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Design of Solar Photovoltaic Based Water Pumping for Automatic Irrigation System

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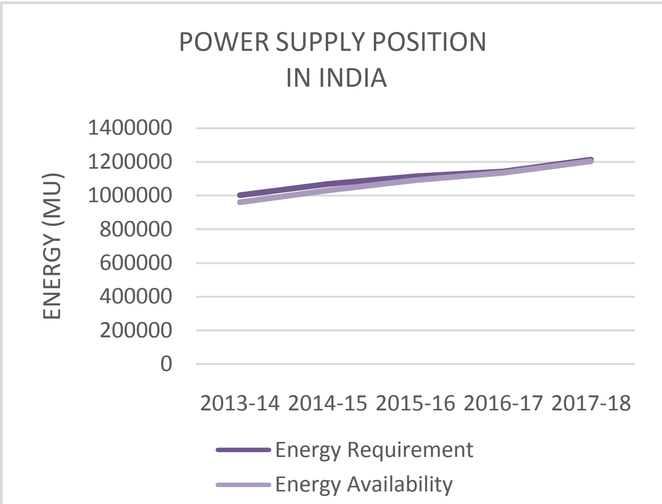
ABSTRACT -This article investigates the feasibility of solar powered irrigation process in India where photovoltaic technology could be used to gather solar energy for running a submersible pump and supply water for crop cultivation Photovoltaic solar energy has been gaining market share over the years due to lower prices and to a significant incentive from the government. It is a clean, static and promising energy source, and such technology has been applied to various applications. This paper presents a prototype of an automated irrigation system for later installation on the field. After the prototype development, we analysed the use of a previously built photovoltaic microgeneration, in order to insert the electricity generated in the automated irrigation system. The photovoltaic microgeneration has an installed capacity of 2.76 kWp and a battery bank with 24 V. The integration of photovoltaic solar energy in the automated irrigation system represented a good application for family farming, minimizing water waste, besides representing the use of a renewable energy source.

KEYWORDS: Automated irrigation, Solar photovoltaic, Micro generation, Renewableenergy

I.INTRODUCTION

A. Energy scenario in India as on March 31,2018[1]



Power supply position in India

Electrical phenomenon generation is an economical approach for exploitation solar power. The energy issue is a global concern, given the recurrent crises in the electricity sector. Over the past decade, the energy sectors of many countries endured intense changes with stimulus to the decentralization of power generation, giving the distribution network a central role in this new model. Energy generation plays a key role in human life, along with means of transportation, telecommunications, water and sanitation. However, both the generation and use of energy should be handled in a harmonious way and appropriate to the environment, so that natural resources can be used rationally and sustainably. Agricultural field always needs and depends on the water level of the soil. But continuous extraction of water from soil

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reduces the moisture level of soil to avoid this problem planned irrigation system should be followed. For this purpose, an irrigation system is introduced in this paper. The proposed system derives power from sunlight through photo-voltaic cells. Hence, the system cannot depend on the electricity. In this proposed model by using sunlight energy, power the irrigation pump, the irrigation of field in cultivation of crops can be achieved in a more simpler and environment friendly manner. The system proposed for irrigation takes into account the solar energy, direct form of energy from the sun, and PV cells to convert energy from one form to another to finally supply water to the fields.

Photovoltaic cell is a system converts light energy into electricity. Photovoltaic cell is otherwise known as “solar cells”. The PV cells which takes sunlight and convert it into electricity this is kept as a small grid. Solar electric panels more commonly referred to as photovoltaic, or PV, panels, it converts sunlight into electricity. The electricity is used to run appliances and electrical devices or stored in batteries to be used later. There are many plants which required minimum level of moisture. If the required level of water is not provided, then the plant will die and results in low production. By irrigate the crop according to the moisture level they need, is provided by the soil moisture sensor.

Even though photovoltaic systems applied in distributed generation are less used than other generation technologies, they are gaining ground globally due to incentive programs and regulations, obtaining strong growth in the market. This type of energy generation from the sun presents itself as one of the most rational forms of electricity generation. Once static and silent, it is a promising technologyfor electricity generation.

Residents of rural areas sometimes have no access to electricity because of distance from the distribution power grid. In this case, they can choose to install photovoltaic panels with an integrated battery system which, during the night, can also make use of electricity. In turn, residents who already have access to electricity in their homes could install photovoltaic panels in order to save money spent on electricity. Those who do not have a place available for installation of photovoltaic panels can install them on the roof of their homes.

