Load Frequency Control with an Optimum Feedback Controller Using a DFIG Based Wind Turbine Generator

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Abstract- It's critical for large-scale power systems to retain frequency and inter-area tie line power close to the scheduled values. Load Frequency Control is aided by Automatic Generation Control (AGC). Due to environmental concerns, renewable energy sources are given more emphasis for energy generation in the current scenario. If load generation is not balanced, frequency disturbances will increase as the penetration of wind energy using doubly fed induction generators (DFIG) in power systems grows. This study uses the DFIG and a unique approach to manage the frequency and tie-line power variation. To operate the integrated two-area power system, an ideal feedback controller is built and the kinetic energy of DFIG is extracted. The time domain simulation response in MATLAB will show the improvement in response following participation in DFIG.

Keywords- Automatic generation control, optimum feedback controller, DFIG, LFC and simulation.

I. Introduction

Constant frequency at the generation output is the most important criterion of a normally running power system. Power generation and demand should be synchronised, if possible. Frequency will deviate if there is a discrepancy between these two. To correct this mismatch, the turbine's speed will be changed to provide the required quantity of energy using stored kinetic energy. The goal is to maintain a consistent turbine speed. As a result, it will be attained when the area control error is zero. With Load Frequency Control (LFC), the Automatic Generation Control (AGC) compensates for frequency variations [1]. Many helpful studies have been published in the area of AGC, and it is designed using various controllers such as PI, PID, and so on. In load frequency control, an adaptive type-2 fuzzy controller was utilised [2]. Because of environmental concerns, energy generation via non-conventional sources is wanted in today's world. Wind energy is the most efficient form of energy. A wind turbine with a Doubly Fed Induction Generator (DFIG) is a suitable option for energy generation. In comparison to the DFIG, the conventional power supply has a significantly long response time. If the load is raised, the kinetic energy stored in DFIG can compensate for the increased energy demand. When compared to a traditional turbine-generator, this extraction of kinetic energy from DFIG requires less time [3-4]. Due to its sluggish response, even during small load variations, the conventional power system is sometimes unable to absorb frequency fluctuations. Taking the foregoing into account, this work proposes a method for frequency deviation control that combines the optimal control method with DFIG. This study considers a two-area power system that is interconnected. After obtaining the state space form of the two-area power system, optimal control theory is used to construct an optimal controller. In state feedback, the intended controller is used.

II. Doubly Fed Induction Generator (DFIG)

A power system with a single turbine and generator is known as a single area power system, whereas a power system with two turbines and generators is known as a two-area power system. Both areas are considered in this work from an experimental standpoint. For the generation, a thermal plant is contemplated. It is necessary to translate it into state space form for experimental purposes. As the number of generation areas grows, so will the number of disturbance forces [5-8]. As wind energy becomes more integrated into conventional power systems, it is desirable that DFIG participate in load frequency regulation. The kinetic energy is stored in the DFIG's turbine blade. As a result, the extraction of this kinetic energy is dependent on the turbine's inertia. The stored energy in the blade can be retrieved by managing this inertia. The DFIG's convertor controllers keep the turbine at its ideal speed in order to extract maximum power during regular

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operation. Figure 1 depicts the active power control model. As wind energy becomes more integrated into conventional power systems, it is desirable that DFIG participate in load frequency regulation. The kinetic energy is stored in the DFIG's turbine blade. As a result, the extraction of this kinetic energy is dependent on the turbine's inertia. The stored energy in the blade can be retrieved by managing this inertia [9-11]. The DFIG's convertor controllers keep the turbine at its ideal speed in order to extract maximum power during regular operation. Figure 1 depicts the active power control model.

