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Introduction

1.1 INTRODUCTION

Solar photovoltaic installed capacity in India has reached 4,060.65 MW [TERI, 2015]. Inspired by the Jawaharlal Nehru National Solar Mission (JNNSM), The Indian Government has set the target of solar installation capacity to be 1,00,000 MW by 2022 under Phase 1-3 [MNRE, 2015]. Here, grid connected rooftop solar PV system and Large-scale grid connected solar PV systems are playing an important role in the targeted solar national mission [MNRE, 2014]. Solar energy is considered as the fastest growing technology in the landscape of the non-conventional power sources. Photovoltaic technology is considered to be a clean and economical energy source among the renewable energy resources [David *et al.*, 2014].

Most of the developed countries like Germany, Denmark, and Spain are making the major contribution in solar power in grid integration [Sahu *et al.*, 2015]. Here, the main source of solar power is rooftop and ground-based installed solar photovoltaic power plants. In the future, development of solar power capacities is more likely to take place in wastelands, high altitude and offshore. A high value of Global horizontal irradiation (GHI) and accessibility of suitable land allow installation of large-scale solar photovoltaic power plants. The main advantages of wastelands, high altitude and offshore are higher GHI, large area to install PV. Solar power is one of the major non-conventional resources which can help balance the demand and supply of electrical energy.

Solar power highly depends on solar resource and because of variation in solar resource due to diurnal effects and seasons, power generated by the photovoltaic system changes with time. So this variation in solar irradiation and seasonal changes are the main causes of the variation of generated solar power. Integration of solar power generation can be difficult with conventional power sources under the condition of high variability which can be the main cause of high cost and more complexity [Wan *et al.*, 2015]. So, solar power forecasting plays a key role for Independent System Operators (ISOs) and Grid integration which can provide relatively low cost and high reliability of the grid [Orwig *et al,* 2015]. Forecasting of generated solar power under different time intervals becomes even more important in grid regulation, load-basis generation, scheduling and unit commitment [Eftekharnejad *et al.*, 2015].

Forecasting concepts for power system operation like load forecasting, resource allocation, and planning were introduced in the mid-sixties [Feinberg and Genethliou, 2005]. Forecasting problem is classified either as operation, planning or energy imbalance (EI) [Kaur *et al.*, 2016]. Accurate solar forecasts have been indirectly more important and the problem has been proven to be complex due to the impact of seasons on the amount of solar irradiation. Therefore, in last few years, a number of regression and time series methods have been developed for forecasting of solar power generation [Inman *et al.*, 2013].

1.2 AUTHOR'S CONTRIBUTION

This work proposes the use of neural network based models of forecasting the generated power output from the solar photovoltaic plant at small and large scale level. 101 kW and 5 MW Solar PV plants are considered as small and large scale respectively. The main objective of this work is to forecast solar power generation for particular forecast horizon for mentioned PV plants. In this study, data is taken from 101 kW Indian Institute of Technology Jodhpur grid connected rooftop- based solar photovoltaic power plant from Jodhpur and 5 MW Gujarat Power corporation Limited Charanka Ground-based solar photovoltaic plant from Gujarat. This work presents an overview of Neural Network (NN) based models and their applications in the field of solar photovoltaic plant generation forecasting. First, some fundamentals of neural networks are explained including perceptron and multilayered neural network. In this work, Artificial Neural Network (ANN) and Generalized Neural Network (GNN) models are used for forecasting the solar power plant generation at small and large scale level. The proposed forecasting model using generalized neural network approach helps to forecast power generation during critical variation in solar irradiation and different seasons. This can overcome the shortcomings of conventional neural network approaches. The generalized neural network has adaptability and be trained with values of input parameters, which are measured in real time, so the generalized neural network is able to provide much better results for complex and dynamic problems like solar power generation forecasting.

1.2.1 Problem Description

Forecasting has now become an important part in most of the domains of engineering. In the last few years, several types of forecasting approaches have been developed such as Time series–based methods including Auto Regressive (AR), Moving Average (MA), Auto Regression Moving Average (ARMA), Auto Regressive Integrated Moving Average (ARIMA), and other regression models. The objective of this study is to develop an advanced forecasting model using neural network approach for solar power generation forecasting.

1.2.2 Proposed Work

It is proposed that the application of a generalized neural network is more powerful and has more flexibility. It is obtained by modifying the standard neural network architecture by introducing fuzzy concepts to make ANN technology more flexible, more computationally efficient, along with the improved level of accuracy. The generalized neural model (GNN) is to train and test the solar power generation forecasting problem. The training, as well as testing performance of generalized neuron model, has been compared with the standard ANN. Then, the tested generalized neural network model has been used for modeling of the solar power generation forecasting. The performance has been compared with actual results under the seasonal and monthly solar power generation for small scale and large scale solar PV plants.

1.2.3 Proposed steps

The neural network based models will be used and applied to power system applications like grid integration and energy imbalance market, in this work.

The basic outline of the proposed work follows:

1. Literature survey of neural network approach for solar power generation forecasting of small and large-scale solar photovoltaic power plants.
2. Study of the small and large scale solar photovoltaic power plants.
3. Data collection and data pre-processing.
4. Develop a forecasting model using Artificial Neural Network (ANN) approach.
5. Develop a forecasting model using Generalized Neural Network (GNN) approach.
6. Finally, apply it to the solar power generation forecasting problem.
7. Then, test and validate the forecasting model using Neural Network (NN) approaches on the basis of standard error metric indices.

1.3 THESIS ORGANIZATION

The thesis has been broadly organized into six main sections. The first section **(Chapter 2)** includes a review of the literature on solar power generation forecasting. The objective is to introduce basic ideas of forecasting methods for solar photovoltaic plant generation. This part also describes the conventional forecasting approaches and other neural network models for forecasting of solar plant generation.

The second section **(Chapter 3)** deals with the description of the solar photovoltaic plant under small scale 101 kW Indian Institute of Technology Jodhpur grid connected rooftop solar photovoltaic power plant and large scale 5 MW Gujarat power corporation limited, Charanka ground-based solar photovoltaic power plant.

The third section **(Chapter 4)** includes the development of forecasting model using the artificial neural network and generalized neural network approach.

The fourth section **(Chapter 5)** includes the Performance indices of PV Power Plant.

The fifth section **(Chapter 6)** introduces the forecasting results obtained from the artificial neural network and generalized neural network based approaches for considered case studies.

Finally, the sixth section **(Chapter 7)** summarizes and concludes the work and discusses the future possibilities in this work.

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