Assessment of appropriate areas for the establishment of Solar Thermal Power Plant in Rajasthan

Sajal Agarwal\textsuperscript{1*}, Harshit Kumar Gautam\textsuperscript{2} and Altaf Hasan Tarique\textsuperscript{3}

\textsuperscript{1,2,3} School of Mechanical Engineering, Galgotias University Greater Noida, 226001, Uttar Pradesh, India.

* sajalagrawal275@gmail.com

Abstract. In past years, cost of photovoltaic has decreased and investments of solar power plant have increased. In spite of this, practical studies remain paramount as cost of installation is comparatively high. One of pivotal parameters in studies is the proper location selection. So, in this paper we mix Analytical hierarchy process (AHP) and multi-criteria decision making method (MCDM) to get the results of the ideal position of sunlight based energy station in Jodhpur, Rajasthan. Using MCDM the models or factors referenced will be weighted to assess possible destinations to find a sunlight based plant. Examination and count of the loads of these variables will be directed utilizing AHP. For this study Sardarpura, Kabir Nagar and Mandore are selected as examples. These places are located in same plane. The decision of such measures is set apart by the impact introduced to the general objective; for this situation in climatic models and geomorphological. In study, it is found that Kabir Nagar is ideal position for establishment of solar power plant. This result is based on criteria, feeder capacities, solar energy potential and earth slopes. The result are ratified by considering the total amount of area and sunshine duration.

1. Introduction

1.1. Sustainable energy in India

The momentum monetary circumstance, the increase in worldwide energy interest and judicious utilization of the accessible assets drives the quest for energy choices to address the issues of the present without trading; the objective of feasible improvement is empowering progresses in the investigation into new methodologies to upgrade the assets and innovations. Keeping that in mind, a few investigations have been created here. In India, the important development regulation of ozone depleting substance discharges set by the consistence of the protocols in European Union white book [1]. Among the various kinds of environment friendly power, sun oriented thermal power is demonstrating dependable and, despite the fact that it has not arrived at adequate development, critical endeavors are being fabricated in innovation research highlighting lower fabricating prices and higher productivity. The significant degree of sun oriented force created in the Region of Rajasthan is on the grounds that this locale has probably the most elevated level of potential or sun based radiation in the country; explicitly nearby Jodhpur. The normal yearly worldwide radiation in the vast majority of its domain surpasses 2400 KW/m\textsuperscript{2} [2].

1.2. Multi-criteria decision making methods applications

The reason or extreme objective of a MCDM technique is to explore various choices in the light of numerous standards and clashing goals [3]. Few renowned MCDM includes the Analytic Hierarchy Process—AHP, its primary component is issuing the choice, whose
pinnacle is frontal intent of the issue and the potential choices to be assessed are situated at the base [4]. The AHP procedure will be utilized to decide the heaviness of the models. Another strategy generally utilized is Order Proclivity Approach by Similarity to Order Preference, this technique is at present used to recognize arrangements that are just conceivable to an exemplary arrangement applying for it some proportion of space, and hence showed arrangements are called settles. Order Proclivity Approach will be utilized in estimating the conveying limit that will fit the various areas to introduce sun based thermal energy stations. The utilization of MCDM has been led in many applications and controls [5], made an audit of the uses of the AHP model incorporated with different method.

2. Multi-Criteria Decision Making techniques (MCDM)

We analyse the choices that we can pick, just as the standards on which said options are to be assessed. This, which from the outset sight is by all accounts basic, frames segment of the entire order that is called multi-criteria decision making (MCDM) [6-8]. MCDM is a system that comprises finest option within a bunch of attainable other options. A MCDM issue with m other options and n measures can be communicated in grid design where A1; A2; ⋯; Am are achievable other options; C1; C2; ⋯; Cn are assessment models; zij is the presentation estimation of elective Ai under rule Cj; and wij is the heaviness of rule Cj. To appropriately decide the heaviness of every rule or calculate included the ultimate result of the subsequent layers, the AHP technique has been utilized inside the MCDM [9]. It is a couple shrewd correlation method of the measures that depends on a square framework where the quantity of lines and sections characteristic the quantity of rules to gauge. The AHP has broadly applied in taking care of an assortment of issues, among which are the applications identified with energy arranging and the conveying limit of environmentally friendly power offices. Then again, to assess different choices as indicated by their appropriateness, the TOPSIS strategy will be utilized. This technique involves activity in getting to know the distances to the ideal as well as the counter ideal points. The philosophy was picked in light of the fact that it doesn't need an appraisal by the master for every one of the other options; they can be assessed straightforwardly from the data set given by the GIS evaluation of every rule for every other option.

