Artificial Neural Network Controlled Load Frequency of Wind Integrated Power Systems

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ABSTRACT

The load frequency control (LFC) is a significant issue for maintaining constant frequency in the operation of electric power systems. The majority of LFCs are outfitted with integral controllers. The integral gain is set to a level that strikes a balance between rapid transient recovery and low overshoot in the overall system's dynamic response. In addition, these controllers are sluggish and cannot account for changes in operating condition and nonlinearity within the generator unit. The variable speed of Doubly Fed Induction Generator (DFIG)-based wind turbines results in variable power generation and nonlinearity in the systems. Large frequency deviation resulting from increased wind power penetration. This places stress on thermal and quick-response generators (Increased requirements on system flexibility). Additionally, it lacks robustness. Therefore, controllers based on Artificial Neural Networks (ANN) can alleviate these issues. The proposed LFC study has implemented ANN-based ANFIS controllers on two area wind integrated power systems in order to simulate the dynamic response of control areas with different loading conditions. The obtained simulation results are satisfactory. The results indicate that ANN-based ANFIS controls wind-integrated nonlinear systems more effectively.

Keywords: Load frequency control (LFC), Proportional-integral (PI) controllers, Doubly fed induction generators (DFIG), Artificial neural network (ANN), and Artificial neural frequency identification system (ANFIS).

INTRODUCTION

Electricity is a base of everything in the present times.The dependence on the electricity is increasing day by day. To cater with the increasing demands the generated power must be regulated to meet the actual power demand while preserving the highest quality for electrical equipment to perform optimally. Due to changing environmental conditions leading to unexpected power demand the conventional power generating plants are unable to meet the rising demand. The increasing demand and shortage of power generation creates degradation in power quality and rapid system disturbances. The imbalance of active (generation) and reactive (Consumption) during the transmission leads to power quality degradation.

Both reactive and active powers influence the frequency and voltage of a system. Alternators have two independent control loops, Automatic Voltage Control (AGC) and Automatic Voltage Regulation (AVR), to regulate frequency and voltage fluctuations, separately. Load Frequency Control (LFC), an essential function of AGC, is used for frequency deviation control with active power control, whereas AVR is used to regulate terminal voltage with reactive power control.

In the operational power system, the vast majority of research focuses on load frequency control. In recent years, intelligent control methods have supplanted the conventional PI controller used in the majority of industrial applications to control frequency problems. The optimised tuning of these intelligent controllers with renewable penetration and non-linearity has been accomplished using numerous techniques and algorithms. The literature enlightens with the work on the pioneers in proposing the optimal frequency governor for a two-area power system[1]. Both control areas are equipped with non-reheat steam turbines for the development of a model for load frequency control.The American Power Systems Committee specifies that the frequency bias for each control area must be equal to the area's frequency response characteristic (AFRC). However, the committee failed to explain the rationale behind this practise, and the author suggested and demonstrated with optimal control methods that not only improved results, but also greater stability margins, can be obtained by adjusting the bias to a slower rate. The enhancement of the variable model for multi-area load frequency issues have also been worked [2]. Mathematical equations were required for the implementation of the advanced control scheme. Also discussed was the feedback controller, which was significantly more effective in terms of construction than the controller previously designed. The result demonstrates effective methods for enhancing the dynamic response and stability limitations of the load frequency control system. The impact of instantaneous variations in wind power on the operation of the system when the components were further subdivided into slow, fast, and ramp components. A long-term simulation model demonstrated that changes in wind power have a minor impact on the overall normal operation of the power system, but there is still a risk of random increases in wind power and power demand that can exceed the system's remaining capacity[3]. In addition, it discussed the various wind-related methodologies and control area performance that can aid in connecting the primary grid to the remainder of the system. The implementation of a proposed DFIG wind model was employed as a power converter as the controlled voltage source to regulate the flow of rotor current in order to obtain the optimal power output [4]. The use of wind turbines with variable speed for effective pitch control is studied by *Muljadi & Butterfield*[5]. In addition, the controlling scheme for the system to minimise load while maximising energy for improved performance was discussed. The effect that unwelcome variations in the wind have on the frequency control of the electricity system in Ireland [6]. Additionally, the various topologies associated with wind generation were discussed. Up until now, there was only one method that could fulfil this requirement, and its wind turbine did not provide maximum power, leaving a margin [7].

