy resource and accordingly, emerging as one of the largest source in terms of the renewable energy sector which is a clean substitute of the fossil fuel based polluting power plants.

Solar Energy is witnessing abundant opportunities in the developing economies, such as India, where the power supply situation and infrastructure development efforts provide a huge market for active investment.

India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. In most parts of India, clear sunny weather is experienced approximately 250 to 300 days in a year. The annual global radiation varies from 1600 to 2200 kWh / sq. m., which is comparable with radiation received in the tropical and subtropical regions. India is moving ahead with an ambitious program to reach an installed capacity of 100 GWp by 2022 to be powered by Solar Energy. Many states in India are setting up multiple utility plants of large capacities to herald the arrival of the renewable energy generation.

Solar PV based Power Plants are built to last 25 years or more. After commissioning of the power plant, the Operations & Maintenance (O&M) activities starts, which are expected to be seamless and trouble free. In spite of the fact that there is no moving parts and solar PV based power plants, the operators are facing numerous operational problems, which are affecting energy generation as well as plant load factor.

In many of the plants, the operational problems related to equipment & components are similar and mitigation measures are available from the manufacturers. There are few operational problems related system and location / atmosphere such as soiling & cleaning of modules, soil erosion due to high wind, instruction for backing down (curtailment) of generation etc., which are not common for every site. Experience of operators of other sites who are not facing similar problems are nor useful to solve such typical site specific problems. Much support from the equipment manufacturers are also not expected to solve these issues. Therefore, these site specific operational issues are required to be mitigated by the operators with the help of agencies, who have experience in the specific fields.

Therefore, this paper identified major operational issues faced by the operators of solar PV based power plant and probable remedial measures of these operational issues.

3 OPERATIONAL ISSUES AND MITIGATION FOR SOLAR PLANTS

The common belief is that solar PV based power plants require very little to almost no maintenance at all. As there is no moving parts in power generation system of solar PV based power plants, apparently this statement turns out to be true, but at the same time it can be very misleading. Practically many of the operators of PV based solar power plant are facing difficulties to maintain energy output and efficiency as per design due to numerous operational problems. Generally the operational problems are common for many plants. The operational issues leading to unavailability of Solar PV based power plant may be attributed to the following:

- Site Conditions / Grid Conditions
- Component / Equipment Failure

3.1 Site Condition

Keeping in view the cost of land, solar power plants are usually located in remote areas. Sometimes in remote areas strong grid is not available and solar power plants are connected with weaker grids, which are not able to evacuate the power generated by the power plant. Some of the plants are located in dusty areas, where air borne dusts soils the solar modules and efficiency & output of the solar module as well as

of the power plant is reduced. In some locations particularly in the deserts, the sands are blown away by strong winds creating cavity in few locations and sand dunes in other locations within the solar power plant. The cavity sometimes exposes the foundations of the modules in such a way that the foundations become unsafe.

3.2 Few of such operational issues are described below.Soiling of Module and Cleaning

As photovoltaic (PV) solar cells directly convert sunlight into electricity, using the photovoltaic effect, any dust cover over the PV module obstruct sunlight to reach the PV cells of the PV nodule and directly affect efficiency and power output. Therefore, it is important to keep the PV modules clean and free from any defect.

In view of the above, soiling of the solar panel is one of the most prominent and common issues in dusty environments, which has a direct effect on efficiency and output of the power plant and affects the revenue of the power plant. It is important over the lifespan of a solar plant to maintain optimal energy output. In order to accomplish this, panel cleaning will be necessary.

Rain cleans modules very effectively, it is worth to note that soiling effects depend primarily on time since previous rainfall. When rain does occur, cleaning of modules are postponed accordingly.

Module cleaning frequency should be dependent on the terrain, soil conditions and geography of the region rather than general perception of a month or 15 days to clean the panels. In Desert lands the sand does not stick much to the glass whereas in other terrains the dust/mud could stick to glass easily and cause a drop in generation. Periodic cleaning is preferred by many of the operators to ensure good irradiance and thereby better energy generation. Thus always the challenges for module cleaning in larger plants are about cleaning cycle Vs the quality of cleaning (Quantity vs. Quality). Monitoring the dirt levels across 300- 400 acres can also be an arduous exercise.