2.1. Analytical Hierarchy Process (AHP)

AHP [9] has four core ideas: organizing the intricate choice issue as a progression of objective, standards and choices, set-wise examination of components on every stage of the pecking order concerning every measure on the former level, lastly vertically orchestrating the decisions over the various levels of the chain of importance. AHP depends on a firm hypothetical establishment. The essential hypothesis of AHP might be improved as follows: we accept that we have n unique and autonomous choices δA1; A2; ⋯; Anp and that they have the loads δw1; w2; ⋯; wnp, separately. The decision maker doesn't have a clue about the estimations of wij; 1 ≤ i ≤ n ahead of time, however he/she is fit for making a couple shrewd examination between the various other options. Likewise, we accept that the evaluated decisions given by the leader on sets of choices (Ai, Aj) are addressed in a (n x n) lattice as given in Figure 1.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

**Figure 1.** Comparison matrix of AHP

The qualities allotted to aij as indicated by the scale are ordinarily in the span 1-9 [9]. Albeit the AHP procedure considers the assessment and examination of choices and accordingly the end-product of the choice issues represented. This article will be centered around the
underlying advances that will set up the loads of the measures on the grounds that the investigation and assessment of options will be created with the TOPSIS strategy.

2.2. Order Proclivity Approach by Similarity to Ideal Solution method

In MCDM, various choices must be assessed and looked at utilizing a few rules. The point of MCDM is to offer help to the leader during the time spent settling on the decision between options. Along these lines, functional issues are regularly described by a few clashing models, and there might be no arrangement which fulfills all standards all the while. Consequently, the arrangement is a trade-off arrangement as per the chief's inclinations. In this sense, TOPSIS depends on the idea that the picked option ought to have the most limited separation from the PIS (Positive Ideal Solution) and afar from the (NIS) Negative Ideal Solution. Order Proclivity Approach by Similarity to Ideal Solution method comprises of accompanying advances. The algorithm (Figure 2.) of the TOPSIS method is given below.

![Figure 2. Algorithm of TOPSIS method](image)

3. Problem Identification

3.1. Solar Energy Potential

Solar energy potential is one of most pivotal norm for finding of SPP location. PV-type area energy generation (kWh/year) and sunshine duration (hours) are sub-norm of it. It is necessary to acquire precise data whether SPP is to be established [10]. In this study, amount of sunshine available and energy of PV/area generation of each area is get from Solar Energy Potential Atlas (Figure 3-8). Data of these areas of Sardarpura, Kabir nagar and Mandore. According to it, the priority order among areas for solar energy potential is as follows: Kabir Nagar, Mandore and Sardarpura.

3.2. Feeder Capacity of Distribution Center

Feeder lines actually transmits power from any power station to its corresponding sub station. Data is obtained from the notification of Directorate General of Electricity Transmission Corporation [11]. The feeder capacity examined while installing energy generation facility in a region. Sardarpura has a number of 4, Kabir Nagar has a number of 7 and Mandore has a number of 12 allocated capacity of feeders.

3.3. Surface Slope

By the use of pythagoras theorem, the tangent of the angle will give rise in the water surface. Usually, land with slope higher than 4% have a lower priority because panels shadow next row and affect the efficiency of system adversely [12-13]. The precedence order between areas for slope is as follows: Mandore, Sardarpura and Kabir Nagar.
4. Results and Discussions

By the use of Saaty’s Fundamental Scale a matrix is formed for pair wise comparison from 1 to 9 [14-15]. A matrix (m x n) for alternatives using each criterion and matrix (n x n) for criteria where m represents the alternatives available and n represents the criteria available. The sunshine duration (Figure 3, 5, 7) and the total amount of energy/PV area (Figure 4, 6, 8) of Sardarpura, Kabir Nagar, Mandore respectively are gives below.

Figure 3. Sunshine duration of Sardarpura [17]

Figure 4. Total amount of Energy/PV area of Sardarpura [17]

Figure 5. Sunshine duration of Kabir Nagar [17]

Figure 6. Total amount of Energy/PV area of Kabir Nagar [17]
Sunshine duration of Mandore is highest in the month of July i.e. 12.09 hours (Figure 7.) while in December sunshine duration of Sardarpura is lowest i.e. 3.56 hours (Figure 3.). Apart from this total energy is almost same in all areas. After analyzing all the data by using AHP we found out that the areas situated in Jodhpur region of Rajasthan are most suitable areas and has gigantic capability for establishments of sun based thermal energy station since Jodhpur has one of the greatest level sun powered radiation in the country (Figure 4,6,8).

Now, Kabir Nagar has better other criteria like location (distance to road, distance to city, distance to power lines and distance to substation), planning regulations, protected areas, road networks, railways, waterways, mountains, etc. After Kabir Nagar, Mandore and then Sardarpura is best for sun based thermal energy station (Figure 3,5,7). When a developer wants to plant a solar based thermal power plant with specific criteria (sunshine hours, total energy, feeder capacity, surface slope, solar energy potential etc.), the starting point is to select the best area based on such criteria. However, the analysis conducted has weaknesses that could be strengthened by including linguistic labels in the methodology which could be applied in the definition of certain factors whose nature is qualitative (agrological capacity, orientation etc.).

