INDIA'S 2022 SOLAR MISSION: A MACRO AND MICRO PERSPECTIVE

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Abstract

Sustainable development being the key moto of today's world, the focus is moving towards renewable energy sources to meet the ever increasing demand for electricity. The research tries to capture the ground level challenges the country must address to realize its solar vision 2022. The research also tries to analyse the micro level challenges a solar PV power project must address drawing upon the experiences from Loxley Solar Farm Project in Thailand. The study aims to bring forth the effort the country needs to put forth to realize its 100 GW solar energy target by 2022. Various socio-economic, environmental and technological barriers are identified and certain proposals on how these challenges can be addressed are discussed.

Keywords: Solar energy, Photovoltaic power plant, Loxley Solar 1, Renewable energy, Solar vision 2022

1. Introduction

India, one of the fastest growing economy in the world is poised to achieve a growth rate which can trigger a major rise in energy demand. If the country continues to grow at a rate of 8 per cent for the next 10 years, the demand for power is likely to soar from the present 120 GW to 315GW to 335 GW by 2017(Frankel et.al 2014). Currently, 61 per cent of total power generated in India are from Thermal power plants and the country accounts for about 4.5 percent of the world's greenhouse gas emissions. In October 2016, India formally joined the Paris climate change agreement with goals to limit global temperature rise. The Indian government has set goals to produce 40% of electricity with non-fossil fuels by 2030.

To meet the soaring energy demand and the need for sustainable development it is ever more important for the country explore the renewable energy alternatives. To move the country to a more sustainable growth path, in 2015, the Indian government increased India's solar power target under *Jawaharlal Nehru National Solar Mission (JNNSM)* 100,000 MW by 2022 from the initial 20,000 MW.

The urgency for mass deployment and development of solar power indicates Governments need for climate and energy security. The research tries to capture micro level analysis of challenges that a solar PV power project must address drawing upon the experiences from Loxley Solar Farm Project in Thailand. The research also tries to capture the ground level challenges the country must address to realize its solar vision 2022 based on published data from variety of sources and certain proposals on how these challenges can be addressed.

2. Literature Review

Over the past decade, Solar energy sector have expanded and transformed dramatically. While great advances in economic developments and technology, on the global scale have made the production of solar energy on a wide scale possible. Investments in clean energy technology is poised for a rapid growth and over the next 25 years the investment in new renewable electric power generation is projected to reach $12.1 trillion on a global scale (Zindler & Locklin, 2016). India alone has set a target to generate 175GW of renewable energy by 2022 and solar power form a larger part of it. Once achieving this goal, the share of solar energy in total electricity generation will increase to 18.9 percent from the current 7 percent (MNRE, 2015). An increase in renewable power capacity is desirable for the country as this will reduce its dependence on fossil energy and thereby improve energy and climate security. The Jawaharlal Nehru National Solar Mission (JNNSM) was launched by the Indian government in 2010 with a target of producing 20 GW of solar power by 2022and later in 2015 the then government revised the target to 100 GW by 2022. "The target was originally based on an expected fall in solar production costs and achievement of grid parity by 2022. But price is not the only challenge towards achieving the target of 100GW by 2022. There are issues relating to land, manufacturing, and technology, among others "(Nathan,2015).

3. Barriers for Solar Power Development in India: The Macro Perspective

The construction of any energy supply or generating system impacts the society at different levels. For instance, it creates an impact on the technical development, on the environment, on the local population and the national economy. Some of these impacts are very difficult to evaluate. The wide spread expansion of renewable energy, particularly solar energy, continues to face barriers despite dramatic cost declines in the last decade.

3.1. Socio-Economic Challenges

The 100 GW solar power target includes 60 GW of ground- mounted medium- to large-scale solar power plants which requires large areas of open land. On an average a ground mounted solar installation requires 5 acres of land for generating 1 MW of energy (CERC,2015). Hence the land required to achieve the target of utility scale solar power is about 1214 sq.km. which equals to about 1.0% of cultivable wasteland and 1.2% of fallow land of the country. The social problem associated with this arises when there is compulsory acquisition of large tracts of land from hundreds of farmers. This leads to loss of livelihood for the landless labourers working in agricultural fields even though the company or government promises them rehabilitation nothing ever happens in reality due to the long processes and red tapes. Involuntary relocation and resettlement, loss of access rights to common property resources, low annual lease rentals and relocation of built-up structures etc. add to this strong social stigma (Yenneti, Rosie & Oleg,2016).