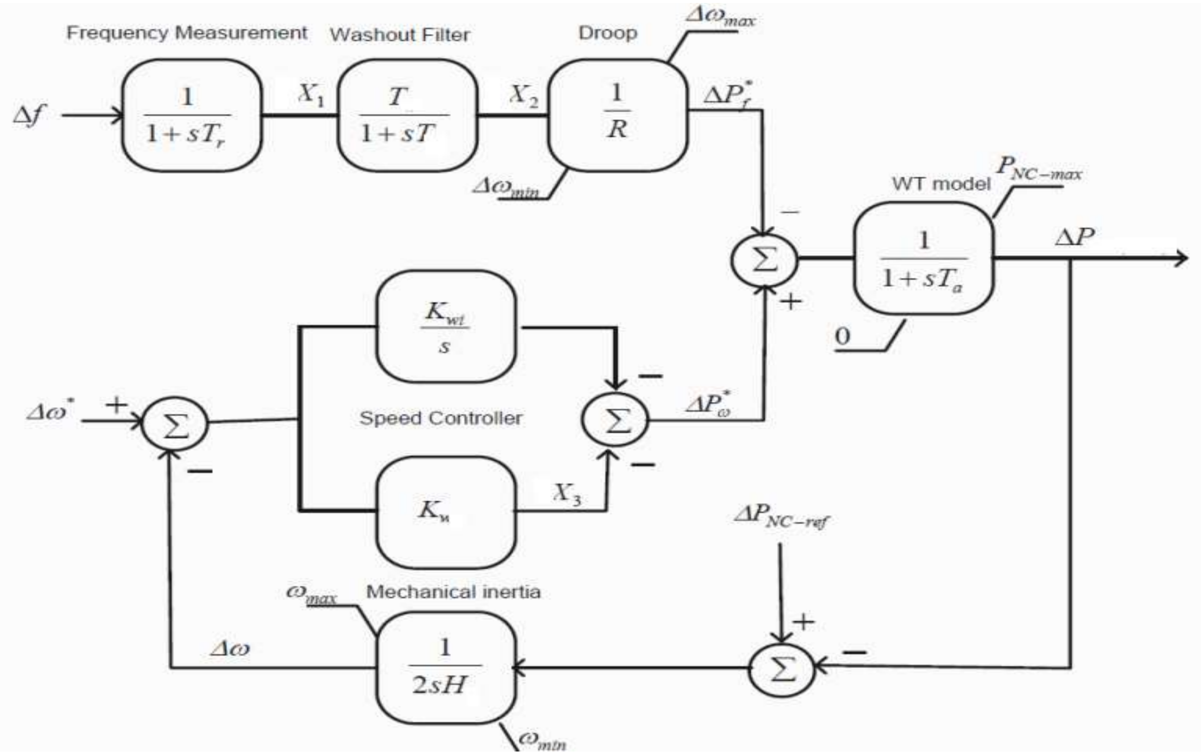

Fig. 1 DFIG based Virtual inertia control [5]

III. Optimum feedback controller

An optimum feedback controller (OFC) provides an algorithm for designing optimal controllers. The designed controller is also known as an ideal feedback controller because it is employed in system feedback. The goal of this strategy is to create a control law called u(x, t) that assists in transferring the system from its initial to final state while minimising the performance index[12-14]. The quadratic performance index is a performance metric that is commonly utilised in optimal control design. This is based on the criteria of least mistake and least energy.

$$X = A\ddot{X} + BU \qquad 1)$$

$$\check{J} = \frac{1}{2}\int_0^\infty X^s\, QX + V^t RV)\, dt \qquad 2)$$

$$V = -TX \qquad 3)$$

$$T = R^{-1}\, B\, P \qquad 4)$$

To describe the power system in state space form, state variables must be assigned to each block's output, resulting in the generation of the 'A' and 'B' matrices. The letters 'Q' and 'R' are matrices, and the Q and R matrices are used as Identity matrices throughout this paper. The number of state variables determines the size of the 'Q' matrix. The total number of state variables in this study is nine. As a result, the 'Q' matrix used here is a 9*9 identity matrix. Similarly, the size of the 'R' matrix is determined by the number of control laws that must be created. Two control laws have been designed in this study, resulting in a 2*2 dimension for the 'R' matrix. The feedback controller gain is defined by the 'K' matrix, which is dependent on the number of state variables. As a result, the 'K' matrix has a dimension of 1*9. To acquire control law 'u,' it is necessary to build the 'K' matrix, which may be derived using the following relation.

