Load Frequency Control of a Hybrid Wind Diesel System Using Fuzzy Logic Control

S Siddik[1], A Selva Vinayagam[2], R Gopinath[3]

Asst. Professor, Sri Muthukumaran Institute of Technology, Tamil Nadu, India[1]

Asst. Professor, Sri Muthukumaran Institute of Technology, Tamil Nadu, India[2]

P.G. Scholar, Sri Muthukumaran Institute of Technology, Tamil Nadu, India[3]

ABSTRACT: Load Frequency control (LFC) in power system is undergoing a lot of changes due to the rapidly growing demand and due to various renewable generation integration to the existing system. This work proposes an LFC scheme based on Fuzzy Logic Control for a hybrid wind-diesel power system. Therefore the objective of this LFC is to minimize system frequency deviations and tie line power changes. The wind power being a highly intermittent source imposes additional power imbalance and frequency deviation problems to the hybrid system. A serious care has been taken to study characteristics of such a system under isolated conditions. Based on the studies made a FLC based LFC scheme for the isolated hybrid wind diesel power system is developed and the performance of the scheme is verified using MATLAB/SIMULINK.

KEYWORDS: Fuzzy Logic, Hybrid Systems, Load Frequency Control, Renewable Generation, Wind Power

I. INTRODUCTION

With more and more stress being given to environmental conservation and greenhouse effect there arises a pressing need to utilize the abundantly available natural energy sources to reduce the amount of green house gases exhausted by the fossil fuelled power plants. Therefore the greatest challenge for an engineer is to develop novel technologies to exploit the energy from clean sources. Even though wind energy poses such qualities but the wind as a source for power production is highly intermittent in nature due to this the power produced from wind is unpredictable and not reliable.

The hybrid wind power with diesel generation has been suggested in [1] and [2] to handle the unpredictable nature of the wind. A hybrid wind diesel system is very reliable because the diesel acts as a cushion to take care of variation in wind speed and would always maintain an average power equal to the set point. In addition to the unsteady nature of wind, the fluctuation of output power of such renewable sources may cause a serious problem of frequency and voltage fluctuation of the grid, especially, in the case of isolated microgrid, which is the a small power supply network consisting of some renewable sources and loads. In the worst case, the system may lose stability if the system frequency cannot be maintained in the acceptable range[3].

Due to the increasing size changing structure, emerging renewable energy sources and new uncertainties conventional LFC designs are usually not suitable for large scale power systems with nonlinearities and uncertain parameters[4]. In order to overcome these difficulties it is required to develop an intelligent LFC scheme. With recent advancements in artificial neural networks, fuzzy logic control, expert systems and natural inspired algorithms development of knowledge based solutions for any problem is taking new dimensions.

Due to the simplicity, robustness, and reliability of the fuzzy logic now a days it is used in almost all fields of science and technology, including solving a wide range of control problems in power system control and operations. The main advantage of fuzzy logic is that unlike the traditional control theorems, which are essentially based on the linearized mathematical models of the controlled systems, the fuzzy control methodology tries to establish the controller directly based on the measurements, long-term experiences, and the knowledge of domain experts/operators.

Fuzzy logic has been used to solve the load frequency problem and it has been documented well. But all the reported works have considered only conventional system. So this paper addresses a new fuzzy logic based load frequency control technique for a hybrid wind diesel system.