3.2. Environmental Challenges

Renewable energy resources, especially solar energy is considered as zero emission, clean and environmental friendly technology. The potential environmental impacts of harvesting solar energy are land and habitat loss, water use and the pollution caused due to the manufacturing of solar PV cells.

Solar power plants require large open spaces and hence an indirect effect of utility scale solar power plants are the fragmentation of land and removal of vegetation for panel and transmission line installation can destroy natural habitats and disrupt migration of animals and birds (Hernandez et.al, 2014). The water requirement for a solar plant varies with the technology used in harvesting the energy. Currently cleaning of panels or reflecting mirrors are done using water and the frequency of cleaning depend up on the location of the power plant. This large requirement of water could further strain the already arid environments which can in turn effect the ecosystem (Mani & Pillai, 2010). Utility scale solar power plants are generally concentrated in arid lands which are prone to high winds. The high winds result in aeolian transport of sand and dust. To an extend these sediment transportation is controlled by the desert vegetation (Hernandez, Hoffackert & Field,2014), But the installation of large scale solar power plant requires extensive modification of land, like vegetation removal, land grading, soil compaction and construction of access roads and these activities increase soil loss by wind and water (Field et.al, 2010). Further the dust deposition on panels and mirrors increases the frequency of cleaning and hence water use. Another treat to the environment arise from the improper disposal of damaged or decommissioned solar panels. Thin film PV cells contain a number of toxic materials such as cadmium, arsenic, silica dust which if not handled properly can cause serious environmental and public health threats (Fthenakis,2000).

3.3. Technological Challenges

Technical barriers to substantial expansion of solar energy include low efficiency of available PV cells, in-adequate grid capacity, lack of clean and efficient storage system and the lack of infrastructure for transmission of generated solar energy from the remote sites to the usage centres. Ramping (i.e. the switching from solar to conventional sources) during the shoulder hours (the hours that precede and follow peak usage) when there are relatively rapid changes in the PV output is another area of concern (Patrick et.al, 2015)

3.4. Barriers for rooftop solar installations

Of the proposed 100 GW target, rooftop installations accounts for 40 % (i.e. 40GW). Lack of attractive incentives, high cost of installation, dual metering etc. reduces the attractiveness of house hold rooftop solar plants. Dual metering refers to the difference in the selling and purchasing of power from grid.

4. The Loxley Power Project Case Study: The Micro Perspective

4.1. *Introduction*

Renewable energy in general, particularly solar energy is gaining greater attention from investors, owing to the emphasis the global community is placing on sustainable development. The need for a non-depleting, sustainable and pollution free source of energy is driving, many governments to move towards renewable energy. Governments are offering huge incentives for setting up solar power plant projects, both in the developed as well as in the developing nations. Many organizations are planning to make a foray into this field due to these incentives, coupled with the desire to make a contribution towards sustainable development. For most of them, this could be a new experience. In addition, for some developing countries, such a project could be a first of its kind, with a large element of uncertainties. How an organization prepares itself to identify the risks and uncertainties involved in a green-field solar project that is a first of its kind in the entire country? What are the possible hurdles that one should be prepared for? How does one attempt to mitigate the risks involved in such a project?

Through this case study we provide a real life example of such a project in Thailand, with a view to share some of the principal lessons from the experience. We follow the developmental life cycle of the project chronologically and document our lessons learnt from the hurdles we faced.

I. The **Feasibility** section discusses the funding issues, after the decision was taken by the Board to set up the project. Essentially, the financial institutions were encountering such a proposal for the first time, and they were not at all convinced that it was feasible.

II. In the **Design** section we focus upon the technical design of the project, some critical choices that had to be made, and their relationship with the equity financing arrangement. The choice of technology in a domain that is still evolving offers fairly complex challenges.

III. In the **Execution** section we discuss issues concerning site selection, civil work, equipment supply and erection and related problems. As the land surface area required for solar plants are large, localities away from large human settlements become an obvious choice, accompanied by several location specific issues.

IV. In the **Commissioning** section, we describe the problems and their solutions during the commissioning of the project.