### Table 1. Saaty’s Fundamental Scale

| Intensity of Importance | Definition           |
|------------------------|----------------------|
| 1                      | Equal Importance     |
| 2                      | Weak                 |
| 3                      | Moderate importance  |
| 4                      | Moderate plus        |
| 5                      | Strong               |
| 6                      | Strong importance    |
| 7                      | Very strong          |
| 8                      | Very strong plus     |
| 9                      | Extreme strong       |

Relative weights are calculated by taking average of the rows. Percentage wise distribution of decision points (Table 1) are found by multiplying decision matrix with weighted vector of criteria. Consistency Index (CI) is computed using equation:

$$CI = \frac{\lambda - n}{n-1}$$  \hspace{1cm} (1)
Table 2. RI Values

|   | RI  |   | RI  |
|---|-----|---|-----|
| 1 | 0.52| 7 | 1.45|
| 2 | 0.89| 10| 1.49|
| 3 | 1.11| 11| 1.51|
| 4 | 1.25| 12| 1.54|

Now Consistency Ratio (CR) is calculated and multiplication of decision matrix and weighted vector of criteria will give percentage distribution of decision points.

\[
CR = \frac{CI}{RI} \tag{2}
\]

Random Index (RI) (Table 2.), if CR is less than 0.1 the comparison will be accepted or else will be up for review [16].

Table 3. Solar Energy Potential comparison matrix

| Solar energy potential | Sadarpura | Kabir nagar | Mandore |
|------------------------|-----------|-------------|---------|
| Sadarpura              | 1         | 1/7         | 1/5     |
| Kabir nagar            | 7         | 1           | 3       |
| Mandore                | 5         | 1/3         | 1       |

Table 4. Surface slope comparison matrix

| Surface slope | Sadarpura | Kabir nagar | Mandore |
|---------------|-----------|-------------|---------|
| Sadarpura     | 1         | 5           | 1/3     |
| Kabir nagar   | 1/5       | 1           | 1/7     |
| Mandore       | 3         | 7           | 1       |

Table 5. Feeder capacity comparison matrix

| Feeder capacity | Sadarpura | Kabir nagar | Mandore |
|-----------------|-----------|-------------|---------|
| Sadarpura       | 1         | 1/5         | 1/7     |
| Kabir nagar     | 5         | 1           | 1/3     |
| Mandore         | 7         | 3           | 1       |

Table 6. Criteria comparison matrix

| Criteria       | Sadarpura | Kabir nagar | Mandore |
|----------------|-----------|-------------|---------|
| Sadarpura      | 1         | 5           | 3       |
| Kabir nagar    | 1/5       | 1           | 1/2     |
| Mandore        | 1/3       | 2           | 1       |

Table 3. shows comparison matrix for solar energy potential. Kabir Nagar has the largest capacity for establishing sun based power plant followed by Mandore and Sardarpura respectively. Table 4. shows comparison matrix for surface slope The province with the smallest slope is Mandore has smallest slope followed by Sardarpura and Kabir Nagar respectively. Table 5. shows comparison matrix for allocated maximum feeder capacity Sardarpura has a number of 4, Kabir Nagar has a number of 7 and Mandore has a number of 12 allocated capacity of feeders. Therefore, Mandore is selected as the primary place for feeder capacity criteria followed by Kabir Nagar and Sardarpura respectively. Table 6. shows the comparison matrix for criteria. The order of priority is as solar energy potential, feeder capacity and surface slope, respectively. The weights of each criteria are 0.65 for solar energy potential, 0.12 for surface slope and 0.23 for feeder capacity. The values of CR are calculated as less than 0.10 for all comparison matrices. After all the steps of AHP carried out,
percentage distribution of alternatives is obtained. Kabir Nagar has 49%, Mandore has 41% and Sardarpura has 10% share.

5. Conclusions
By using AHP we found out that the area of Kabir Nagar has the largest capacity for establishing sun based power plant followed by Mandore and Sardarpura respectively. Kabir Nagar, situated in Jodhpur region of Rajasthan is the most suitable city and has gigantic capability for establishments of sun based thermal energy station since Jodhpur has one of the greatest level sun powered radiation in the country. Kabir Nagar, Jodhpur has a territory of 22.1 square kilometers (8.5 sq mi). It is found at 26.29°N, 72.98°E. It has a normal height of 7 meters (22 feet). Mandore is selected as the primary place for feeder capacity criteria followed by Kabir Nagar and Sardarpura respectively.

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