B.**Solar Photovoltaic applications in water pumping**

The majority of India’s poor (some 770 million people or about 70 percent) are found in rural areas. And third, India’s food security depends on producing cereal crops, as well as increasing its production of fruits, vegetables and milk to meet the demands of a growing population with rising incomes. To do so, a productive, competitive, diversified and sustainable agricultural sector will need to emerge at an accelerated pace. agriculture sector challenges will be important to India’s overall development and the improved welfare of its rural poor. Raising productivity per unit of land will need to be the main engine of agricultural growth as virtually all cultivable land is farmed. Water resources are also limited and water for irrigation must contend with increasing industrial and urban needs. Promoting new technologies and reforming agricultural research and extension: Major reform and strengthening of India’s agricultural research and extension systems is one of the most important needs for agricultural growth. Incentives to pump less water such as levying electricity charges or community monitoring of use have not yet succeeded beyond sporadic initiatives. Other key priorities include: (i) modernizing Irrigation and Drainage Departments to integrate the participation of farmers and other agencies in managing irrigation water; (ii) improving cost recovery; (iii) rationalizing public expenditures, with priority to completing schemes with the highest returns; and (iv) allocating sufficient resources for operations and maintenance for the sustainability of investments. Therefore, to tackle the issues faced by the rural farmers in India and increase the pace of agriculture in India to match with that of world, we need to use technology as a tool to achieve the desired results. This papers aims at introducing technology as a way to improve the irrigation system in rural areas through the use of solar energy. With decreasing solar modules prices (70% in the last 4 years), solar pumps are fast becoming a viable financial solution for irrigation. Some factors restrict the use of this technology, such as the high cost of photovoltaic modules, the growing worldwide manufacturing of photovoltaic modules and it’s no operation during the night. However, future generations will benefit from the use of clean and sustainable energy sources in order to contribute to the preservation of the environment, speeding up implementation of photovoltaic energy in the market. This study aims at introducing a solar energy powered irrigation system for agriculture use in rural areas and the implementation of technology in irrigation systems.

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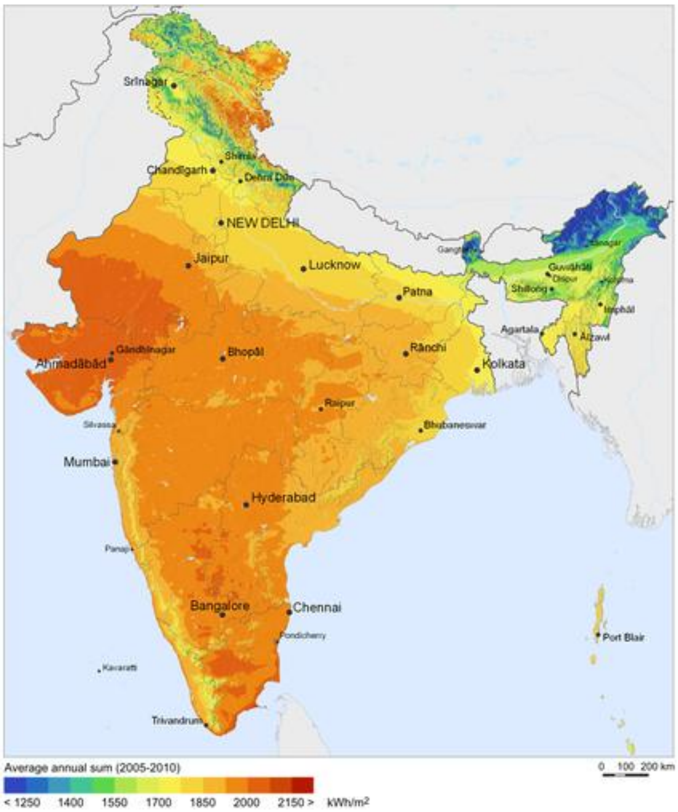