Cleaning early in the morning when the modules are wet from dew is probably the best time to clean the panels because dust can easily be rinsed without coating removal or damage.

Generally cleaning by water is considered to be appropriate by many of the operators. In general leaning of PV modules by water for many of the plants are not feasible due to the following reasons:

- Many locations may have limited water sources and this can hamper module cleaning activities.
- The water sources, usually the bore wells in the plants are required to be maintained in running condition to ensure continuous supply of water during period of cleaning.
- Otherwise water needs to be procured from outside in tankers. Due to movements of tankers within the plant area, dirt level will be increased and additional soiling of modules may take place.
- Higher the frequency of module cleaning with water increases the chances of vegetation growth, which then becomes an obstacle for smooth O&M as well as creates shadow and in turn reduces generation.
- Poor quality of water may affect the metallic parts, which calls for additional maintenance.

Vegetation growth is always a concern in solar plants. So trimming the vegetation growth round the year, particularly after the monsoons is necessary.

Mitigation Measures:

a) One of the best ways one can deal with soiling is to combat it, before it even happens. Result of few surveys reveals that if the tilt angle is more than 5 degrees, accumulation of dusts on PV modules reduces significantly.

If the plant is located in a very dusty environment and daily cleaning is not envisaged, it would be well worth it to consider a higher tilt angle even if maximum solar irradiance is gained from an angle of 5 degrees or lower. This is because over time there will be less soiling, and ultimately more energy will be produced in the long run, as well as not having to clean as often.

Tilt angle more than 5 degrees is one of the most effective way of keeping the PV modules lean in desert areas, where the sands are not sticky and there is no presence of sticky dust and / or mud.

This is a way to combat soiling before one need to clean the panels.

b) Mechanized cleaning of panels using robots is being adopted in other countries. These methods either do not use any water or very less water and offering hope for water starved regions to help operators and the country save a precious commodity, water. Few Indian operators have also started using mechanized (robotic) cleaning of solar modules and getting good results. The other advantage of mechanized cleaning is that the cleaning can be done on daily basis, which is most effective to achieve maximum output and efficiency.

Figure 1: Mechanized (Robotic) Cleaning System

One of the mechanized (robotic) cleaning system is shown in Figure 1.

c) Any construction activity involving excavation / movement of soil during commercial operation of the solar PV based power plant increases the dust level in the power plant resulting chance of soiling the PV modules.
Avoiding major construction activity involving excavation / movement of soil inside solar PV based power plant helps in keeping dust level to be minimal and can be helpful to keep the PV Modules in cleaner condition.
However, it is more a wish and sometimes it is difficult to implement.

3.3 Effect of High Wind

Similar to soiling, wind is a locational issue. Due to high wind speed the soil erosion and creation of cavity in one location and sand dunes in other locations are observed for the sandy soil mainly in the deserts of Rajasthan. The soil erosion is primarily due to increase in intensity of wind due to restricted open area at the lower end of Module Mounting Structure tables, which are located on outer/peripheral zones with appreciable variation in ground levels / topographical conditions & surrounded sand dunes.

Factors & Causes for wind erosion

The predominant factor of Wind erosion in the arid area are the soil condition, intensity of vegetation, intensity of wind & obstructions for the passage of wind. The major factors are given below:

i. **Wind-speed:** Wind erosion phenomena increases proportionately in the presence of strong, regular prevailing winds or gusts.

ii. **Soil texture:** Loamy sand, rich in particles between 10 and 100 microns in size, is the most vulnerable soil. More clayey soil is much stickier, better-structured, and hence more resistant. Coarse sand and gravelly or rocky soils are also more resistant since the particles are too heavy to be removed by wind erosion. The optimum size of sand for wind erosion is about 80 microns.

iii. **State of the soil surface:** If the soil surface is stony, forming a "pavement", the risk of wind erosion is lower.

iv. **Moisture in soil increases** cohesion of sand and loam, temporarily preventing their erosion by wind.

v. **Vegetative Cover**: Lack of permanent vegetation creates loose, dry, and barren soil that is perfect for wind transport.

