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Solar Photovoltaic Pumping Systems Site Selection Using Remote Sensing and GIS

Mukesh Kumar Mehla

Depat. of Soil and Water Engineering, College of Technology and Engineering, MPUAT, Udaipur, Rajasthan (313 001), India

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Corresponding Author

Mukesh Kumar Mehla

e-mail: mukeshmehla310@gmail.com

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E-mail: *bioticapublications@gmail.com*

Abstract

The solar photovoltaic pumping system utilizes the solar energy to pump water. Efforts are being made to incorporate renewable energy sources in agriculture sector especially for irrigation to provide sustainable energy source which is freely available and ecofriendly with advantage that it can be utilized at off grid and remote locations. One of the most important aspects for achieving such ambitious plans is to identify the promising locations to develop such systems to reap maximum benefits. This is where remote sensing and GIS comes into play these tools can be used for large scale analysis for selection of suitable sites based on factors like local climate, soil, topography, availability of solar radiation, vacant land with open cover free area, groundwater, distance from highways and existing transmission lines etc. Then a number of maps are generated and over laid by using GIS software to find suitable locations for SPV systems based on criteria.

Introduction

India is one of the fastest growing economies in the world with India having GDP growth rate 4.2 % when global GDP growth is around 2.5 %. Along with rapid development India have to tackle the ever-growing demand of energy for its population as well as industries. Use of fossil fuel for power generation is not sustainable approach to our power problems also commitments to Conference of Parties 21 (COP21) in IPCC under United Nations Framework Convention on Climate Change (UNFCCC) to stop relying on fossil fuels and shift to renewable resources. Fossil fuels are responsible for rise in carbon dioxide, increasing Greenhouse effect that result adverse economic, ecologic and social impacts. Renewable energy systems have potential to fulfill this future demand, Government of India have set target to achieve total renewable capacity of 175 GW by 2022 out of which 60 GW is wind power, 100 GW is solar power, 10 GW of biomass/ bio fuel power and 5 GW hydro power, increasing the annual solar installations by four times (Singh, 2018).

Therefore, Solar Photovoltaic systems have good scope in future, by connecting renewable energy systems to power grid in rural areas can provide good opportunity for community centric power generation which will also add into agenda of Doubling the farmers' income that is promised by government and a clean energy system that would also help in controlling pollution, environmental damage. Farm scale adoption of renewable energy system adopting technologies like solar pumps, wind mills, solar trees, and solar ponds can be good alternative to current technologies (i.e. thermal, nuclear power). Also use of solar photovoltaic power systems (SPVS) and wind energy systems (WES) in remote areas where traditional power grid system is not feasible economically or

due to some physical limitation is also an intriguing aspect.

Solar Photovoltaic Pumping Systems

An array of the photovoltaic cells converts the solar energy into electricity, this power generated from solar PV (photovoltaic) system is used to operate pump set to uplift and deliver water. A system with 1800 watt PV array capacity and 2 HP pump can give a water discharge of 1.4 lakh litres per day from a depth of 6 to 7 meters. This is adequate for irrigating about 5-8 acres of land holding for various crops.

Figure 1: Solar Photovoltaic Pumping System in Field

The amount of solar power that can be harnessed depends upon many factors like slope, inclination, material used, conversion efficiency etc. but performance of SPV is directly related to the solar flux from sun which reaches the earth surface which is around 1,367 W/m² this is also called Solar constant given in units. For running SPV system average daily solar radiation is 7.15 KWh/ sq. meters (Bhattacharya, 2009). On the surface of PV array is required and a normal Solar Photovoltaic cells and modules are rated for 1000W/m², $AM_{1.5}$ global and 25 °C temperature. For a 1 KW rooftop system area of 12 sq. meters (130 square feet) which is flat, shadow-free, facing south is preferred. There are number of factors like local climate, soil, topography, availability of solar radiation, vacant land with open cover free area, groundwater, distance from highways and existing transmission lines and so on which should be considered for selecting suitable sites (Table 1).