The above map shows the average solar radiation in India

II.REVIEW OF LITERATURE

The World Bank in its report on Solar Power Barrier in India mentions the current energy scenario in the country and various barriers hindering the development of this renewable energy in India. The report focuses on the availability of solar radiation data and technological equipment required. Mahendra Lalwani and Mool Singh in Conventional and Renewable Energy Scenario of India display the distribution of different energy sectors across the country and their usage in the present scenario. Dr. J.P Kesri, Mohit Gupta, Aadish Jain and A.K,Ojha in Review of Concentrated Solar Thermal Technologies(2015) explain the various type of solar concentrators used, their usage on capturing the solar radiation to operate solar powered equipments. The paper focuses on the urgent need to adopt renewable energy resources as alternative in the current stage of fossils and oil. Jia Uddin, S.M Taslin Reza (2012) mention the proposed model of Solar Irrigation system. The paper supports the statement that variable rate automated controlling approach improves the overall irrigation system reducing the total cost and increase the production of crop yield. The irrigation model displayed uses PV cells to operate and offers a better alternative. Satyendra Tripathi and Lakshmi N (2013) in Solar Powered intelligent irrigation system focus on the need to modernize the irrigation system of India and propose an irrigation model, a low cost and reliable model, for farmers which can be operated easily through solar radiation and moisture content of the field.

III.THEORETICAL CONSIDERATION AND COMPONENTS OF SOLAR PHOTOVOLTIC SYSTEM

A. Photovoltaic Energy and its components

In recent years, there was an increase in the use of alternative energy sources to complement the global energy matrix. However, such sources of global renewable energy generation have impacts and constraints, imposing some limitations.

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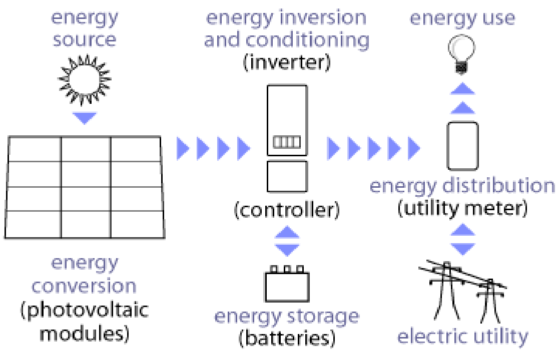
These limits are important for the planning and design of sustainable energy policies, demanding specialized studies for obtaining good performances in the installation of systems, in order to avoid serious consequences. Renewable energy sources are classified as hydro, thermal solar, photovoltaic solar, wind, ocean, geothermal and biomass. These sources use natural resources such as wind, water, solar radiation and heat as the operating principle for its generation. Hence, the applications of renewable energy sources are quite diverse and have been sought by several users.

The basic photovoltaic unit is called a solar cell, which together in groups form the photovoltaic panels, interconnected elements that compose the electric generator of a photovoltaic installation. The panels convert radiation into electrical energy by the photovoltaic effect. Such a phenomenon can be done because the panel is composed of semiconductor materials with specific properties.
Its production of electricity is the photovoltaic effect based on direct or indirect conversion of sunlight. The direct sunlight is extremely important for the generation of photovoltaic energy once the indirect approach does not produce an ideal performance to the system. Therefore, the panels should be able to capture the maximum amount of solar radiation during the day.

Since the conversion of solar energy to electrical energy is accomplished by converting the radiation into electrical energy, the higher the incidence of solar rays on the panel, the greater will be the power generated by the photovoltaic system. There are some methods used for increasing energy production, such as solar trackers, which provide a performance better than those with fixed angle due to the amount of direct radiation on the panels.In power generation, some concepts are fundamental, such as solar radiation that is transmitted to our planet through space as electromagnetic radiation. The incidence of this radiation on the photovoltaic modules cause the photovoltaic effect, which is the operating basis of solar photovoltaic systems. From this transformation of solar radiation into electrical energy, a potential difference arises, which is an electrical voltage.

Solar radiation suffers the influence of atmospheric air, clouds and pollution before reaching the ground. Hence, it is necessary that the photovoltaic panels are properly installed for capturing as much solar energy as possible. The classification regarding the connection to the power grid is of three types: isolated generators (off-grid), network-connected generators (Grid-tie) and hybrid generators. The off-grid generators are those with no connection to the electrical distribution network. These systems are usually installed in places not served by power distribution companies, thus requiring the use of a battery bank to store the generated energy and to provide it during the period of no solar radiation. They are mainly composed of photovoltaic panels, charge controller, batteries and inverters, as shown.