Wind turbines store kinetic energy in the rotating blades of their generators. It also discussed the value of inertia, which was not yet displayed but was incredibly useful for the grid. Due to this, the turbine's inertia and frequency control can easily synchronise with the grid for a brief period of time [8]. Unwelcome variations in load cause repeated, continuous variations in frequency and tie line power with respect to time, which can be minimised using a variety of controllers, thereby enhancing the system's efficiency [9]. This instantaneous control of changes in frequency and tie-line power is essential for the system's smooth operation in the presence of high wind penetration. The PSO method has been enhanced to incorporate parameters of membership functions [10].

The concept of an additional control loop connected to a DFIG-based wind turbine to support the inertia response by discharging the turbine's kinetic energy when the generator's frequency decreases [11]. In addition to the generation rate constraints, *Liu Xiangjie et al.* [12] discussed the application of predictive algorithm for the LFC. In his investigation, he employs this generalised predictive algorithm for the LFC to create a Controlled Auto-Regressive Integrated Moving Average model.*B. Franoise et al.* [13] explained the application of layered neural networks for non-linear system control. In addition, the implementation of a feed-forward neural network controller within a two-area system that can further reduce frequency variation and produce zero steady-state frequency error was discussed. The outcome demonstrated the training of the controller using back propagation and a time algorithm.

A.P. Birch et al. [14] discussed the use of neural networks in the predictive LFC standard. In addition, the advantages of the proposed control scheme over the conventional schemes were discussed. The results validate the efficacy of the proposed technique, which can further enhance the system's overall efficiency.*H. Shayeghi et al.* [15] discussed the use of a non-linear ANN controller that depends entirely on the AGC of the power system. The simulation result demonstrated the implementation of the proposed controller, which was both highly effective and more efficient in the case of GRCs. In addition, it demonstrated that the proposed controller is more capable than conventional PI controllersAlso, a layered ANN controller for the minimization of LFC-related problems in the power system and implemented it in three interconnected thermal and hydro regions. The study's findings demonstrated that this controller is more effective than conventional ones [16]. The application of artificial intelligence to the power system was discussed [17]. In addition, it discussed the artificial intelligence technique that was subsequently employed for the various conventional artificial tool applications.

The stability of the designed control scheme under nonlinearity and load change is verified. The coordinated unloading scheme is used to track active power demand from the system response in order to design wind-generated models. This coordinated control strategy can achieve a rapid response to load changes without incorporating pitch angle control for wind turbines. The impact of this control is investigated via simulation of system design.

Due to economic and environmental constraints, conventional power plants are unable to meet the rising demand. Recent increases in renewable energy penetration can be attributed to the growing demand for and the benefits of RES. After the 1990s, the generation of electricity by wind turbines expanded and has accelerated in recent years. India ranks fourth behind Denmark and the United States in terms of wind power generation capacity. But India has the highest growth rate among them. Modern power grids are densely populated with wind turbines (WTs). Due to the variable nature of power generation, however, WT participation in primary frequency control is restricted. In addition, PI controllers may not be able to control frequency oscillations in a renewable power system that has been penetrated by load disturbances.

In order to control the real power and change in frequency with less complexity in a wind-integrated nonlinear system, intelligent techniques are introduced. The primary objective of this study is to examine the dynamic performance of ANFIS controllers based on neural networks. In a wind-penetrated system, in response to a load disturbance and as a primary frequency controller.