Figure 2: Soil Erosion and Accumulation due to high wind

Example of Soil Erosion and Accumulation due to high wind is shown in Figure 2.

In some of the solar PV based power plant in Rajasthan, it has been observed that as an effect of soil erosion, cavities created adjacent to the foundation, poses threat to the stability of the foundation and corrective actions had to be taken.

Mitigation Measures:

Many soil conservation practices can be implemented to control erosion of soil due to high wind. Conservation practices are designed to either reduce the wind force at the soil surface or create a soil surface more resistant to wind forces. The following are few of the methods, which are being adopted to mitigate the erosion of soil due to wind.

- Growth of Vegetation.
- Soil stabilization techniques (compaction, grouting, mixing with lime/cement, chemicals/polymers)

- Bituminous apron to protect the top surface

3.4 Curtailment of Power Generation

The proportion of Renewable capacity in the generation portfolio continues to expand as India adds Renewable Energy (RE) capacity to meet its 2022 commitment (of 175 GW). As seen in few states, rapid expansion of RE capacity led to significant curtailments of generation of RE including Solar PV. With rapid expansion of RE capacity, this situation may get worse and spread to other states as well unless steps are taken to control the same. The curtailment of generation of power is one of the key issues for some of the solar plant in India. The stakeholders (planners, developers and lenders) thus have following key questions:

- Is the system ready to absorb all of RE generation (as must run)?
- What levels of curtailments of generation may be expected if adequate steps are not taken in time?
- Which states are more vulnerable to curtailment of generation from renewables?
- Which indicators can developers look at to assess curtailment risk?

In India, curtailment of generation of RE could be caused by one of the following two factors:

a) Technical curtailments:
b) Economic curtailments:

Technical curtailments:

When a transmission system is incapable of accommodating the full dispatch of RE facilities due to technical transmission issues, the curtailment is called technical curtailment or involuntary curtailment. Many times grid availability becomes a constraint in the dispatch of RE power. Some of the key technical reasons leading to curtailment can be:

- Transmission unavailability / under capacity
- System operating requirements leading to requirement of back down

Economic curtailments:

Curtailments may also be driven by economic incentives or disincentives such as availability of cheaper power from other sources. Distribution Utilities sometimes may not be keen to buy RE power due to high tariffs of RE. Such curtailments are termed as economic or voluntary curtailments. So far, none of the utilities has reported economic curtailment.

It is difficult for generators to clearly distinguish between technical and economic curtailment. The impact on the generation utility remains the same whether the curtailment is due to economic or technical reasons.

Mitigation Measures:

The generation utilities are not in a position to mitigate this issue themselves. Mitigation of this issue will come with joint efforts of generation, transmission and distribution utilities.

3.5 Component/ Equipment Failure

3.5.1 PV Module

As PV modules are the most important and most expensive component of any solar PV based power plant, maintaining PV modules is key to achieve an ideal power output. Throughout the life of a PV system, there are multiple issues that can lead to panel failure, or loss of optimal efficiency. The major issues encountered in PV Module during the operational phase are provided hereunder.

Panel Cracking

Panel cracking can be caused from a variety of sources. Physical impacts, oscillation from wind or manufacturing defects can lead to cracking. Cracks can isolate cells of large portion of a module and increases the electrical resistance, thus the module leads to loss of efficiency. The regular monitoring of measured values compare to estimated value of the PV plant is necessary to identify the degradation of the module. In case major degradation in performance is observed, the electroluminescence test is carried out in order to identify the cracks.

PV Module indicating cracks is shown in Figure 3.