The Grid-tie generators are effectively connected to the public power grid. Once they are directly injected into the power grid, there is no need for battery bank. They are basically composed of the photovoltaic panel and the inverter, besides the components of control, protection and monitoring of the energy generation. The photovoltaic park of Sarnia, in Canada, is an example of a large centralized photovoltaic plant with an installed capacity of 80 MWp. Hybrid generators are isolated systems operating together with other generators such as wind, gas, diesel, coal, nuclear, etc., as shown in Figure 3. In some cases, this union may be more beneficial than a photovoltaic system operating independently, since it promotes a reduction of the installed power of solar panels, thereby reducing the total costs

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B. Automated Irrigation System

The agricultural industry is interested in improving its production process in order to reduce spending on labour, energy, water waste in irrigation, excessive use of pesticides, fertilizers, among others, andreductions in these costs will increase profit. One of the solutions is applying automation in the farm, through an interdisciplinary work of distinct areas, which can bring positive results Some automated systems are controlled by Programmable Logic Controller (PLC), a technically viable alternative able to control and monitor processes such as the irrigation system, amount of energy used, pesticide use etc. Other automated systems may be controlled by microcontrollers, such as ArduinoR, which use Atmega family's chip in their microcontrollers
Automated systems provide a great improvement in production processes. Besides reducing human-based problems, it will also reduce problems related to inadequate operation and/or to waste of any raw material. However, designing fully autonomous systems may sometimes not be a viable alternative due to complexity and to socioeconomic conditions.The automation of irrigation is a very important step both for those who work directly with this process and for humanity in general, thereby minimizing water waste. New irrigation strategies have been constantly created, especially in regions where such resources are scarce, thus forcing the installation of modern irrigated crops systems. The installation of real-time sensors provides the linking of information about spatial and time development of biotic and abiotic stress, such as instructions of the irrigation system allowing producers to maximize the efficiency of the proper use of water, to generate sustainability and to decrease negative effects on the environment.

IV. AUTOMATIC IRRIGATION SYSTEM AND ITS COMPONENTS

With the alarming rate of depletion of fossil fuels, it is more ethical to shift on Renewable Energy Sources like Solar energy and wind energy.The vehicle designed for AIS(Automated Irrigation System) completely runs on Solar Energy making it more efficient to run and environment friendly.Automatic Irrigation system shows the steps required to convert solar energy into irrigate crops in the fields through technology.

Solar Panel: A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications.

Charge Controller : A solar charge controller manages the power going into the battery bank from the solar array. It ensures that the deep cycle batteries are not overcharged during the day, and that the power doesn't run backwards to the solar panels overnight and drain the batteries. Some charge controllers are available with additional capabilities, like lighting and load control, but managing the power is its primary job.

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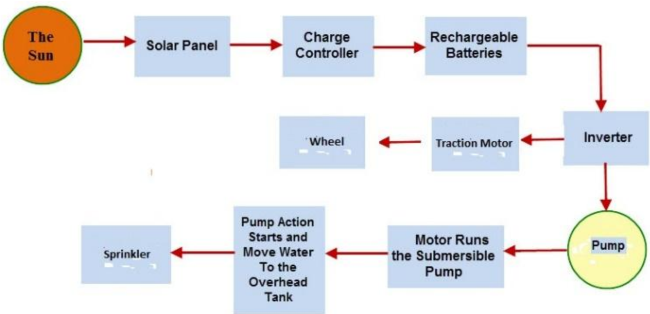
Rechargeable Batteries: the rechargeable batteries enable to covert electric energy into the storable chemical energy and realize the recyclable conversion/storage between electric energy and chemical energy. the exploitation of solar energy in rechargeable batteries could not only achieve the large-scale application of solar energy, but also assist the conventional rechargeable batteries in saving the input electric energy.

Inverters: electrical energy from photovoltaic solar panels to drive AC motor water pumps. electrical energy from photovoltaic solar panels to drive AC motor water pumps.

Pump: A typical solar water pumping system is known by the sum total of solar array size that is required to run the attached pump. Each solar array has a number of solar modules connected in parallel or series. Every solar PV panel generates current by converting solar radiation to electrical energy. The electrical energy from the entire array is controlled, tuned and directed by the inbuilt controller in DC pumps or through the Variable Frequency Driver(VFD) and enables the connected pump (may be submersible or surface) to draw water and feed the delivery pipelines. The water thus drawn from ponds, rivers, bore wells or other sources by a solar water pump is pumped to supply water as required. It can be stored in tanks from where it is later channelled to fields or the supply from the pump may be coupled with drip irrigation systems to provide optimised water to fields directly.

