Site Suitability Methodology for Solar Power Generation Plant in India using RS & GIS

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Abstract— Solar radiation is received as heat and light which can be converted into useful thermal energy or for the production of electricity either through solar photovoltaic route or through solar-thermal power production. Availability of purely reliable solar radiation data is vital for the success of solar energy installations in different sites of the country. For this purpose, the amount of solar radiation incident is measured using both remote sensing satellite and ground stations installation which is obtained over years in hourly manner. Using solar radiation data, A Multi-Criterion Site Suitability Analysis can be performed for finding out regions having greater capability of producing greater yield throughout the year by overlaying with other GIS Layers. This analysis will tend to produce sites suitable for energy production by integrating it with the existing natural and artificial system influencing and controlling the energy production and forecasts the future expansion with other renewable energy sources.

Key words: microstrip, antenna, array, Ku- Band

I. INTRODUCTION

Monitoring and Mapping is a major application of Geographic Information System involving real time and future prediction, which helps human being to analyse and associate actions depending on the outcome produced by it. Geographic Information System (GIS) along with other major geographic platforms helps in aiding the management of natural resources of the Earth. Managing natural resources involves the better usage of it by mapping its presence, tapping or utilising its energy by monitoring and producing efficient & effective yield. Integrating natural resources management with intelligent system that are capable of performing all the actions of management are the recent trends in advanced world. This study deals with the mapping, monitoring and management of natural resource that is abundant on the surface of earth i.e. the Solar Radiation incident on the surface of the earth. Mapping, monitoring and management of solar radiant energy on the surface of the earth involves the usage of satellite remote sensing and other geographic data in to the GIS platform. And the purpose is to produce maps for selecting suitable site by monitoring different factors which aids and assists the productivity and management

A. Need for Solar Radiation Data:

A whole array of applications, viz. thermal conversion, photovoltaic conversion, photochemical utilization, biomass conversion, passive solar lighting and heating of buildings, detoxification etc. is becoming apparently viable and enhances the society's energy management planning and hence its efficient applications. The economics of these technologies depend on the efficiency of the utilizing processes, so that the operating costs are comparable, if not cheaper, with the present day processes based on conventional fossilized energy utilisation.[1]

Thus, to design operating systems which will have the highest achievable efficiency under comparable costs, the reliable database on different aspects of solar radiant energy is essential. The more accurately the solar resources are known, the better becomes the system design. The radiant energy available at a location changes throughout the day and year due to varying weather patterns. By knowing the variability, storage systems can be designed and used optimally.

Solar radiation data also help determine the best geographic location for maximum utilisation as it will have a direct influence on the design of the systems. Photovoltaic and photochemical conversions need spectral distribution over space and time. Location, climate and atmospheric conditions have strong influences on the spectral distribution of solar irradiance.

B. Need of GIS Based Site Suitability Analysis:

This GIS based approach for Multi-Criterion Site Suitability Analysis aims at providing

1) Best possible solar site for establishment, based on different influencing factors.
2) Decision making capability on type of solar-electric energy generator.
3) Solar Irradiance prediction for maximum solar yield production.
4) Operation and Maintenance of plant on basis of accessibility and cost.
5) Easy monitoring and co-operation with integrated GIS electric grids.

II. OBJECTIVE AND SCOPE

A. Objective:

- To carry out suitable site selection for large scale solar power plant in India for fulfilling the power needs and to produce energy from renewable sources.
- To select site which is not purely based on remote sensed solar irradiance data, rather depending on other factors which influence solar production.
- To prove GIS analysis produce site suitability maps and zones on multi-criteria basis which is very useful in prediction of solar yield, which in turn helps in decision making on type of solar plant to established.

B. Scope:

- Analysis aids in working and capital investment for a solar power plant and also in future assessment of site for Hybrid plants.
- Future prediction for maximum solar yield production using existing years of solar data.

– Establishment of remote sensing techniques as the best possible method for assessment and monitoring of solar irradiance.

III. REQUIREMENTS

Different factors that determine the productivity of power through solar photovoltaic method are to be determined as the main focus of this study orient towards the site selection and these factor are used as a weighting factor for selection of best possible site for generation in multi-criterion site suitability analysis. GIS software provides as a major backbone for performing the operation of site selection from scratch to scrutiny.

The variability of data that are used in this project determines the methodology of the multi-criterion site suitability analysis along with production of high success rate. The collection of data involves the usage of satellite and field remote sensing data that are converted in to GIS data by appropriate data collectors. These data comprises of the remotely sensed solar radiation data to the ground station collected meteorological data.

Collection of material required for the project involves source data from many providers and are manipulated to produce GIS layer of different conditioning factors which are later ranked and weighted to produce suitable site for solar power generation in Tamilnadu.

Materials required for site selection of solar power plant in Tamilnadu using multi-criterion analysis requires collection of data from vast sources for a continuous period of time. The data used to generated suitable site should be of continuous range prior to the period of study as these help to understand about different phenomena present and able to model that can predict future possibilities. The materials used for this analysis are divided into two basic categories and are Data and Software.