II. MODEL DISCRIPTION

The basic configuration of an isolated hybrid wind diesel power generation system is shown in Fig 1 The PPC (Programmable Pitch Control) is installed in the wind side while the governor is installed in the diesel side. In additional the random wind energy supply, it is assumed that loads with sudden change have been placed in this system. These result in a serious problem of large frequency deviation in the system such power variations and frequency deviations severely affect the system stability. The life time of machine apparatuses on the load side affected by such large frequency deviations will be reduced. For mathematical modeling, the transfer function block diagram used in this study is shown in Fig 2. The PPC is a 1st order lead lag controller with single input feedback of frequency deviation of wind side. The hybrid diesel power generation proposed with Programmable Pitch Controller (PPC) in the wind side can be expected to be a cost effective device for reducing frequency deviations.
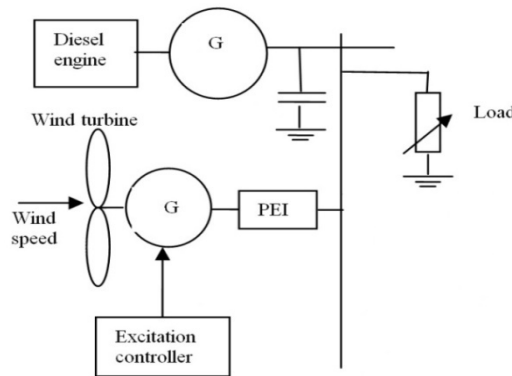

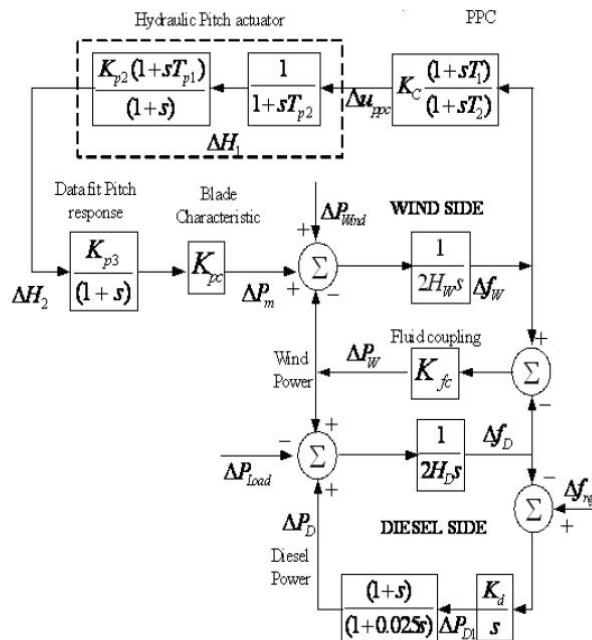FIG. 1 BASIC CONFIGURATION OF A ISOLATED WIND DIESEL SYSTEM

FIG. 2 HYBRID SYSTEM TRANSFER FUNCTION MODEL

The state equation of linearized model in Fig 2 can be expressed as follows[4]

$$\Delta \dot{X} = A\Delta X + B\Delta u_{PPC} \qquad (1)$$

$$\Delta Y = C\Delta X + D\Delta u_{PPC} \qquad (2)$$

$$\Delta u_{PPC} = K(s)\Delta f_w \qquad (3)$$

III. FUZZY LOGIC CONTROL

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s.

A fuzzy logic controller consist of four sections namely fuzzifier, inference mechanism, rule base and defuzzifier as shown in Fig
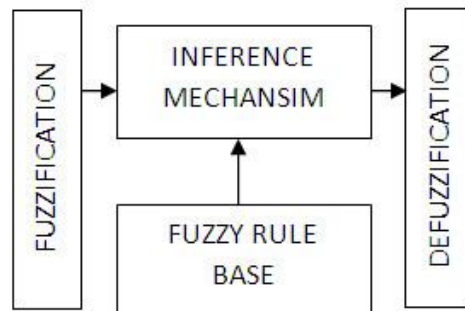

FIG. 3 STRUCTURE OF FUZZY LOGIC

Generally the design of a fuzzy logic based controller has four steps as follows
Step 1) Defining the input and output variables with their ranges
Step 2) Fuzzification of the input and output crisp values into fuzzy sets
Step 3) Defining an inference mechanism and forming rule base
Step 4) Defuzzifying the output fuzzy sets into crisp values

In case of LFC for the purpose of design of fuzzy controller the ACE (e) and its derivative (de) are taken as two inputs i.e. they are used to as IF-part in the formation of rule base whose output gives the THEN-part. In this case as told above two inputs signals ACE (e) and its derivative dACE(de) are converted to fuzzy numbers first in fuzzifier using five membership functions. The membership function are defined as Positive Big (PB), Positive Small(PS), Zero (ZZ),Negative Small(NS),Negative Big (NB), Small (S), Medium (M), Big (B), very Big (VB), Very Very Big (VVB). Finally resultant fuzzy subsets representing the controller output are converted to the crisp values.

