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A New Soft Computing Fuzzy Logic Frequency Regulation Scheme for Two Area Hybrid Power Systems

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ABSTRACT- Modern renewable energy power system designs provide significant application benefits, but they also produce losses. The total generation, total load demand, and system losses must be balanced in order for this structured power system to operate reliably. The actual and reactive power balances are disturbed as a result of changes in load demand. System frequency and tie line interchange power deviate from their planned values as a result of this. A high system frequency deviation can cause the system to crash. In that case, multiple connect area systems use intelligent load frequency control techniques to deliver dependable and high-quality frequency and tie line power flow. Here, a standalone hybrid power system is taken into consideration, with generated power and frequency being controlled intelligently. In addition to the unpredictable nature of the wind, frequent adjustments in the load profile can produce sizeable and detrimental power variations. The output power of such renewable sources may fluctuate to the point that it causes significant frequency and voltage changes in the grid. An intelligent approach recently proposed to address the load frequency control (LFC) issue of an interconnected power system is known as fuzzy logic PID controller (FLPIDC). Standard proportional integral derivative (PID) controllers are used to control each section of the system.

Keywords: hybrid power system, Load Frequency Control, FLPIDC, PID.

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1. INTRODUCTION

In developing countries, the use of renewable energy sources to make electricity has grown in recent years. As development moves faster, more people will need electricity, which makes the gap between supply and demand even bigger. As a result, meeting the rising demand for electricity with traditional sources is becoming increasingly difficult[1]. The primary benefits of using renewable energy sources for power generation are that they don't require any fuel and are environmentally benign and sustainable, but they also have the drawback of being erratic in nature. In order to consistently power isolated loads, renewable energy sources like wind, solar, and micro- and mini hydro are often linked with diesel systems. A small distribution network is used to operate parallel diesel generator sets with synchronous generators and renewable sources to meet load requirements[2].

Due to the low generation capacity of grid-connected systems, particularly in developing nations, many rural and isolated places worldwide still lack access to electricity[3]. If some of the locations have independent or separate power systems to satisfy local load requirements, the supply-demand mismatch can be reduced. Additionally, when wind speed at the planned site is significant for electricity generation and grid access is challenging, wind power is anticipated to be economically attractive. On islands and/or in remote areas, this is most typical[4].

Furthermore, when the wind speed at the planned site is significant for electrical generation and electricity is not readily available from the grid, wind power is anticipated to be economically attractive. On islands or in rural areas, this is a frequent occurrence. Because the diesel works as a buffer to accommodate for changes in wind speed and keeps the average power constant at the set point, a hybrid wind-diesel system is particularly dependable[5]. A remote community's rising load demand necessitates the expansion of this hybrid power system. Where there are numerous water streams, one is added in parallel (a micro-hydro-producing unit). The generation controller's design and mode of operation will largely determine how well the final hybrid power system serves the consumer load[6].

In comparison to conventional power systems in various countries, hybrid power systems, e.g., have a very small capacity. However, they are critical because they are the only source of electrical supply for communities in areas where

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conventional grid supply is unavailable. Diesel generators are used in irrigation and mobile communication towers in India[7]. The Indian Defense Organization has diesel generator sets for supplying power to contingents that include radar communication, offices, and residences. There are also a large number of industrial units that rely solely or partially on diesel generators due to a lack of grid availability or continuity. India has a lot of wind resources, but it also has a lot of solar potential and a lot of untapped biomass potential. As a result, various agencies (government and private) are working to develop hybrid systems for efficient power generation while also obtaining carbon credits [8].

Large and severe power oscillations may happen as a result of the wind's unpredictability and the rapid changes in load requirements. Serious frequency and voltage fluctuations in the grid may result from the output power of such renewable sources fluctuating[9]. A suitable control approach is therefore needed to keep the scheduled frequency constant. For maintaining frequency oscillations and maintaining the system frequency within a reasonable range, an efficient controller is essential. The system may become unstable if the frequency cannot be maintained within a reasonable range. A good frequency controller is therefore eagerly awaited[10].