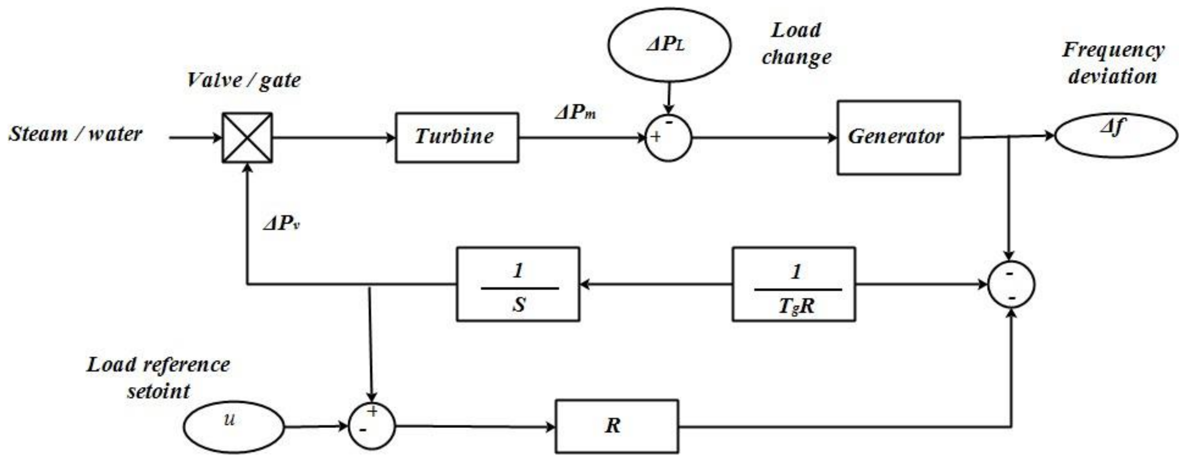

Figure 1 Speed governing system block diagram[1]

METHODOLOGY

A typical power system model with generating units, tie-lines, and power system loads. Power produced by a generator from natural sources, transmission lines transmit bulk power from generating units to loads, and a distribution system provides power to various loads. The fluctuating load on the power system causes disturbances that can lead to instability and, in extreme cases, blackouts. Using a mathematical model and Simulink, it is necessary to examine load change response in order to solve this issue. A mathematical model of load change is obtained by linearizing the operating point in real time. However, nonlinear differential equations must be solved for large perturbations. LFC is fundamentally reliant on small signal analysis. The linearized models of the governor, turbine, and power system, which are frequently used for modelling isolated and interconnected systems

Method of ZIEGLER–NICHOLOS PI controller Tuning

Developed by John G. Ziegler and Narhaniel B. Nichols, the ZIEGLER–NICHOLS tuning method is a trial-and-error technique for tuning the PID controller.Zeroing out the integral and derivative gains.The Kp gain is then increased from 0 until it reaches the maximum gain value of Ku where the output of the control loop is stable and oscillates consistently. P, I, and D values are set based on Ku and oscillation period Tu, depending on the controller type employed

The intelligent technique of artificial neural networking is applied to a variety of optimization problems. ANN controllers are based on the human brain's structure. These controllers operate similarly to the brain in that they learn from previous experience. The controller stores historical data that is used to construct a vast parallel network and train the network to solve specific problems. Neurons, a specialised type of cell that stores information and reflects past experience while performing similar tasks, are the fundamental component of the human brain. Similarly, ANN controllers are comprised of neurons that resemble highly complex parallel and nonlinear processing systems. These controllers consist of an input layer, a concealed layer, and an output layer. Initially, the input layer transmits signals to the hidden layers, where computation is performed, and finally, the output layer transmits output signals. These controllers are trained using a Back Propagation algorithm