From Table 1 we can infer the rules which can be expressed in terms of IF-THEN statement as follows "IF ACE is **NS** and dACE is **PB** then the output is **VB**"

TABLE 1
RULE BASE

		dACE				
		NB	NS	ZZ	PS	PB
ACE	NB	S	S	M	M	B
	NS	S	M	M	B	VB
	ZZ	M	M	B	VB	VB
	PS	M	B	VB	VB	VVB
	PB	B	VB	VB	VVB	VVB

IV TEST SYSTEM

To investigate the effectiveness of the proposed control a simulink model of wind diesel   hybrid   system   has been developed as shown in the Fig. In order to prove the superiority of the proposed controller two cases are taken into considerations namely

- a. Step change in Load
- b. variable wind Input.

Fig 4 shows the variable wind input applied using the simulink signal builder. Fig 5 and Fig 6 shows the test system with existing pitch control and proposed fuzzy logic controllers respectively
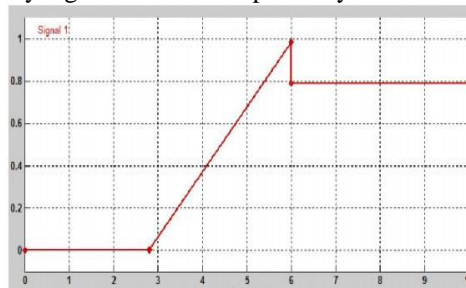
FIG 4 VARIABLE SPEED WIND INPUT

V RESULTS

The operation of a wind diesel hybrid system for a step load change with PPC and FLC are compared. MATLAB/SIMULINK environment was used to design, test and validate the effectiveness of the two LFC schemes. Fig 7&8 shows the frequency response of the hybrid wind diesel system for step load changes. From Figure 7 we can see that the frequency deviations of the system has reduced to zero. Comparing the frequency response results with PPC it is quite apparent that the FLC highly improves the frequency response of the hybrid wind diesel system. Similarly fig 9and fig 10 shows the frequency response of the system for a variable wind speed input and again the superiority of the FLC can be verified.
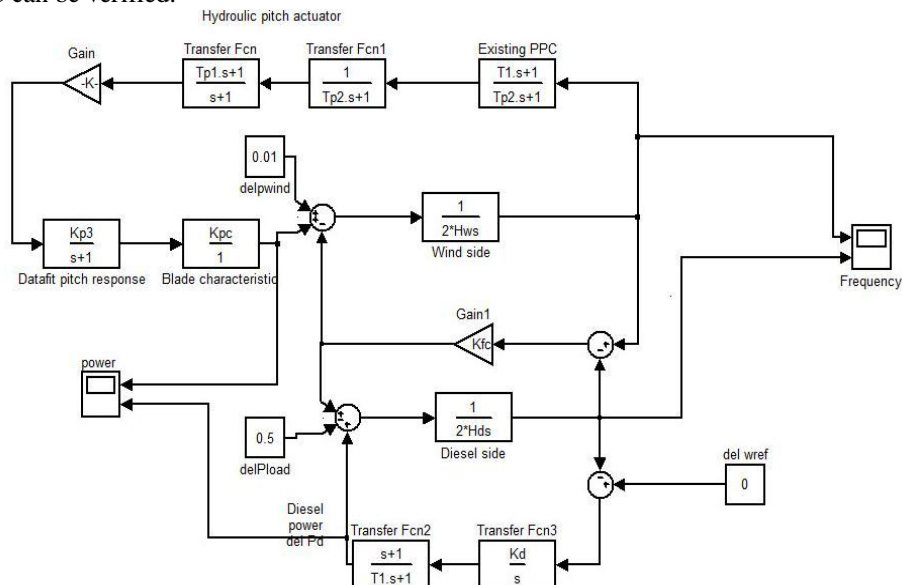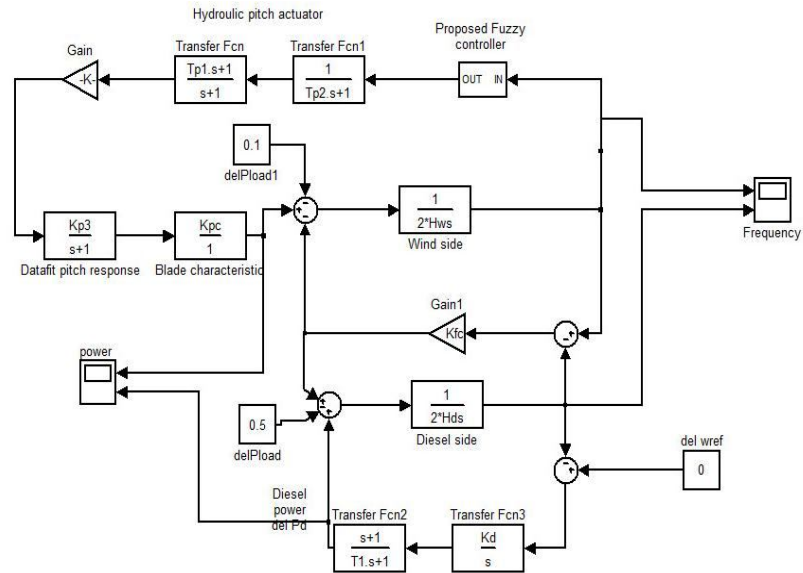