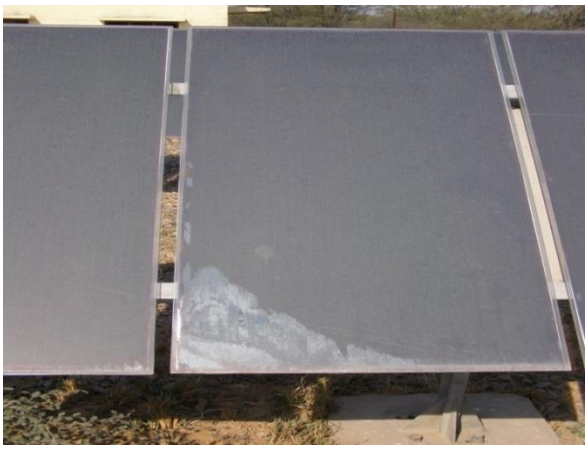

Figure 3: PV Module indicating Cracks

Panel Discoloration

Visual discoloration is a common defect that reduces the amount of sunlight that penetrates into a solar cell. This means solar cells being less exposed to solar irradiation and generating less energy. It leads to loss of efficiency is because different color panels changes the wavelength of light that can be absorbed. Different types of semi-conductor materials absorb different wavelengths. The causes of discoloration are poor encapsulant quality, high temperatures, humidity, and ocean sault if a PV system is located near an ocean. Similar to panel cracking, there is not much can be done to reduce the effects of discoloration once it has occurred, other than replacing the panel entirely. Chances of discolor is lees for better quality panels.

Figure 4: PV Module indicating Discoloration

PV Module indicating Discoloration is shown is Figure 4.

Mitigation Measures

Exact method to see how much power is lost, other than comparing the energy output before and after discoloration has occurred is not available.

Hot Spots

It is a common misconception that solar panels are the most efficient in the highest temperatures. Solar cells do not gain efficiency based on temperature, but instead based on the amount of solar irradiance. On the other hand, high temperatures can actually damage solar panels and can lead to hot spots. Hot spots occur when a panel is shaded, damaged, or electrically mismatched. Hot spots decrease power output, and because solar cells are attached in strings, just one hot spot can lead to multiple cells functioning poorly.

PV Module indicating Hot Spot is shown in Figure 5

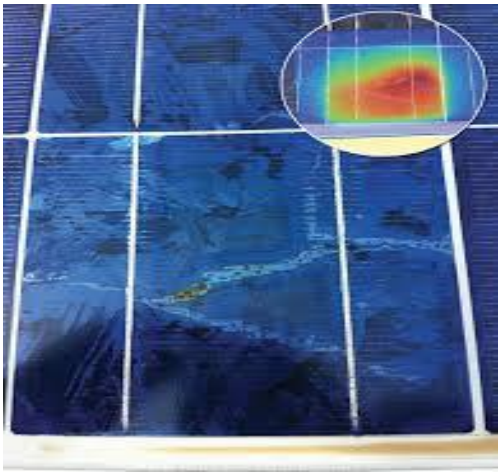

Figure 5: PV Module indicating Hot Spot

Mitigation Measures

Depending on the severity of other issues that could lead to hot spots, a panel replacement might be decided. Hot spots can be easily identified with the use of an Infrared Gun.

Technology driven tools like Thermal Imager to detect string faults, early module damages quickly can be very helpful to contain downtimes and/or generation losses.

4 CONCLUSION

It has been observed that soiling and cleaning of solar PV modules, soil erosion due to high wind and curtailment of generation are the major site specific operational issues of solar PV based power generation.

In dusty areas keeping the PV modules clean to achieve desired output and efficiency is a challenge. Mechanized (robotic) cleaning have merits over water based cleaning. Tilt angle more than 5 degrees is one of the most effective way of keeping the PV modules lean in desert areas, where the sands are not sticky.

Growth of Vegetation, Soil stabilization techniques (compaction, grouting, mixing with lime/cement, chemicals/polymers) and Bituminous apron to protect the top surface are considered effective to arrest erosion of soil due to high wind.

Technology driven tools like Thermal Imager to detect string faults, early module damages quickly can be very helpful to contain downtimes and/or generation losses.