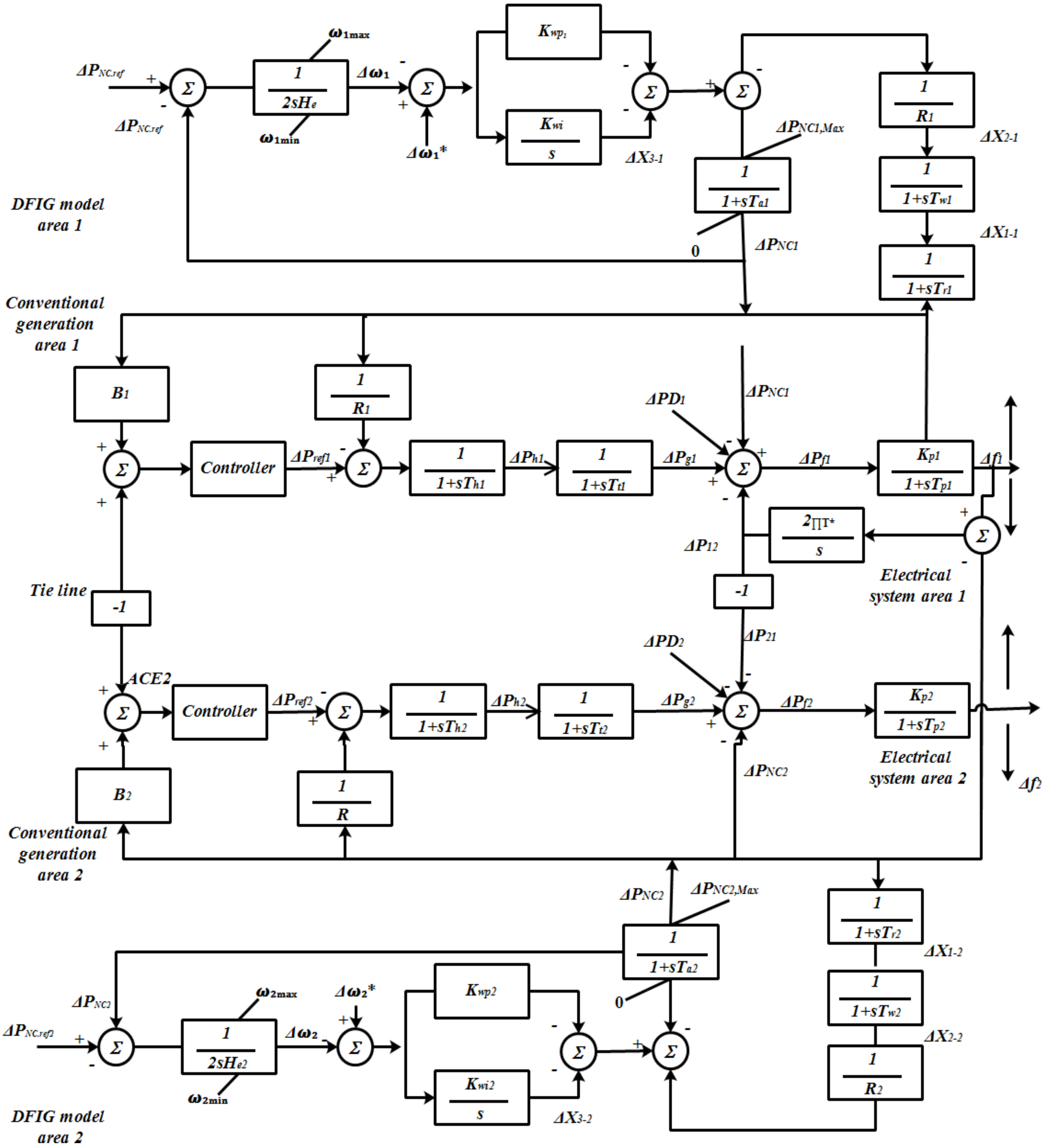

Figure 2. Linearized model of wind integrated two area systems with secondary control loop

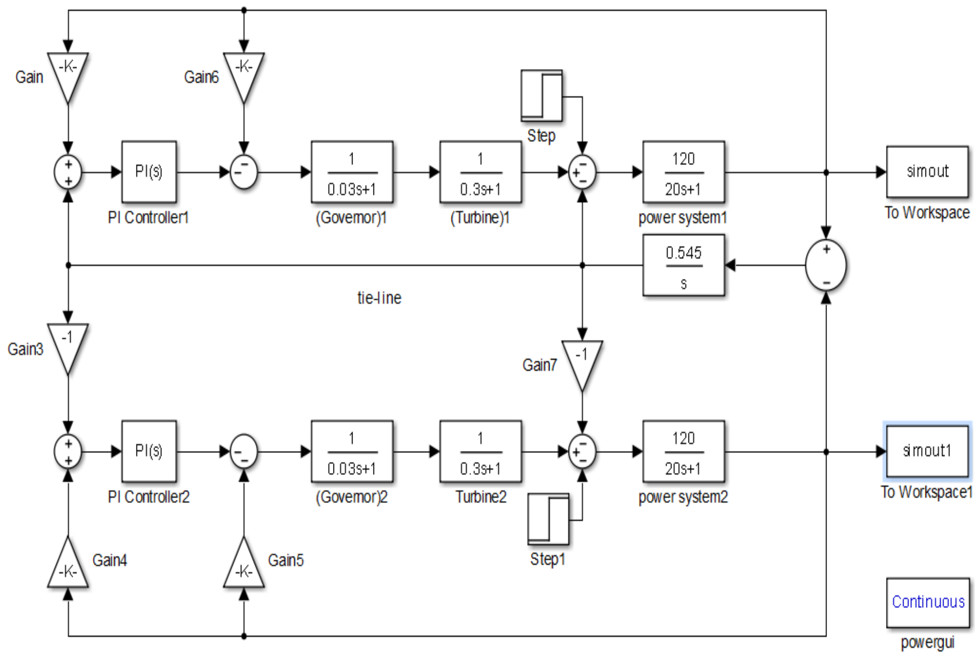

Figure 3: Simulink model for load frequency control with PI controller of 2-area system.