V. In the **Operations and Maintenance** section we discuss some real life technical problems that require studying and researching in depth by researchers engaged in finding solutions for renewable energy sources through solar plants.

VI. In the **CSR** section, we describe the community related issues, comparing them with the experience of some others in the same community, providing certain indicators of what succeeds and what does not. These situations are particularly valid for green field sites deep in the midst of a traditional community.

The Loxley Solar Farm, an 8.67-MW facility is spread over an area of 215 rai (approximately 344,000 square meters) in Prachin Buri province of Thailand, 180 kilometres away from Bangkok and was built at a cost of 805 Million Baht (approx. 155 Cr. Rupees).

4.2. Research Methodology & Data Sources

The paper draws its information from the experience of the Project Manager of Loxley Solar 1, who was responsible for the complete project right from the initiation of the project to till date, as the Project is currently in operation. In order to elicit the relevant data, we followed an action research methodology, including site visit, presentations from the PM, question and answer session for gaining clarity and collection of additional information through e-mails and the Internet. We have adopted the Project Life Cycle framework for structuring this paper.

All data for this study were obtained directly from the project authorities. The author from India visited the project site and had extensive discussions with the PM. Some additional information's were provided by the PM through e-mails.

4.3. Project Feasibility and Funding

4.3.1. Finance

Loxley Pub. Co. Ltd. was the main promoter of this project and MFC Energy Funds Co. the major equity partner. Leonics Ltd, a local supplier for power invertors was selected for the supply of all power inverters, with the condition that they should participate in the equity of the company. In this manner, Loxley hoped to ensure long term commitment from Leonics towards servicing the inverters. Initial studies by the project manager had shown that many solar plants faced problems with the power inverters, and servicing them was a major issue. The proposed cost for the project was around 1 Billion Baht. To initiate the project and to rise required funds Loxley Public company entered into a joint venture to setup L Solar Co. Ltd with an initial registered capital of 220 Million Baht. The Loxley Solar Farm is owned by the L Solar 1 Co. Ltd, a joint venture between Loxley Public Co. Ltd (45%), MFC Energy Funds (24.99%), Leonics Co. Ltd (16%) and the remaining by a private investor.

4.3.2. Commercial

The Ministry of Energy of Bangkok offered a Power Purchase Agreement (PPA), with an assured 'adder' price of 8 BHT per unit for a period of 8 years from the date of commencement of generation. The electricity generated is supplied to the grid through Thailand's Provincial Electricity Authority (PEA), under countries Very Small Power Producer (VSPP) added tariff scheme. The IRR for the project was estimated to be more than 10 %. Ministry of Energy has since revised their policy, and have replaced the 'adder' price with 'Feed-in-Tariff' arrangements.

4.3.3. Technical

The principal components of a solar project are the photovoltaic (PV) panels. PV panels usually comes in two major categories: amorphous and poly-crystalline silicon wafers. The project utilises a-Si thin film (Amorphous Silicon Thin Film) PV panels as poly-crystalline silicon wafer panels deteriorate above 25 degrees Celsius. For Thailand with an average temperature greater than 30 degrees Celsius, a-Si PV cells were adjudged to have a better cost-benefit ratio.