A. Proposed model of Automated Irrigation System



The below proposed system shows the practical usage of the irrigation system designed.
The wheels attached at the bottom of the system rotate as the system starts operating and let the water in into the machine. As the water is pulled into the machines through wheels, it passes through the pump, the battery and the inverter. Traction motor refers to a type of electric motor. Attraction motor is used to make rotation torque on a machine. It is usually changed into a straight line motion. Motors on solar positioning equipment orient panels to follow the sun daily and seasonally. Motors on solar trackers must withstand extreme temperatures, twice that of a normal industrial setting, they also must have protection against water and dust. This can be achieved with sealing. The solar energy derived from the sun. although varying at different time of the day, is focused on the solar panels attached at the roof of the system.

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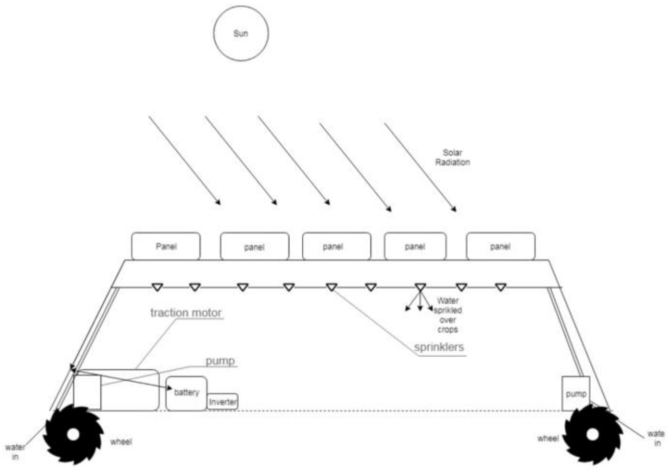

B. DESIGN OF SOLAR PV WATER PUMPING SYSTEM

A solar water pumping system is designed with solar photovoltaic panels and locally available electric pumps. All components in the system design have been procured locally except solar panels. A DCDC Buck converter is used to integrate with the solar water pumping system to operate it efficiently. The microcontroller based solar tracking system has incorporated in order to attain maximum solar power for electricity generation and thereby increasing the system efficiency.

B.1 Solarwaterpumpingsystem:

The solar-powered pumping system can be used anywhere but it is appropriate for rural areas of India which is facing energy crisis like other developing countries of the world. However due to geographical position, India has ample sunshine through the year which makes it ideal location for utilization of solar energy. Small farms, villages, and animal herds in developing countries require hydraulic output power of less than a kilowatt. Many of these potential users are too far from an electrical grid to economically tap that source of power, and engine-driven pumping tends to be prohibitively expensive as well as unreliable due to the high cost of purchased fuel and insufficient maintenance and repair capabilities. Though the installation cost of solar powered pumping system is more than that of gas, diesel, or propane-powered generator based pumping system but it requires far less maintenance cost. However, by comparing installation costs (including labour), fuel costs and maintenance costs over 10 years with other conventional fuel based pumping system, the solar PV water pumping system can be a suitable alternate option. This system has the added advantage of storing water for use when the sun is not shining, eliminating the need for batteries, simplicity and reducing overall system costs. Solar water pumps are designed to use the direct current (DC) provided by a PV array, although some newer versions use a variable frequency AC motor and a three-phase AC pump controller that enables them to be powered directly by the solar modules. Since solar cell is expensive and its electricity production is of intermittent nature therefore solar pumps need to be as efficient as possible i.e. they need to maximize the gallons of water pumped per watt of electricity used.
The long-term cost analysis makes the solar PV pumping system comparable to most other remote watering options in the rural areas. The lifetime of solar water pump is usually 20 years, which ultimately is lower than the life span period cost compared to the conventional pumps. By using solar PV pumps, load on the grid system can be reduced and the subsidy on the diesel can be lowered.

