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Optimal sizing of photovoltaic/battery/diesel based hybrid system and optimal tilting of solar array using the artificial intelligence for remote houses in India

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ABSTRACT

The optimal sizing and tilting of a hybrid photovoltaic/battery/diesel generator system are performed in this paper for the remote locations in India, using artificial intelligence techniques (AIT) without the metrological data. Initially, the optimal sizing and tilt angle calculation were done for different cities of India, for low cost and zero load rejection with the available metrological data. Using the latitude, longitude and altitude of any remote location, the optimal size of a hybrid system is found through AIT. The tilt angle for the photovoltaic (PV) array to be installed in any remote location is also predicted to reduce the hourly usage of diesel generator (DG) for all the four seasons and the number of visits for manual tracking is optimized to three per year through this research. The predicted optimal values, using adaptive neuro fuzzy inference system (ANFIS) and artificial neural network (ANN) are compared with the calculated values. The life cycle cost (LCC) of the optimized hybrid system is compared with the standalone PV as well as the DG system cost to prove its cost effectiveness. The validity of the sizing procedure for different load demand is also proved with loss of load probability (LLP) of 0.0026.

1. Introduction

Due to the raise in lifestyle facilities, the energy demand is rapidly increasing. Especially, the developing countries like India are having fast growth even among worldwide recession. Though the Indian sub-continent is running toward the third position in the world on the platform of the largest energy consumer, the overall electrification rate in India is 64.5%, while 35.5% of the population still lives without access to electricity. Of those who are in access with electricity in India, are also distributed with intermittent and unreliable supply. This affects India's manufacturing capacity directly and slows down the growth and education of the poor people. As the country has not highly developed economically, it could not have the resources to extend its generation and the utility lines immediately for all the scattered population in the remote areas. So, this research is to motivate the poor and needy toward the low cost optimized renewable energy system for their remote houses in case of no utility access. In the study of economic viability of the standalone photovoltaic system (SAPV) [1] it has been proved that for the lesser load demand, the usage of solar system is economical through the life cycle cost analysis. Also, in literature, the authors [2] claimed that to make the system independent from utility in remote areas, integration of other sources is vital. So, in this paper a hybrid PV system is chosen considering the climatic variations and lesser load demand. For the remote Indian houses, by considering the economic status, among the different hybrid systems the solar PV system is included with the current trend of using diesel generator back up to reduce the initial cost. Ashok [3] claimed that for the region of Western Ghats, the micro-hydro-wind system is the optimal combination. But as the other locations of India are facing water scarcity for the basic life style, this system cannot be used. So to receive the uninterrupted electricity with the low cost and reliable system, the optimal sizing procedure has to be implemented [4] in this hybrid system. Due to the high dependency of the performance and rating of solar based system on the climatic conditions [5], the different parameters like beam radiation, diffused radiation, latitude, longitude and altitude are studied and collected for different locations based on the requirement for sizing. Along with the optimal sizing, to reduce the hourly usage of the diesel generator through maximum PV energy generation, the optimal tilt angle is calculated in this paper with suitable models. Even though 40% extra generation is possible through automatic tracker usage [6], to reduce the wastage of energy, the manual tracking

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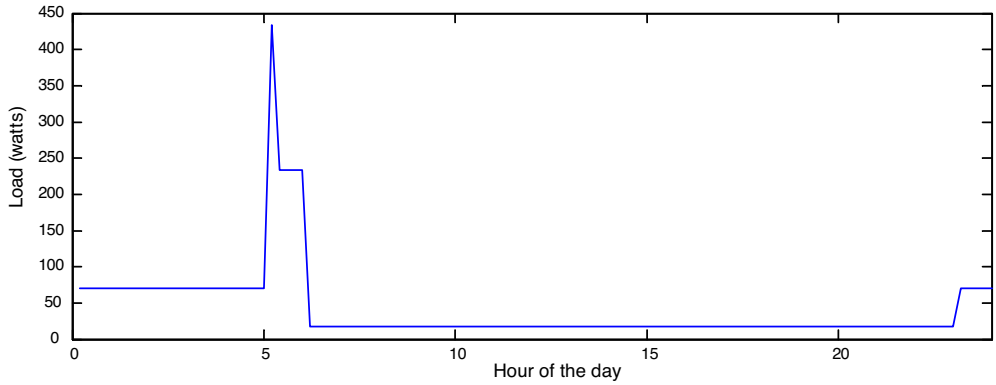