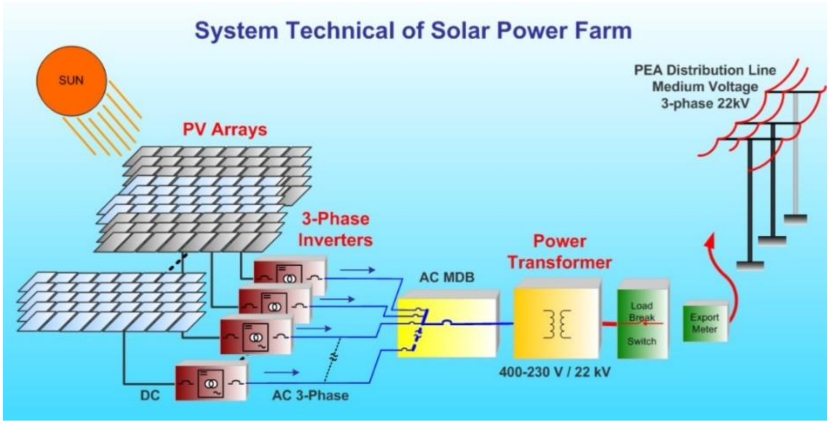
4.3.4. Site Selection

For any solar power plant, the selection of project site plays a vital role towards sustained profitability. A fourfold site selection criterion was adopted for project site selection in Loxley Solar - 1 project;
i) Solar radiation (greater than 5 Kwh/M^2/day), ii) Incidence of flooding of the area, iii) Wind and dust flows and iv) Temperature profiles of the region. Foothill regions of mountains were avoided as such areas are likely to face longer periods of cloudy atmosphere in a day. Cost of land was another overriding issue. Although Bangkok had a higher temperature profile, suggesting a better power generation potential, the cost of land was prohibitive. The present location has acceptable sunshine hours, the cost of land was affordable, and the soil has fairly good load bearing capacity. The soil characteristics enabled the structures on which the PV cells would be mounted, to be directly driven into the soil, without requiring any RCC foundation work. The selected site was approximately 40

meters above MSL and hence there was little chance of flooding. However, the site did face an issue of wind and dust emanating from the nearby potato processing plants. The dust from these factories is carried over to the farm by wind, and settles on the panels, reducing their efficiency. This necessitated regular cleaning arrangements during the operations phase.

4.4. Project Design

The Solar plant was designed to generate approximately 35000 to 40000 units per day (approximately 12-14 Million kilowatt hours (kWh) per year). The plant utilizes leading-edge DuPont Apollo amorphous thin film photovoltaic modules. The project activity comprises of 86,688 units of solar panel connected to total 8 inverters with 7 inverters of 1,000 kW output capacity each and 1 inverter of 1,250 kW output capacity, amounting to a total generating capacity of 8.25 MW. The plant doesn't have any power storage devices and is directly connected to grid.



Source: Project Design Document (PDD)

Three phase grid connected Central Inverter (of 1000 kW/1250 kW) supplied by LEONICS is used to convert DC power from PV panel into AC power. Each central inverter is connected to four or five 250kW module inverters. In order to supply electricity to the Thai national grid, the generated voltage from central inverters are stepped up to 22 kV using three phase transformers.

4.5. Project Execution

The project was completed within a span of 23 Months from the initial planning phase and the construction was completed in just 9 Months. Table.1 shows the project time line with key activities.

Time Frame	**Activities**
December 2009	Pre-Feasibility Report, Application for BOI, PPA documentation.
February 2010	Initial Biz Plan, Investment Plan.
February –April 2010	TOR/Tender Offer Bidding/ Technology concluded/ Finalized/ Financial Plan. , Meet Funding Institutions/ Local Bank
April 2010	Submitted PPA/ Receive LOC
April – July 2010	Public hearing on land deposited, Site Survey/RFP/PV Module and EPC Bidding/ Plant Design / System investment
19th August 2010	Board Kick Off and Project Progress Update Meeting
December 2010	Contract Term Sheet/Share Holder Agreement/ Sign EPC/PMC Raise initial Fund/ Share Holder/ Bank
January - September 2010	Site Preparation/ Civil Works Plant Construction, Project Management 8 -9 Month duration.
October - November 2010	Plant Construction, Completion PQ, Commissioning COD
December 2011	Start Generating Revenue

Various factors like average sun radiation per sq. meter per day, the lands topography, impact of wind, dust and chances of flooding was considered for site selection. A total of 215 rai of land was acquired for the project. A total of 45917CUm3 of land were removed and 27646Cum3 of land was filled as a part of site preparation works. The site received on an average 5kWh/m2-day of Sun radiation. A total of 86688 amorphous thin film solar panels was erected on approximately 19300 pole structures.

4.6. Commissioning

As a part of the commissioning efforts, the central control room was extended to serve as a learning centre to help promote the use of PV technology. The education centre at the solar farm is open to visitors who are interested in learning about benefits of solar energy and innovations in PV technology.