B.2 Components used for the designed system:

1. Solar Panel
2. Chopper
3. Battery

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4. D C Motor
5. Connector

In Components are sized accordingly and then connected directly with the panels to examine the converter design. There are different sizes of PV modules commercially available. For the proposed system, solar panels are used. The specifications of the solar panels are provided below:

Rated Current: 7amps
Rated Voltage: 24volts
Short Circuit (SC) Current: 8.07amp
Open Circuit (OC) Voltage: 42volt
Cell Temperature: 25°c

Six 250Wp solar panels have been used to provide DC power supply for the water pumping system. Such 6 solar panels supply 1500Wp power during the normal condition. The solar panels are connected in two arrays, the first, second arrays and 6 panels. All six panels are connected in parallel to provide power supply to the pumping system.

B.3 solar panel **(Stand-Alone System):**

- 1500W
- Inverter set
- Charge regulators
- FF~70%
- Efficiency =15-20%
- Tolerance =-3 to +15
- V max =34v
- Vo c =42v
- Imax =7A
- Is c =7.05A
- UPS back up
- Battery of 1800 Ah

Calculation for the number of batteries that we use in our project
Generally the sun gives 1000W/sq.mt
A solar panel is 15% efficient, So we get 150 WattPanel size=10*10[1sq.m=10.7sq.ft]10sq.m=107sq.ft=>10sq.m=10.344

We use 6 panels each of 250 watts (250*6=1500 watts)
The size of the motor that we use is 1hp (750watts) (Watts) 750*5=3750 w-hr
Usually battery is specified in amp-hr
The specification of the battery that we use is 180Ah

- We require 3750/.8=4687.5 whr
- .8 is efficiency of motor
- We use 12vbattery so4687.5/12=390.62Ah
- Battery energy stored 390.62/180*.6=3.66(Since battery is 60% efficient)
- We require 4 batteries to supply power to load for 4-5 hrs.
- Module costs typically represents only 40-60% of total PV system cost and the rest is accounted by inverter, PV array support, electrical cabling and installation
- Most PV solar technologies rely on semiconductor-grade crystalline silicon
- The high initial cost of the equipment they require discourages their largescale commercialization
- Initial cost of system
- 1 watt = Rs. 95.50

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- Total system wattage 1500
- 1500 x 95.50= Rs. 143250
- 1.5 kw means 1.5 unit
- According to government rules 1 unit cost for commercial purpose is Rs. 13
- In one day this system works for 6+2 hrs means 8 hrs
- 8 x 1.5=12 units
- 12 x 13 = Rs. 156 daily
- Total 300 days we will get sunshine because we ar in tropical zone
- 300 x 156 = Rs. 46800
- Now 143250/46800 = 3.2 years
- Reliability of solar is 15 - 20 years
- Hence after 4 years we will get profit
- Thus this recommends use of solar
- If Rs. 5.50 for unit thus payback period is 7 years
- 13 years of profit
- If Rs. 3.50 for unit payback period is 9.6 years
- 10 years profit

V. CASE STUDIES

A. CASE STUDY 1

Building a 5 MW solar PV plant in Rajasthan, India, under Phase 1 of the Jawaharlal Nehru National Solar Mission (NSM) presented a number of challenges for Mahindra EPC (MEPC), a wholly-owned subsidiary of the Mahindra Group, as this was their first experience with utility-scale solar. The plant needed to live up to the expectations of the Mahindra Group, one of the most respected corporations in India, known for "getting it right the first time". The developer wanted to be the first to achieve non-recourse funding, meaning lenders would demand rock-solid guarantees of the plant's long-term performance. And it was crucial to meet the commissioning deadline to avoid high penalties imposed by the government under the NSM. Wanting to take no risks, Mahindra EPC partnered with SunPower for their bankable technology, proven experience and collaborative approach, choosing SunPower's single-axis Trackers as the most efficient, reliable and cost-effective way to maximise power generation. SunPower assured the MEPC team that, despite their lack of familiarity with trackers, the SunPower single-axis Tracker was easy to install, and that the SunPower team would be available to help every step of the way, from site preparation to commissioning. Thanks to SunPower's support and to its own highly committed and energetic team, MEPC managed to commission the 5 MW plant ahead of schedule, in a record time of just 110 days.

