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Investigation of feasibility study of solar farms deployment using hybrid AHP-TOPSIS analysis: Case study of India

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ABSTRACT

Presently, the usage of solar energy has increased with the advent of Renewable Energy Sources (RES) and bypassing traditional energy sources such as fossil fuels. Government of India (GoI) is adopting various policy measures to promote diffusion of solar energy across the nation and has huge solar energy investment plans in near future. In this regard, selection of appropriate site for solar power installation is of prime concern. It is a critical issue that needs to be analyzed in depth for producing solar power efficiently because various key factors viz. social, technical, economic, environmental and political aspects are associated with it. Considering the fact that there are lots of factors which affect the solar farm site selection, it is imperative to organize them in a systematic hierarchy. In this direction, present study aims to select appropriate site in an Indian case using hybrid combination of two Multi Criteria Evaluation (MCE) methods- Analytical Hierarchical Process (AHP) and fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Present investigation reveals that Sonepat is the best location for solar installation followed by Rohtak, Chandigarh, Gurgaon and Hisar in state of Haryana, India. The purpose of the investigation is to present an effective, efficient and systematic decision support framework which might help policy planners in the evaluation process of appropriate solar farm site selection in India.

1. Introduction

Energy is the national resource and fundamental need of mankind [1]. Utilizing clean energy source is a major challenging issue for the mankind in 21st century [2]. World community is facing the challenges of climate change and global warming. Adoption of Renewable Energy (RE) systems is considered among most promising solutions to address presently existing issues worldwide. RE play a pivotal role in addressing climate changing issues and boost energy security [3]. Although the objective to achieve energy efficiency has been handled deliberately prolonged, very few nations have acted in serious manner and translated this into emphatic country policies [4]. India is among those few nations that have taken initiative to implement the necessary paradigm shift in the manner of producing, transmitting and distributing RE. The social and economic development of a country depends on electrical energy availability. In India, electricity demand has been increasing at continuous rate due to growing population, recent emerging industrial and agricultural sectors etc. [5]. The rapid growth of Indian economy has initiated the need to enhance existing energy capacity [6]. It is estimated that 20 GW of additional generation capacity per annum can only fulfill the growing needs [7].

In this direction, solar energy can play crucial role to increase energy independence and mitigate global warming aftereffects [8–10]. India is among few fortunate countries which have enormous potential of solar energy [11]. It receives solar radiation almost throughout the year because of its favorable geographical location [12–14]. India occupies seventh position in producing energy in the world and has plenty of both exhaustible as well as RES. Harnessing the untapped and unmatched solar potential would not only assist in improving total energy mixture but also reduce the emission of harmful and toxic gases. India has huge investment plans for solar power installation in near future such as 100 GW till 2022 in national solar mission [15–19]. To accomplish this target, it is necessary to identify the feasible locations for deployment of solar energy in the country. However, the present investigation focuses on Haryana state of India. The research motivation for present investigation is presented in subsequent subsection.

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1.1. Motivation of present study

Solar farm site selection is a vital strategic decision. It may puzzle the electricity generation, grid enterprises and concerned authorities due to amalgamation of economical perspective and sustainable development of the concerned region. Great efforts are underway regarding lowering the manufacturing costs and achieving higher efficiencies because solar energy technologies lack adequate maturity so far.

Moreover, the locations exhibiting sound solar potential need not be most suitable sites for establishing solar farms because there are lot of factors which affect this decision [20]. Therefore, solar farm site selection becomes one of the most indispensable concerns for administrators of solar industry for maximizing the overall performance [21]. Previous studies in this regard have focused on the factors influencing solar farms and assessed the positive or negative impacts. Literature review reveals that no study is available that ranks the influential factors of solar farm site selection.

Haryana state was formed on 1st November 1966. It is a major industrial hub that enjoys the 1st highest per capita income of the nation [22]. Within a couple of decades, it established itself as a prosperous entity. It shows growing agricultural sector as well as fast growing industrial and educational sector. Its economic strength is due to achievements in the fields of information technology, software exports, health sector, telecommunication, petro-chemical production and power generating capacity [23]. Haryana Power Generation Corporation Limited (HPGCL) has presently installed generation capacity of 2782.4 MW due to thermal power stations at Panipat, Hisar and Yamunanagar [24]. Haryana Government is planning to generate 200 MW power using solar energy, out of which 50 MW will be generated in 2015–16. Moreover, Haryana Renewable Energy Department (HAREDA) is also putting efforts to install 5 MW solar power plants sanctioned by Ministry of New and Renewable Energy (MNRE) in 2014-15. A feasibility analysis is being carried out to identify 2000 acres of land in Haryana state [25]. The present study is an effective step in this direction. In view of the above mentioned facts, certain objectives are set up which are presented in forthcoming subsection.