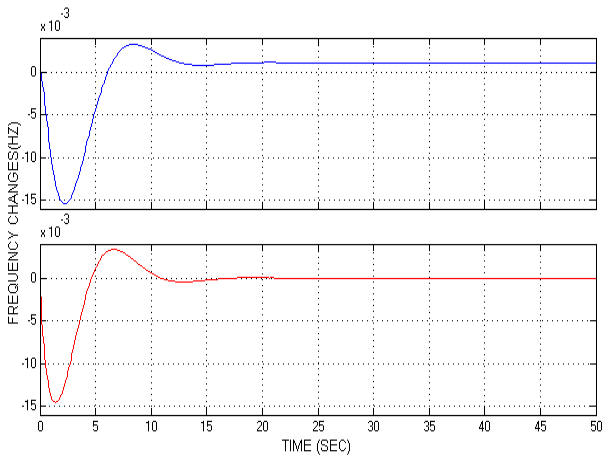FIG.5 HYBRID SYSTEM WITH PPC

FIG. 6 HYBRID SYSTEM WITH FLC

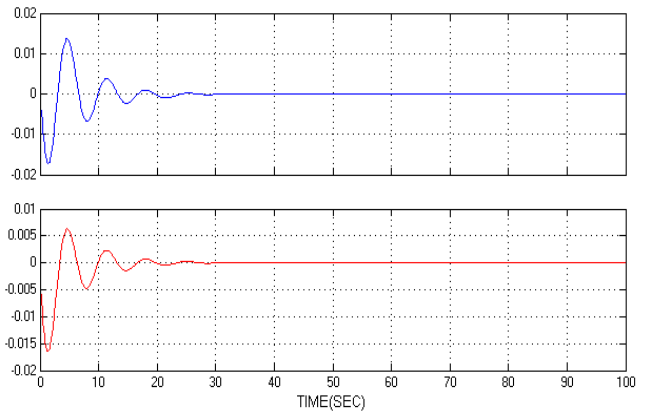FIG. 7 LFC OF HYBRID SYSTEM WITH PPC FOR VARIABLE LOAD
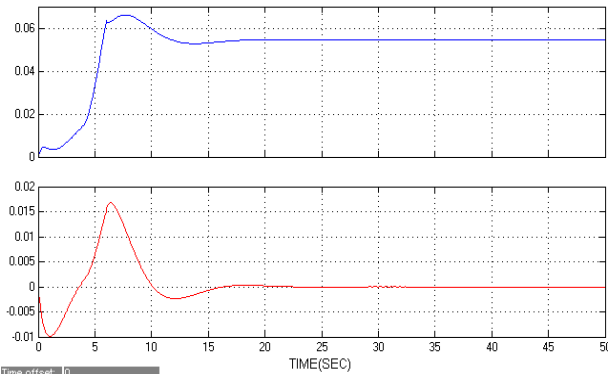