IV. Simulation Result

It is assumed that there is a 08% load perturbation in Area-1 in this study. The wind-generated energy is combined with the total generation. The addition of DFIG to the system will increase the system's transient response. The performance indicator rises as wind energy penetration into the grid rises, according to the study. As a result, a 15% wind penetration is taken into account in this study, and the responses are based on that figure. Figures 2 and 4 illustrate the comparison of frequency deviation in Area-1 and Area-2, as well as tie-line power deviation, between with and without DFIG. By monitoring these responses, it is clear that DFIG has improved Area-1 and Area-2's transient response by integrating Active Power into the grid. When DFIG is added, transitory oscillations are immediately smoothed down. The tie-line power deviation is also improved by DFIG. According to the requirements, the tie-line power is split between two zones. As a result, it is required to quickly settle down the tie-line power, which is accomplished with the help of DFIG. Figures 3 and 5 demonstrate the response of both areas, when OFC is used in conjunction with DFIG in a power system vs a power system without DFIG. With the help of state variables, a feedback regulator in the form of OFC seeks to minimise the error of each state of the power system. The OFC forces each state's error to be zero. As a result, the incorporation of OFC has improved transient time response. Because OFC forces the poles to stay on the left side of the s-plain, it ensures stability. As a result, combining OFC with DFIG improves both the transient responsiveness of frequency variations and the stability of the system. When OFC and DFIG are introduced simultaneously, the performance index improves in terms of undershoot, overshoot, and hence the performance index.

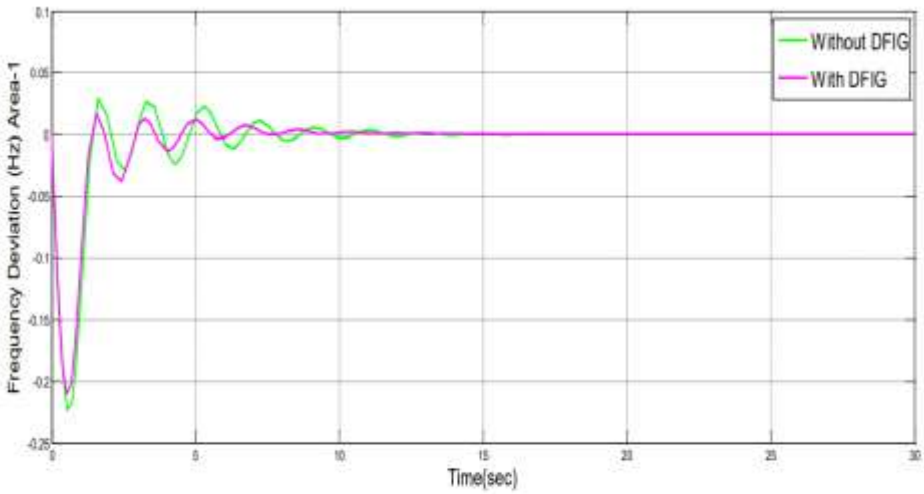

Fig. 2 Frequency Deviation in Area-1

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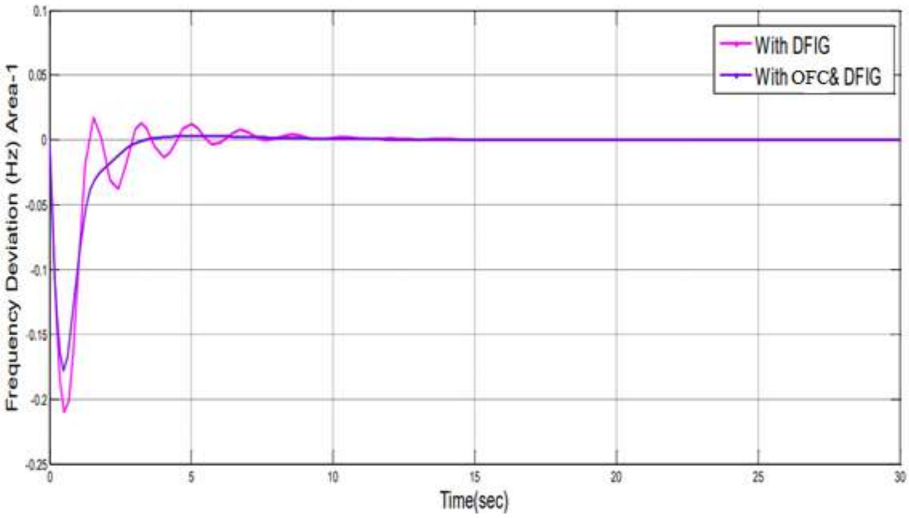