4.7. *Operations and Maintenance*

The plant started operating on December 2011 and generates approximately 12-14 million kWh electricity per year. The plant requires constant inspection and timely maintenance to ensure maximum efficiency. Like in any other kind of power plants, a solar PV plant also requires routine inspection and servicing of equipment to prevent breakdowns and reduce energy yield losses, continues condition monitoring of equipment and plant operations to address potential problems at early stages to prevent shutdowns. The Loxley Solar power plant is equipped with modern instrumentation and control systems, with live display of the operational parameters, being continuously updated on three large LCD screens at the Learning Center. However, routine manual inspections are done by operating personnel out in the field to directly monitor the plant performance. At present it is generating 35,999 to 40,000 units if electricity per year

The yield from the PV module is highly dependent on the cleanliness of the panels. The panels in the plant required routine cleaning due to the dust emanated by the nearby potato processing plants During the initial phases of operation, the plant employed manual labour for cleaning of the panels and it required more than 40 workers, 25-30 days to clean the panels. The company used to spend around 300,000 Thai Baht for each cleaning cycle. Later the company brought down the man power, duration and cost of cleaning to about 35000 per cycle by developing a custom equipment for the purpose.

The most complicated components of the PV plant are its electrical systems like inverters and breakers. Being made up of sensitive electronic devices they need very high care from the hot, humid and dusty conditions of the site. Periodic checking of both underground and above ground wiring cables, earthing protection etc. are also done to ensure personnel and equipment safety and is also required for maintaining plant efficiency.

Periodic inspection of mounting structures is done to check for miss alignment, bending, crack etc. Also during rainy season there is a chance for top soil erosion due to improper drainage system which can lead to caving of structure foundation. The under growth should also be controlled as they can grow tall and cause shadowing effect on the panels.

Another critical activity that could increase or decrease the cost of operations and maintenance is inventory management, which is also essential for the timely completion of maintenance activities. .

4.8. CSR Activities

As a part of the project the company is involved in lot of CSR activities around the plant area. To help promote the use of PV technology, the Loxley Solar 1 project includes an education centre which is open to external visitors interested in learning about benefits of solar energy and innovations in PV technology. As the plant has been built in acquired land and as there were cases of vandalism using sling shots the company has engaged the local people and developed the area surrounding the plant into agricultural land and has also helped in setting up income generating sources for the local population. The company has setup a 'Sufficiency Agricultural Learning Centre' in the south-eastern part of the site by growing plants and herbs as a model for the local Bothong community.

4.9. Limitations of the case study

The case study utilizes data collected from the Project Manager of Loxley Solar 1 power project, site visits, presentations from the Project Manager, e-mail conversations between the author and the PM. The case study has some missing data especially about the 'Commissioning' phase of the project.

5. Recommendations

There are a number of legitimate barriers to the substantial expansion of solar energy in India. Several of these barriers have straight forward solutions and other need extensive research and policy changes. Currently the India focuses on harvesting solar energy using PV panels which require huge expanse of land. Development and implementation of concentrating photovoltaic technology and commercialization of the solar power tree technology which requires only 4 Sq. ft area to generate 5kw compared to the 400 Sq. ft (CSIR-CMERI) required for conventional PV layout can substantially reduce the land requirement. Construction of Green Energy Grid corridor and promotion and construction of High Voltage Direct Current(HVDC) transmission lines to carry the power generated from remote plants to load centres can tackle the issues related to Grid capacity and lack of infrastructure. Policy changes at both central and state levels are required to address the issue of dual metering in case of rooftop installations. Another solution to this is the implementation of community based mini-grid and implementation of Blockchain technology to manage the trade of power between the producers (houses with rooftop installations) and consumers with in the community.

6. Conclusion

For India to realize its ambitious solar goal its necessary to break the above barriers. There are a number of legitimate social, economic, environmental and technological barriers to the substantial expansion of solar energy in India. Several of these barriers have straight forward solutions and other need extensive research and policy changes. The development and implementation of new technologies, developing infrastructure and optimum utilization of resources can address many of these macro-economic barriers, the only requirement is the mind set to do so.

The Loxley power project provides a perfect example for understanding the process of project development and execution of a solar PV power plant. The project offers an insight into the micro challenges faced by a developer during the different phases of project life cycle. The major micro challenges in solar power project are associated with site selection, operation and maintenance, security of the project site and equipment's against vandalism and theft and the challenge of engaging the local people and enlisting there support in the project development. Loxley solar-1 project provide a live example of how to engage with the local people to ensure smooth running of a solar power plant.

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