A. Data:

Data requirement for site suitability varies from ground obtained measurements to satellite observed readings and the data used in this project to select suitable sites for power generation by a solar plant were the following

1) Solar Irradiance Data (Direct Normal Irradiance & Global Horizontal irradiance) from NREL & Solar Energy Center, India on 10 K.M Resolution.
2) Solar Radiation Map of INDIA from Solar Energy Center.
3) Boundary Shapefiles of India from open source network.
4) District Boundary from OSM Data.
5) Transportation Network & Water Bodies Shapefiles from Internet.
6) Elevation Data of 30m resolution ASTER GDEM from USGS Data Archive.
7) Transmission Line Network Data
8) Generation & Distribution Station Point Data
9) Rainfall Data (Hourly, Daily, Monthly, Annual, Sub-divisional, Heavy Spells in 24Hrs).
10) Temperature Data (Hourly, Daily, Monthly, Maximum & Minimum, Extreme Values).
11) Relative Humidity Data (Hourly, Daily, Monthly).
12) Surface Wind Speed and Directions Data.
13) Bright Sunshine Hours Data (Hourly).
14) Amount and types of clouds observed Data (Twice daily / 8 times daily).
15) High Resolution Maps from Google Earth.

IV. METHODOLOGY

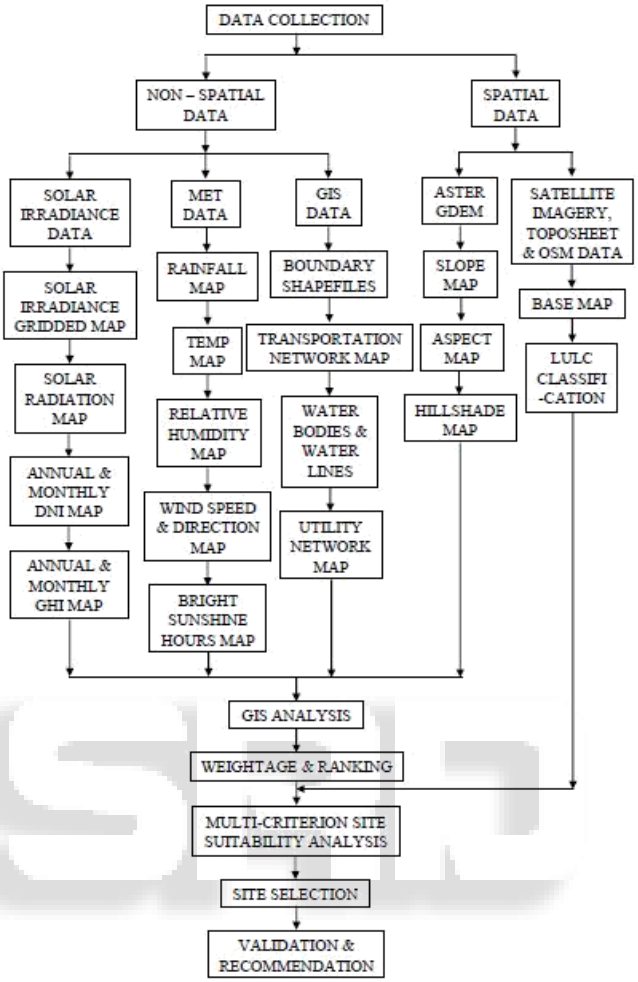

Fig. 1: Flow Chart for Methodology

A. Data Collection:

Data collection is the initial process that gathers all the necessary data needed for the analysis. Data collection initiates the process of understanding the principle of solar power production and the factors that influencing it. Collection of data involves two active works, one is the collection spatial data and another is collection of non-spatial data. Both these data forms the fundamental for site selection.

B. Spatial Data Collection:

Spatial data in site selection of solar power plant involves collection of Toposheet, satellite imagery, Digital Elevation Model and OSM data. Spatial data are layers or maps which are geographically represented. These layer or maps has their unique usage in the process of site selection by MCA.

C. Non-Spatial Data Collection:

Non-spatial data are data or information about an area or a place that are used to produce layer or maps that can be geographically represented. Non-spatial data collection involved in the process of site selection is the collection of solar radiant energy and Meteorological data for years

previous to the study period. Also collection of GIS maps & data to obtain shapefiles on different features involved in the study.

D. Generation of Solar Irradiance Maps:

Solar irradiance data were obtained for INDIA from the NREL, USA for the period starting from 2002 to the period ending 2011. These solar irradiance data are obtained by cumulating the readings obtained by the Meteosat satellite using SUNY Model which calculates the average of the reading taken hourly to produce grids of 10KM resolution. The data obtained where in comma separated values mentioning the latitude and longitude of the location of observance along with the monthly and annual DNI & GHI. Then these data where prepared as a map of high resolution solar resource map providing 10KM resolution. Then these Gridded map produced by interpolating the values of solar irradiance observed hourly are used to generate map of annual and monthly DNI & GHI for the study area. This gives the monthly and annual cumulative of solar radiance falling on the surface of the region under study.

