Neurocomputing 170 (2015) 428–438

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Reservoir based learning network for control of two-area power system with variable renewable generation

Iroshani Jayawardene [a], Ganesh K. Venayagamoorthy [a,b,*]

[a] Real-Time Power and Intelligent Systems (RTPIS) Laboratory, The Holcombe Dept. of Electrical and Computer Engineering, Clemson University, Clemson, SC 29634, USA

[b] School of Engineering, University of Kwazulu-Natal, Durban 4041, South Africa

ARTICLE INFO

Article history:
Received 13 September 2014
Received in revised form
24 December 2014
Accepted 26 January 2015
Available online 14 July 2015

Keywords:
Echo state network
Extreme learning machine
Phasor measurement units
PV power
Prediction
Tie-line power flow control

ABSTRACT

The penetration of renewable energy sources into the electric power system is rapidly increasing. Integrating variable renewable energy sources into the transmission grid introduces challenges in real time power system operation. This causes power and frequency fluctuations and raises stability concerns. In this paper, a 200 MW photovoltaic (PV) plant is integrated into a two-area four-machine power system. In order to maintain the system frequency, a dynamic tie-line power flow control is implemented using predicted PV power as an input to the automatic generation controller in Area 1, which transfers power to Area 2 with PV generation. The prediction performances of two learning reservoir based networks, an echo state network (ESN) and an extreme learning machine (ELM), are investigated for day and night time operations. The experimental study is performed using actual weather data from Clemson, SC and a real time simulation of a utility-scale PV plant integrated power system. Phasor measurement units (PMUs) are used to provide input signals to automatic generation controllers in the two area power system. Typical tie-line power flow control results based on ESN and ELM models are presented to show the impact of predicting PV power in improved automatic generation control with variable generation. ESN and ELM models provide minimal tie-line power flow deviations from reference power flows during day and night time operations, respectively.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

The use of fossil fuel as an energy source introduces several environmental concerns due to greenhouse gas emissions and environmental pollution. Furthermore, the worldwide price fluctuations and uncertainty in fossil fuel has become a challenge in securing sustainable power systems. These reasons increase the requirement of clean, safe and environmental friendly power sources. Therefore the use of environmental friendly, sustainable and renewable energy sources such as photovoltaic (PV) and wind power has been increasing [1]. Renewable energy sources can be used with an alternative power or demand side management technologies to get maximum penetration of clean energy. Among the existing renewable energy sources, the use of PV plants is increasing due to the high presence of solar insolation in many places for longer periods of time and incentives from governments to encourage clean sources of energy [2].

Even though the use of renewable energy has advantages compared to use of fossil fuels, concerns still exist in the reliability and security of the power systems with high integration of PV power. The power and frequency fluctuations in systems with utility-scale MW PV plants affect the steady state and transient stability of the system due to the unpredictable variable PV generation [3]. PV power generation mainly depends on weather conditions such as solar irradiance, temperature and cloud covers. The effects of the variability and uncertainty caused by PV plants in bulk power system operation can be reduced by accurate short-term predictions of PV plant power outputs.

Artificial neural networks (ANNs) have been used widely for nonlinear prediction such as power system loads, wind power generation and PV power generation. Echo state network (ESN) and extreme learning machine (ELM) are reservoir based neural networks, which are rich in dynamics, fast and easy to develop. Therefore, these two network models are developed and compared for predicting PV plant power outputs during day and night conditions in this paper.

A two area four machine power system (Fig. 1) is considered in this study. Area 1 transfers power to Area 2 which has a 200 MW

* Corresponding author.

http://dx.doi.org/10.1016/j.neucom.2015.01.089
0925-2312/© 2015 Elsevier B.V. All rights reserved.

utility-scale PV plant installation. The power system with the PV plant is simulated on the real time digital simulator (RTDS). The PV plant output in the RTDS simulation is generated using actual solar irradiance and temperature data captured by the Real-Time Power and Intelligent Systems (RTPIS) Laboratory weather station at Clemson, SC. Frequency and tie-line power flow control are essential to maintain the security of the power system. In other words, fluctuations in the frequency and tie-line flow as a result of variations in the PV plant power needs to be minimized. A secondary control strategy, automatic generation control (AGC), with tie-line power flow control was implemented in Area 1 to maintain the desired system frequency and to minimize power fluctuations [4,5]. AGC is capable of increasing/decreasing power outputs of conventional generators (G1 and G2) in Area 1, varying the tie-line power flow to balance the PV power variability and achieve maximum penetration of PV power in Area 2. The AGC in Area 1 accomplishes the above mentioned objectives using predicted PV power reference values to control the tie-line power flow. The optimal frequency bandwidth of the AGC is determined by simulating the system with different PV power prediction time steps. Phasor measurement units (PMUs) are used to provide input signals to the automatic generation controllers in the two area power system.

The remainder of this paper is organized as follows. Section 2 describes the two-area power system with a utility-scale PV plant used in this study. The tie-line bias control with PV power prediction is described in Section 3. Section 4 describes the reservoir based learning networks used to predict PV power output. Typical results obtained are presented in Section 5. Finally, conclusions are given in Section 6.