Project Overview Location: Phalodi, Rajasthan, India
Completed: January 2012
System Size: 5 MW
System type: SunPowerTM SerengetiTM modules mounted on SunPowerTM Trackers
Project Partners EPC Contractor: Mahindra EPC Services Pvt. Limited
Project developer: Mahindra Solar One PVT. Limited, a joint venture between the Mahindra Group (26%) and Kiran Energy (74%)
Benefits
• 5 MW plant commissioned in just 110 days
• First PV plant connected to the grid under Phase 1 of India's NSM scheme
• First power plant in India to obtain non-recourse financing
• Solar electricity generated powers 60,000 rural homes

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B. CASE STUDY 2

World's Largest Solar Steam Cooking System at Tirumala, Andhra Pradesh The world's largest solar steam cooking system has been installed by the Tirumala Tirupathi Devasthanam (TTD) at Tirumala in Andhra Pradesh. The system has a capacity to prepare food for 15,000 people/day and employs automatic tracking solar dish concentrators, which convert water into high pressure steam. The steam thus generated is being used for cooking purposes in the kitchen of TTD. It has been hooked up with the existing boiler working on diesel so as to make the system reliable under all climatic conditions. The system has been designed to generate over 4000 kgs of steam/day at 180 degrees centigrade and 10 kg/sqcm which is sufficient to cook two meals for around 15,000 persons. It is modular in nature and consists of 106 automatic tracked parabolic concentrators arranged in series and parallel combination, each of 9.2 sq meter reflector area. Each unit of concentrators is connected to a central steam pipeline going to the kitchen. The system is made of indigenous components and the reflectors are of acrylic mirrors having reflectivity over 75%. Its installation was completed during September 2002 and was inaugurated on 11th October 2002. The system is expected to save around 1,18,000 litres of diesel per year, valued at Rs. 2.3 million. The total cost of the system is about Rs. 110 million, which includes back up boiler, utensils and annual maintenance contract for five years. The system has been installed by M/s Gadhia Solar Energy Systems, Valsad under a demonstration scheme of MNES with 50% financial support. Balance of the cost has been borne by the TTD trust. A total of 6 such systems have been installed in the country. This technology could be very useful at places where rice is the staple food and cooking is done on a very large scale.

VI.ECONOMIC ANALYSIS

The Indian renewable energy sector is the second most attractive renewable energy market in the world as per the Renewable Energy Attractiveness Index 2017. India's installed renewable power generation capacity (including hydropower) increased from 42.4 gigawatts (GW) in FY07 to 107.81 GW in FY18 (as of February 2018), which is 32.26 per cent of the total installed capacity. Power generation from renewable energy sources in India reached 85.65 billion units in FY18 (up to January 2018). India has the fourth largest installed capacity of wind power and the third largest installed capacity of concentrated solar power (CSP). India added record 11.0 GW of combined wind and solar capacity in 2016-17. Hydro power forms the largest source of energy constituting over 43 per cent of the total renewable power generation installed capacity. India witnessed highest ever solar power capacity addition of 5,525.98 MW and 467.11

MW of wind power capacity addition in 2017-18 (up to November 2017). 15,000 biogas plants were installed during the same time period. Off-grid power equivalent to 168.87 MW was added in the country during January – November 2017.

The Ministry of New and Renewable Energy, Government of India, has formulated an action plan to achieve a total capacity of 60 GW from hydro power and 175 GW from other RES by March, 2022, which includes 100 GW of Solar power, 60 GW from wind power, 10 GW from biomass power and 5 GW from small hydro power. This has been proving to be the major thrust for the sector in India as the market players have sufficient incentives to move to clean source. Under Union Budget 2018-19, Rs 3,762 crore (US$ 581.09 million) has been allocated for grid-interactive renewable energy schemes and projects.

As India looks to meet its energy demand on its own, which is expected to reach 15,820 TWh by 2040, renewable energy is set to play an important role. By 2030, renewable sources are expected to help meet 40 per cent of India's power needs. The non-conventional energy sector has received a total FDI equity inflow of US$ 6.26 billion during April 2000 to December 2017.

The features that affect the economic viability may be summarized as,

1) cost of the system
2) depreciation
3) interest on capital
4) cost of energy and the scenario, i.e, the variation of the cost of energy during the life time of the system
5) subsidies or incentives.