Fig. 3 Frequency Deviation in Area-1 with OFC

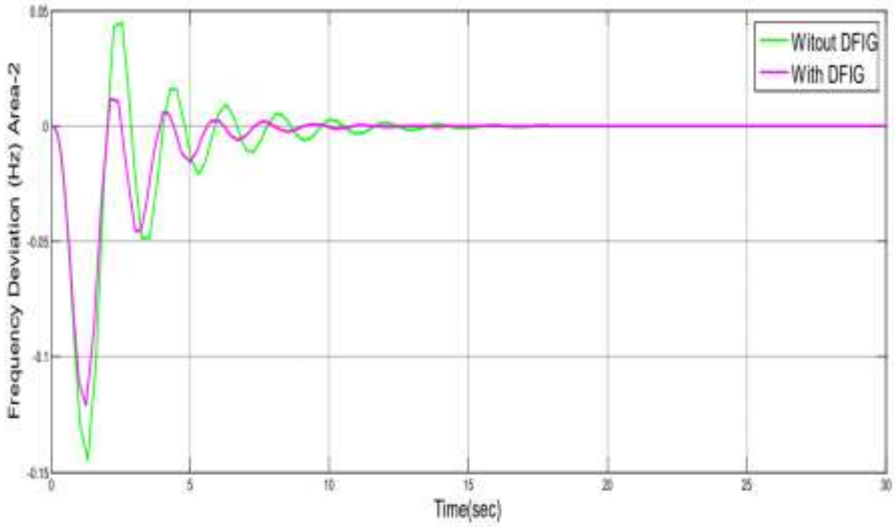

Fig. 4 Frequency Deviation in Area-2

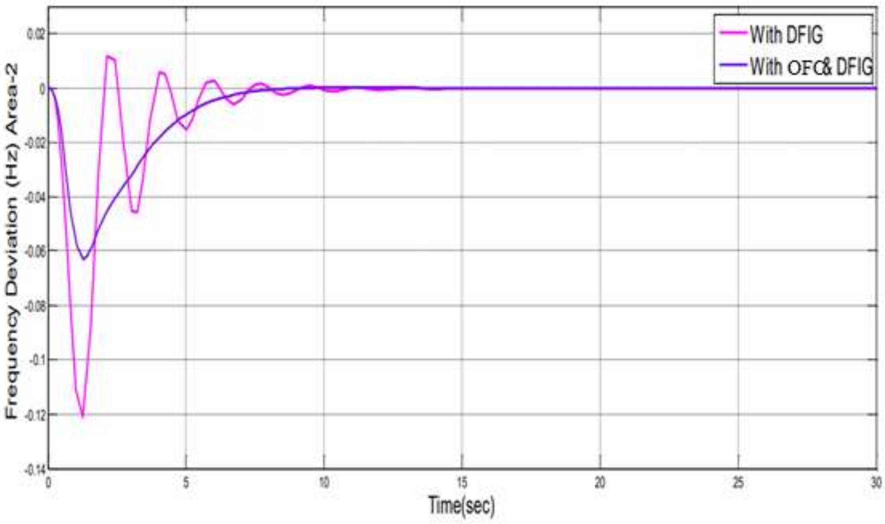

Fig. 5 Frequency Deviation in Area-2 with OFC

V. Conclusion

With the use of OFC and DFIG, this research provided a strategy to reduce ACE. After inserting DFIG and, the time response of frequency deviation in both areas, as well as the time response of tie line power deviation, has been improved. The primary loop's principal job is to govern the power system, while the secondary loop resets the set-point so that the system operates at the optimal demand-generation balance. The primary loop response is increased when the DFIG is inserted, and the DFIG thus aids the transient element of the reaction to settle down as quickly as possible. It is desirable to have a reliable system when time response improves.

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