Fig. 1. Time series based load.

is discussed here. The authors [7] discussed the different schemes of solar panel tilt angle optimization to improve the efficiency and the reliability of the system with no additional cost for the tracking. The different methods are monthly based optimization; Seasonal based optimization and the yearly based optimization. The building integrated photovoltaic systems (BIPV) on all of the available roof areas can make each and every house an energy-positive building [8]. Even though, there is a significant increase in the total electricity generation through the BIPV of housing units with certain shape-site configurations [9], the optimal sizing alone is considered here to avoid the building revamping. Since, the optimal sizing of a hybrid system and the optimal tilting is discussed [7,10] only with the available metrological data of a particular location, the prediction ability of the AIT is used in this paper for the location with no metrological data. In literature [11–13] there is only a prediction of performance, energy consumption, sizing curve, solar and wind energy parameters. Considering this huge research gap on the prediction of sizing and tilting of a hybrid energy system, the problem statement for this work is identified as – which optimal combination of PV array, battery and DG will contribute for the required

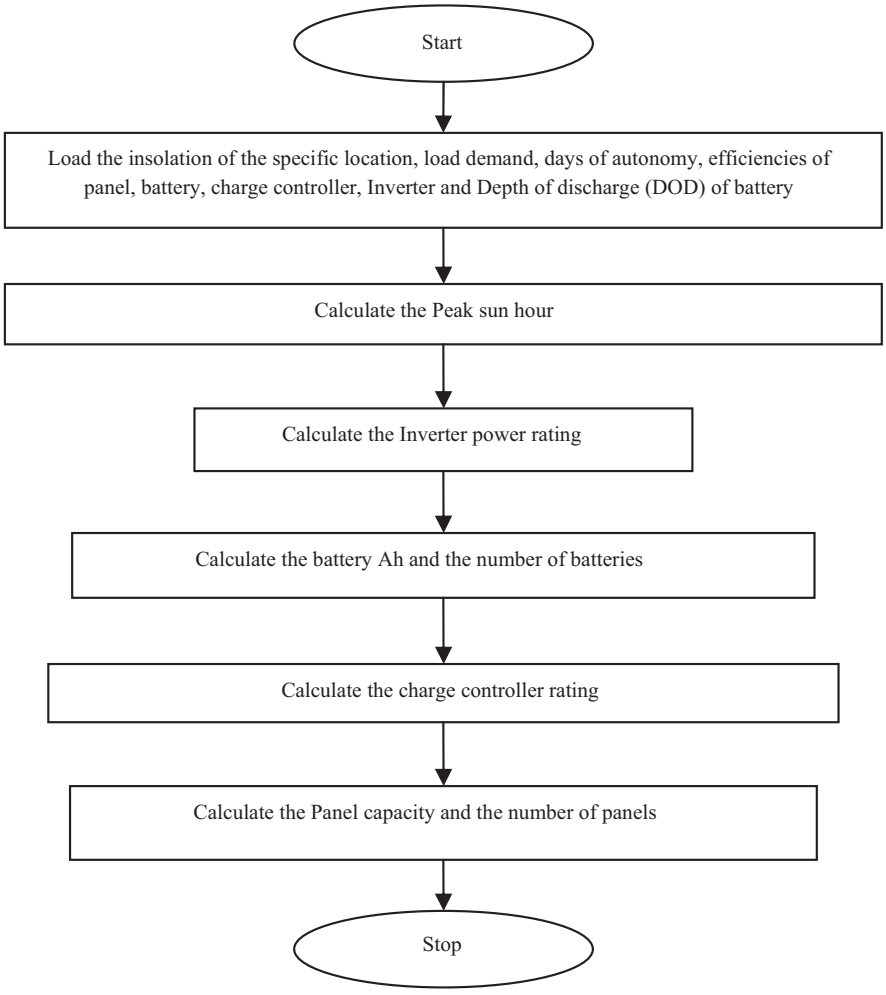

Fig. 2. Flowchart for sizing of stand-alone PV system.