The total solar energy available is enormous. Total human energy needs by the turn of the century are estimated at ~43 TW (Terra Watts). The total energy available from the sun is estimated to be between 85,000 and 120,000 TWs. Solar energy is clean, safe and easy to install. The energy captured is immediately available. Maintenance of equipment is low and the life expectancy of equipment is measured in decades, not years. Equipment is modular, so repair and replacement do not require a complete changeout.

A. Employment

The first point is that there are a huge number of people employed in renewable energy jobs globally. There are almost 10 million of them around the world. Slightly over 3 million are employed in solar power. Large hydropower employs about 1.5 million people, and 1.2 million are in wind power employment. Advanced energy — which includes solar, wind, energy efficiency, energy storage and EVs — contributed $1.4 trillion to the global economy in 2016. Another benefit is that wind turbines can be installed in rural areas at existing farms to provide much-needed income to local people. Here's another fascinating example: "The report looked at the 23 largest wind farms in Illinois, finding that they will add almost $6 billion to local economies over their lifetimes and have resulted in the creation of more than 19,000 jobs during the construction periods. The projects will also support 814 in the state. The Union of Concerned Scientists made a great point in one its recent articles on renewable energy: "Compared with fossil fuel technologies, which are typically mechanized and capital-intensive, the renewable energy industry is more labour intensive. Solar panels need humans to install them; wind farms need technicians for maintenance. This means that, on average, more jobs are created for each unit of electricity generated from renewable sources than from fossil fuels." That is true even when wind and solar power are *cheaper* for the customer.There are two main reasons why renewable energy technologies offer an economic advantage: (1) they are labour intensive, so they generally create more jobs per dollar invested than conventional electricity generation technologies, and (2) they use primarily indigenous resources, so most of the energy dollars can be kept at home. So, renewable energy can generate better jobs and more of them.

B. Economic simulation

Renewable energy contributes more economically than only jobs and pollution reduction. Doubling the share of renewables in the global energy mix by 2030 would increase global GDP by up to 1.1% or USD 1.3 trillion. The report shows that such a transition increases global GDP in 2030 between 0.6% and 1.1%, or between around USD 700 billion and USD 1.3 trillion compared to business as usual. Another key, and very striking, benefit is how renewable energy investment can impact trade. "For fossil fuel importers, the switch to a greater share of renewables has potentially favourable trade implications. Reducing fuel imports can improve trade balance and improve GDP. According to an analysis conducted by the Union of Concerned Scientists, implementing a national 25% by 2025 renewable electric standard would result in the following benefits: $263.4 billion in new capital investment for RE technologies, $13.5 billion in new landowner income from biomass production and/or wind land lease payments, and $11.5 billion in new property tax revenue for local communities In the development scenario, the quantitative analysis implies that the added value brought about by wind and solar PV power industry, directly and directly, is about 5.0 times in 2030 more than that in 2015," a study of renewable energy economic benefits in China estimated. "During 2016–2030, about 8674 billion RMB (1300 billion dollars) and 6949 billion RMB (1042 billion dollars) added value could be generated respectively by wind power industry and solar PV power industry, accounting for about 0.58% and 0.47% of GDP.

C. Government initiatives

Some initiatives by the Government of India to boost the Indian renewable energy sector are as follows:
In December 2017, a new policy was released for testing, standardisation and certification of products used in the renewable energy sector to address quality issues and develop standards as per international practices.

- Around 4.96 million household size biogas plants were installed in the country under the National Biogas and Manure Management Programme (NBMMP) by 2016-17 end.
- The Government of India has announced plans to implement a US$ 238 million National Mission on advanced ultra-supercritical technologies for cleaner coal utilisation.
- The Ministry of New and Renewable Energy (MNRE) has decided to provide custom and excise duty benefits to the solar rooftop sector, which in turn will lower the cost of setting up as well as generate power, thus boosting growth.

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- The Indian Railways is taking increased efforts through sustained energy efficient measures and maximum use of clean fuel to cut down emission level by 33 per cent by 2030.
- The Union Cabinet has approved raising of bonds worth Rs 2,360 crore (US$ 366.2 million) by the Indian Renewable Energy Development Agency (IREDA), which will be used in various renewable energy projects in FY 2017-18.
- The Union Cabinet has approved construction of 10 units of indigenous Pressurized Heavy Water Reactors (PHWR), with a nuclear capacity of 700 MW each, which is expected to bring substantial economies of scale and maximise cost and time efficiencies, and thereby boost India's nuclear industry.

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