FIG. 8 LFC OF HYBRID SYSTEM WITH FLC FOR VARIABLE LOAD

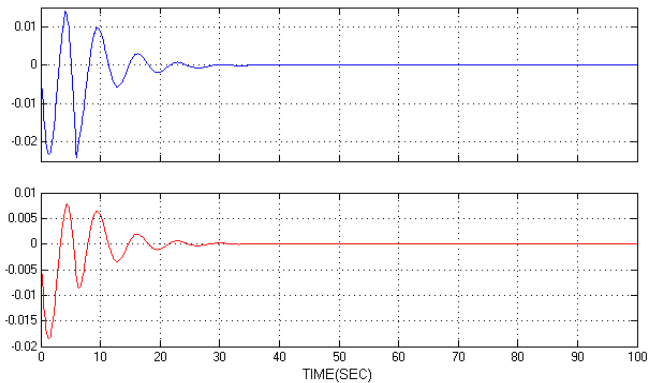FIG. 9 LFC OF HYBRID SYSTEM WITH PPC FOR VARIABLE WIND SPEED

FIG. 10 LFC OF HYBRID SYSTEM WITH FLC FOR VARIABLE WIND SPEED

VI CONCLUSION

In this paper a fuzzy logic based frequency controller for hybrid wind diesel has been proposed to improve the frequency response of the hybrid wind diesel system. The simulated results shows that the control strategy that has been proposed is promising to eliminate the frequency deviations in the system when there is load changes

REFERENCES

[1] Hunter R.E.G.,*Wind-diesel systems a guide to technology and its implementation*, Cambridge University Press 1994.

[2] Lipman NH. , *Wind-diesel an autonomous energy systems*, Elservier Science Publishers Ltd 1989.

[3] H. Bevrani, *Robust Power System Frequency Control*, 1st ed. New York: Springer, 2009.

[4] Cuk Supriyadi A., Takuhei Hashiguchi, Tadahiro Goda and Tumiran "*Control Scheme of Hybrid Wind-Diesel Power Generation System*" INTECH PUBLICATIONS

[5] *IEEE Committee Report. Standard definitions of terms for automatic generation control on electric power systems*. IEEE Trans Power Appl Syst 1970;89.

[6] Amenedo JLR, Arnalte S, Burgos JC. *Automatic generation control of a wind farm with variable speed wind turbines*. IEEE Trans Energy Convers 2002;17(2):279–84

[7] Gu P., Petkov Hr. & Konstantinov M.M., *Robust Control Design with MATLAB*, Springer, 2005.

BIOGRAPHY

S SIDDIK was born in Tamil Nadu, India. He received his B.E. degree from Madras University in 1997 and is M.E. degree from Anna university in 2013 he has around eight years of Industrial experience and around four years of academic experience. His area of interests are Renewable energy sources, intelligent control, Micro Grid and power system operation and control.

A SELVA VINAYAGAM was born in Tamil Nadu, India He received his B.E. degree from Pallavan College of Engineering in the year 2001 and his M.E. degree from Annamalai University in 2004 he has around six years of academic experience. His current areas of interest include Power system operation and control, Load frequency control and Economic Dispatch.

R. GOPINATH was born in Tamil Nadu, India received his B.E. degree from SAACE in 2012 and he is currently pursuing his M.E. degree from SMIT, his areas of intrest include Load Frequency control, Hybrid systems and Intelligent control.