Advantages of a Solar Water Pumping System

- No fuel cost - as it uses available free sun light
- No electricity required
- Long operating life
- Highly reliable and durable
- Easy to operate and maintain
- Eco-friendly

Table 1: Approximate cost of solar photovoltaic pumping system of different HP

Capacity of SPV system	Total Head (Suction & delivery) in m	Solar PV (watt)	Cost (Rs)
2 HP (surface pump)	10	1800	2,90,000
4.6 HP (submersible pump)	30	4800	7,15,000

Selection Criteria for Solar PV Installation (Khan and Rathi, 2014)

In order to identify potential sites for Solar PV system installation, availability of solar radiation should be considered first. Based on different data sources, such as weather station data and elevation data, solar radiation can be estimated using different approaches. Additionally, Light Detection and Ranging (LiDAR) data or high resolution Digital Elevation Model (DEM) data have been implemented to estimate radiation at the small scale or regional level. Other optical imagery has also been applied to detect solar radiation at the macro level. The thermal band of optical imagery with detected surface temperature information can also be used to calculate solar irradiation.

Different environmental and economic concerns; and energy generation potential should be taken into account during the site selection process. These include, amount of incident solar radiation, availability of vacant land for its present as well as for its future development, accessibility to site from highways as it affects the transportation cost and thus the initial cost, distance from transmission lines to minimize the losses. Solar PV panels works efficiently within a range of temperature which is 25 °C to 45 °C, the degradation of cells happens due to high wind velocity, extreme temperatures, shadow on modules and dusting on arrays, thus variation of local climate is significant criteria for this work. Geotechnical issues like consideration of groundwater resistivity, load bearing properties, soil pH levels and seismic risk are important criteria. Geotechnical political issues such as Site near to Sensitive military zones and historical places should be avoided. By considering Topography of site, flat or slightly south facing slopes are preferable for projects in the northern hemisphere. Efficiency of plant could be reduced significantly if modules are soiled. It is, therefore, important to consider local weather, environmental, human and wildlife factors. The criteria should include dust particles from traffic, building activity, agricultural activity or dust

storms and module soiling from bird excreta. In order to consider these factors and to identify potential sites for solar panel installation a Multi-criteria Analysis (MCA) is conducted based on following factors:

- Availability of solar radiation
- Availability of vacant land
- Accessibility from national highways
- Distance from existing transmission line
- Variation in local climate
- Use of nearby land
- Topography of site
- Water requirements for pump selection
- Geotechnical issues
- Geotechnical political issues
- Module soiling

Site Suitability Analysis of Solar PV

The criteria stated in previous section were classified on the basis of their implication as Analysis criteria and Exclusion criteria. Analysis criteria are those which enhance the suitability of site and have positive connotation and exclusion criteria are those which restrict the alternatives and have negative implication. Various thematic maps were generated for the analysis criteria with the help of GIS software. The suitable sites obtained from the intersection of all maps.

Major Steps Involved in Identification of Solar Photovoltaic Power Systems (SPVS) Sites Using Remote Sensing and GIS:

- Studying different criteria based on which Solar photovoltaic systems (SPVS) are located, quantify weights to the different criteria parameters based on their effect on the working and efficiency of the system.
- Using GIS software to generate different criteria layers based on DEM, slope, radiation, topographic, roads, transmission lines etc. data obtained from different layers.
- Extract zone having suitable condition for solar photovoltaic plant site by calculating an index from different criteria layers and classifying the sites according to their suitability.

Data Required

- Digital elevation model (DEM).
- IRS-1D LISS III image.
- Solar radiation data.
- Topographic map.
- Land use and Land cover.
- Ground water.
- Road, railways and transmission network maps etc.

Data Sources

- NRSC portal (http://bhuvan.nrsc.gov.in)
- India Meteorological Department (www.imd.gov.in)
- Soil and Land Use Survey of India (slusi.dacnet.nic.in)
- Open Series Maps(OSM): Survey of India (www.surveyofindia.gov.in)

Conclusion

Solar photovoltaic pumping systems have great potential to revolutionize agriculture sector. There is huge scope of adopting renewable energy sources for irrigation. Solar energy can be used to operate pump sets for irrigating field and excess energy can be sold off by connecting it with the national grid. It can be remote locations. Finding a suitable location for a solar power development project is complex and time-consuming task factors like location, slope, topography, purchase price, solar power efficiency, environmental impacts, and public opinion etc. effect the site selection. Different methods are proposed for SPV site suitability analysis but using a multi criteria based, using raster layer parameters, which can be conducted using “map Algebra” in a GIS environment gives better and faster results. Generating different thematic maps to identify suitable sites is important for optimization of resources and maximizes benefits.

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