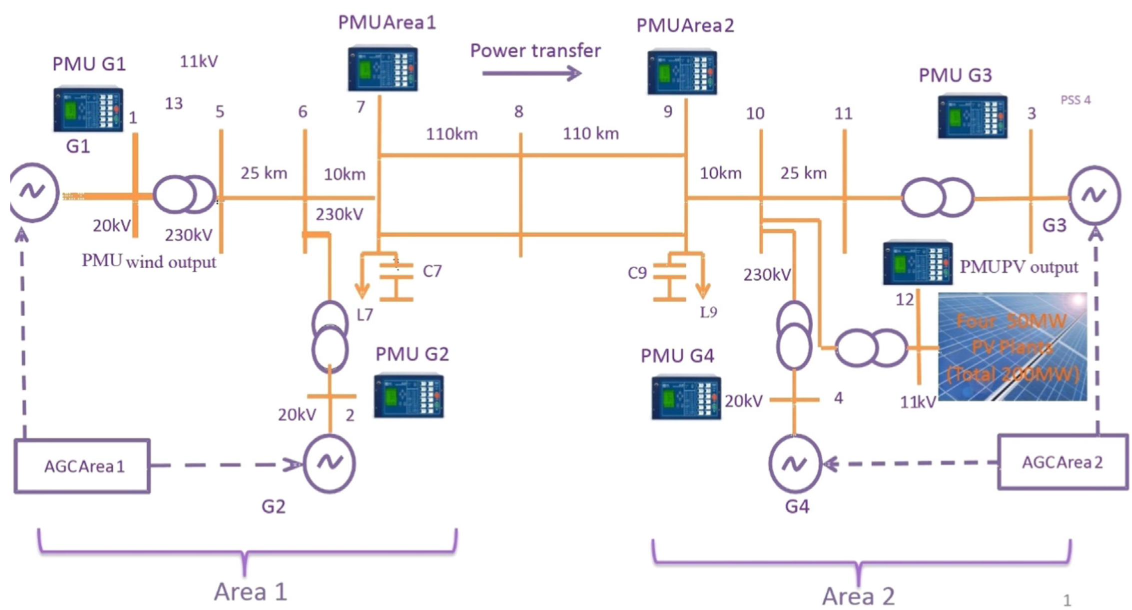

Fig. 1. Two-area four machine power system with a 200 MW PV plant connected at bus 12 in Area 2. Each power system area is equipped with an automatic generation controller. AGC in Area 1 performs tie-line bias control and AGC in Area 2 performs frequency control.

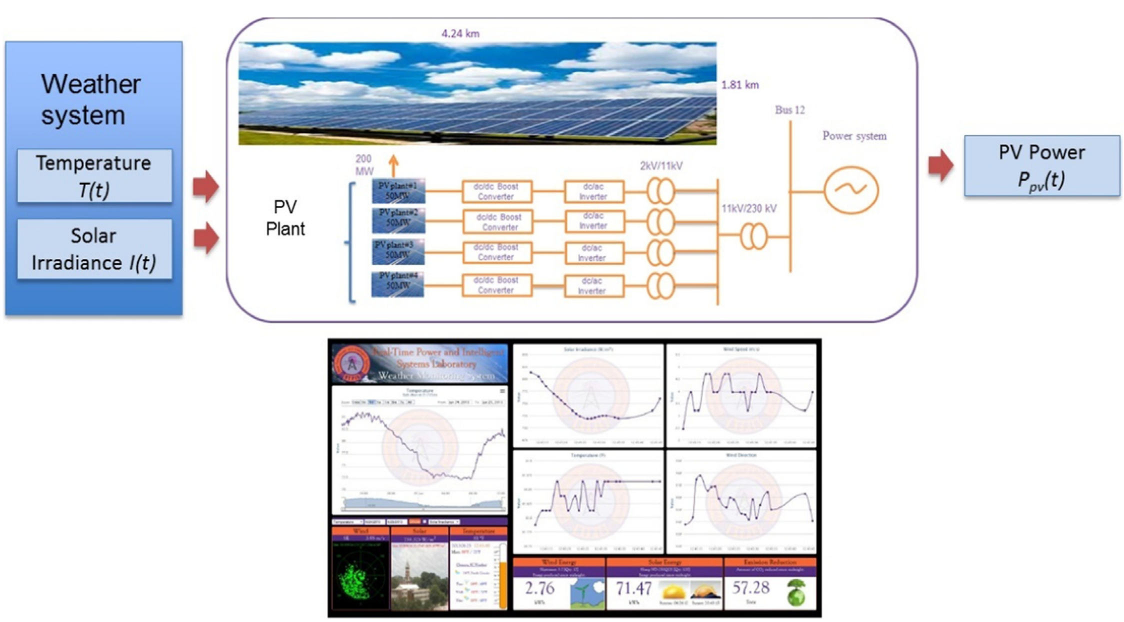

Fig. 2. 200 MW PV plant and the RTPIS Lab (Clemson, SC) weather monitoring system.

Download English Version:

https://daneshyari.com/en/article/406061

Download Persian Version:

https://daneshyari.com/article/406061

Daneshyari.com