1.2. Objectives of present investigation

The present energy needs are being fulfilled using exhaustible and depleting fossil fuels which affects the environment in harmful manner [1]. Recognizing this serious concern, Haryana Government notified a “Policy for Promoting Generation of Electricity through RES” on November 23, 2005. Its prime objective is to provide favorable environment for solar energy establishments and its products. But for establishing solar farm, it is the need of hours to identify an accurate, systematic and efficient decision frame work which might assist the decision makers. Selecting unsuitable location for solar power plants may lead to wastage of energy and resources [5]. In this direction, the objectives of present study are as follows:

- To identify the key factors affecting the deployment of solar farm before its site selection.
- To organize and prioritize the recognized key factors to develop solar farm site selection decision framework.
- To select appropriate site for solar farming considering a real world example- Indian case.

Haryana state has been selected as a case example for present investigation because of its new peaks of growth and glory in industrialization, infrastructure and setting new benchmarks for the peers to achieve all-round progress [26]. Haryana state is segmented into four zones to select five promising locations and the best one is identified using AHP-fuzzy TOPSIS. Fuzzy decision-making is a powerful technique for decision making [27]. In the present research, AHP and the fuzzy TOPSIS have been identified as appropriate methodologies. AHP is a key multi attribute decision assisting method popular in both academic research and engineering applications. The unique features of AHP such as simple to understand and apply in complex issues spread it to multiple disciplines worldwide. TOPSIS is another technique that assists decision makers in multi-criteria real world issues such as organization of the complex problems to analyze, compare, and rank alternative solutions [28]. The present study is directed towards providing a support tool to the decision makers so that appropriate site may be selected to generate solar power efficiently.

The present investigation is organized as follows: Section 2 discusses related work regarding the solar farm site selection. Section 3 presents the recognized key factors through extensive literature review which might influence the selection of solar farms. Section 4 highlights the framework of present investigation. Section 5 elucidates the methodology utilized to carry out the investigation. A real world example has been presented in Section 6. In Section 7, results of AHP and fuzzy TOPSIS techniques have been discussed. Section 8 gives discussion of findings of the present investigation followed by concluding remarks with future suggestions.

2. Related work

This section explores the relevant literature on solar farm selection and discusses the research gaps to reach to the present investigation.

2.1. Solar energy farming and site selection

It is the prime concern to deploy sizable solar systems at suitable sites on national scale. Huge investment of land, money and manpower is required to install solar power plants. The identification of feasible geographical areas for implantation of solar projects is not only influenced by solar potential but other factors such as economic, environment, technological, society specific and risk aspect affect also the same [29]. Therefore, identification of the suitable geographical areas for developing solar plants is crucial [30].

The selection of well-suited site is among fundamental decisions in the starting-up, expanding, or relocating the units [21]. It is extremely important to identify and prioritize the feasible areas before construction of expensive solar farms so as to have the best productivity and moderate payback [29]. Specifying the priorities for solar projects would assist in lowering the socioeconomic cost, developing infrastructure, and preventing the environmental penalties. Moreover, such strategic decisions will affect the operation and maintenance of the system economically and help in developing the concerned regions in the most sustainable manner.

2.2. Importance of social, technical, economic, environmental and political factors

Recognition of social, technical, economic, environmental and political (STEEP) factors is the preliminary and vital phase for establishment of new solar farms and to avoid delays in approval procedures of central and state government [5]. An outline of the related work by various researchers is presented here. For example, Schlecht and Meyer has considered solar irradiation, site attributes, infrastructural connections, cost of development, market and political factors for pre-feasibility analysis and site selection for Concentrated Solar Power (CSP) [31]. Uyan has studied economic and environmental factors for study of selection of solar site in Karnipar district in Turkey [20]. Effat has considered various dimensions for solar site selection in Egypt country such as solar radiation mapping, aspect angle, proximity to power lines, main roads and cities [32]. Chen et al. has considered four dimensions in solar farms site selection that includes environ-