RESULTS & DISCUSSIONS

LOAD FREQUENCY CONTROL USING PI CONTROLLER

Since more than a decade, proportional integral controllers have been the standard control method in the power-generating industries. In this work, a PI controller is used as a conventional controller to limit the frequency change for two interconnected systems with varying load variations

Conventional power plants are primarily thermal (steam) generators, as they produce the majority of the nation's electricity. Despite the fact that these plants have a high cost of power generation, they are a more reliable source for satisfying large loads. Figure 3 depicts the Matlab/Simulink model of the PI controller for a two-area system. In the developed controller all the optimized gains of PI controllers are set.

Two Area Systems Simulink Model with Wind Penetration

As conventional or non-renewable sources are limited in quantity and more expensive than renewable sources. Integration of renewable sources is practised there in order to meet the required energy demand at the lowest cost. Despite the fact that conventional plants are used as base plants, renewable power generators play a significant role in meeting fluctuating power demand.

Wind turbines are more cost-effective and dependable sources of electricity. Integration of wind turbine generators and conventional generators is achieved through the parallel connection of both generators operating as a cohesive group in a single control area. Wind turbines may also be positioned close to the load they serve. Both generators in the system may be controlled independently, or they may be coordinated for greater stability.

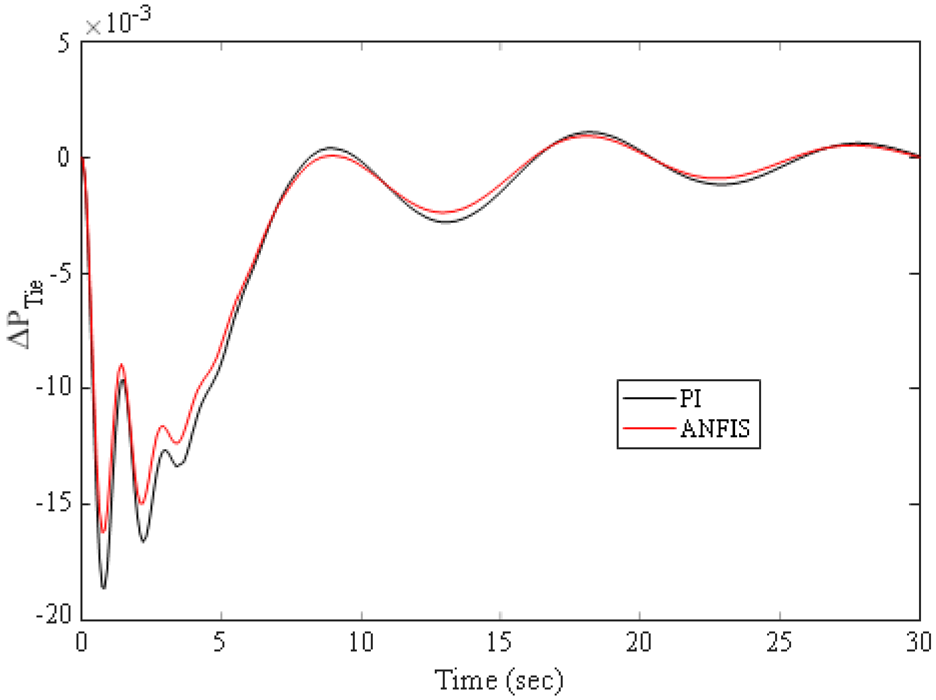

Figure 4: Change in tie- line with 1% load change

CONCLUSION

This paper suggests an ANFIS controller based on neural networks for wind-penetrated power systems. The training procedure of the ANN-based ANFIS has been described in depth. The model of a two-area wind integrated system is developed and used to evaluate the robustness of the ANFIS-controlled system in the face of load disturbances. The results of simulating PI and ANFIS controllers for two distinct load changes are plotted.

A model of a two-area wind-integrated transfer function with minor perturbations has been developed. The conventional PI controller tuned using the Ziegler-Nichols method yields satisfactory results for LFC in the absence of nonlinearity in the system. Nevertheless, wind turbines introduce a nonlinearity into the system that cannot be ignored in the LFC problem. The graphical results demonstrate that ANFIS reduces peak overshoot and settling time. Also, it is essential to note that ANFIS reduces settling time as system load increases.

FUTURE SCOPE

The proposed controller may be considered for load frequency control problems occurring in real time.Although wind turbines are used for primary frequency control, they can also be used for secondary frequency control.With real-time data simulation, load frequency control can be performed for multi-area systems.Future work will incorporate other intelligent techniques, such as NARMA L1 and L2, to control the load frequency of an integrated wind turbine system.

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