E. Generation of Meteorological Maps:

Meteorological data collection and processing involves the accumulation of hourly, daily, monthly and annual data of different meteorological parameters and creation of different layers for the period of the study. Meteorological data collection and processing helps in understanding the different meteorological conditions prevailing over the study region which aids and disturbs the suitability selection. Different meteorological data required and that helps in delineate the best site for solar power production are rainfall, temperature, relative humidity, bright sunshine hours, wind speed and direction and also cloud coverage. These data collected were based on the availability of data and the time interval between readings of a particular MET parameter.

F. Generation of Different GIS Layers:

Generation of different GIS layers involves the digitization of boundaries for the country, state and districts of the study area and creation of Transportation network (road & railway), Hydrology bodies & network (water bodies & water line), Utility points and network (generation, transmission & distribution network). All these networks and point are data obtained from either open source data providers or from internet. Some data were also obtained from the concerned state authority. These layers where produced by incorporating the GIS data in ArcGIS to produce layers, which are later processed to perform GIS analysis & to provided rank & weightage for performing multi-criterion analysis.

G. Generation of Slope, Aspect & Hillshade:

ASTER GDEM of 30m resolution is obtained for the whole study area and where extracted exactly for the region of study using the boundary shapefile in ArcGIS. Later this extracted DEM data is used to obtain slope, aspect and Hillshade map for the region by using surface toolbox of Spatial Analyst tools in ArcGIS.

Slope, aspect and Hillshade maps where generated by providing appropriate values in the toolbox to produce accurate result. These maps are later used in the multi-criterion analysis to select suitable site for solar power generation.

H. GIS Analysis:

Different GIS analysis are to be performed on different layers obtained from different sources to produce intermediate GIS layers that will be capable to differentiate the study region. This differentiation is based on the outcome of GIS analysis to produce interdependencies between the different layers.

Some of the GIS analysis to be performed on the maps and layers produced are overlay analysis, proximity analysis, neighborhood operation and much more. The output layers obtained from this analysis are to be used to perform MCA by providing appropriate rank and weightage.

I. Ranking & Weightage:

Ranking and Weightage are to be provided to the GIS analysed layers based on the impact it creates on the selection of site. Each and every layer has its own importance and varies according to the terrain variability and environment condition. Ranks and weightage shifts positions on the basis of variation of season. These ranks and weights are carefully selected which will later be used in multi-criterion analysis to produce suitable site.

J. Multi-Criterion Site Suitability Analysis:

GIS based Multi-criterion site suitability analysis is the major part of this study and is to be carried out to produce suitable site that should have the following parameters.

- Provision to install a solar power plant without affecting the surrounding environment or not to disturb any ecology.
- Should have abundance of solar radiance over the selected site for a long period of a year.
- Accessibility to the site by all means.
- Proximity to deliver the production to the existing system.
- Reduction in initial capital of investment by providing appropriate knowledge.
- Should provide data and models to predict the future to ease the operation and maintenance.

On performing GIS based MCA for site selection, the selected or delineated sites are further scrutinized by validating it with remote sensed satellite imagery, which is to be performed as next process.

K. Creation of Basemap:

Creation of basemap is to be performed either by using Survey of India Toposheet or by using open source OSM data. This process is normally done only after the obtaining the possible sites that are feasible for solar power generation. This process is performed post Multi-criterion analysis which is used to validate and provide recommendation to the site selected.

L. Classification of LULC:

LULC classification has also to be performed to validate the result produced by the multi-criterion site suitability analysis and is normally obtained by classifying land resource satellite data either by unsupervised or supervised method. This process of classification also requires validation of the

classification result, which is to be performed by using high resolution satellite imagery from Google Earth.

M. Site Selection:

Site selection is the process of finalizing the GIS based MCA process by validating the selected site by comparing the resultant sites with LULC classification results of land resource satellite imagery. This process determines the success of the GIS based MCA for selection of solar power plant site.

N. Validation & Recommendation:

Validation & Recommendation is provided to the selected site either by ground surveying and measurements or by comparing sites using high resolution maps. Recommendations can is also be provided to the site by calculating the probable yield that can be produced by usage different type solar power plant.

V. SUMMARY

This GIS based approach for multi-criterion site suitability analysis of solar power generation plant in India establishes the advantage of using satellite-borne measurement of solar radiation falling up on the surface of the earth and also determines the importance to factors that aids and disturbs the productivity of electric energy. This multi-criterion analysis brings out the interdependencies between several environmental parameters which determines the radiant energy on surface.

Then this analysis involves collection of different remotely sensed data starting from acquisition of solar irradiance data from Meteosat satellite using SUNY model to DEM from ASTER 30m GDEM. Also this analysis involves the usage of ground based measurements of major meteorological parameters. GIS data and maps relating to transportation, water resource & utilities were also to be used for gaining appropriate results.

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