2. PROPOSED TECHNIQUE

For an electric power system to be good, both frequency and voltage must work at their rated levels. In order to keep these power system parameters constant, the control system is essential. Since the LFC turbine governor technique proved insufficient, a second control was added to the governor using a signal that was directly proportional to the frequency variation. LFC speed governor systems most frequently employ PI and PID controllers. It would be desirable to increase PID controllers' capacity to handle the demands of contemporary applications. The considerable impact of performance improvement is the main driver behind the development of better techniques for constructing PID controllers. Therefore, this paper suggests a new multistage fuzzy logic approach in order to fine-tune the parameters of a PID controller for improved system performance.

In remote, isolated places where the wind speed is strong enough to make electricity, the isolated hybrid system uses more than one source of energy to make electricity[11]. An autonomous system has more challenging frequency control. In the article, an isolated hybrid power system is implemented with a unique intelligent multistage fuzzy logic PID controller to control the frequency deviations[12]. An autonomous system has more challenging frequency control. In the proposed article, the LFC of an isolated hybrid power system is controlled using a novel, intelligent multistage fuzzy logic PID controller. The suggested controller maintains the increased dynamic performance of the hybrid power system while controlling frequency and generated power more effectively than previous controllers[13].

From the *figure 1* in two are energy systems, the incremental tie line power is represented as

$$\Delta Ptie12(s) = [\frac{2\pi Tp12}{s}](\Delta F1(s) - \Delta F2(s)) \quad (1)$$

Where $(\Delta F1(s)$ & $.\Delta F2(s)$ are system frequency deviations.

The tie line current flow represented as

$$I12(s) = \frac{(V1<\theta)-(V2<\theta)}{j(X12)} \quad (2)$$

The tie line current flow with controller represented as

$$I12(s) = \frac{(V1<\theta)-(V2<\theta)}{j[(X12)-Xcontr} \quad (3)$$

Where X12 is reactance of the tieline power

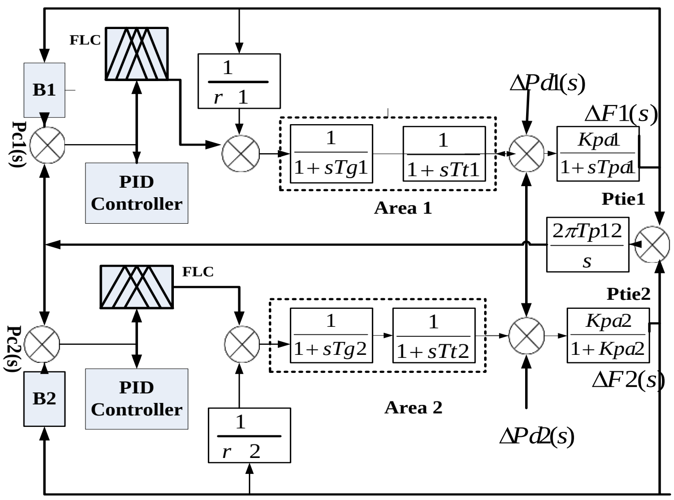

Figure 1: Block diagram of Multistage FLPIDC for LFC of a hybrid power system

Complex power of incremental tie line represented as

$$P12 + jQ12 = S12 \quad (4)$$

$$P12 + jQ12 = V1 * I12 \quad (5)$$

Tieline power flow can represented as

$$Ptie12 = \frac{V1*V2}{j[(X12)-Xcontr}\sin(\theta 1 - \theta 2) \quad (6)$$

3. DESIGN OF MULTISTAGE FLPID CONTROLLER

3.1 Introduction

A FLC's fundamental configuration consists of four primary components[14]-[15].

- Fuzzification
- Interface mechanism
- Knowledge base
- Defuzzification

The initial process is fuzzification, which includes shifting the input and output ranges of the FLC into their respective universes of conversation. The second step involves separating these inputs into linguistic variables. The fuzzification module's parameters depend on the structure of the Membership Functions (MF)[16].

FLC's interface mechanism plays a crucial function. In this stage, the membership values obtained in the Fuzzification step are merged to determine the firing strength of each rule. Using a set of language control rules, each rule specifies the domain experts' control objective and control policy. Next, based on the firing strength, the subsequent portion of each qualified rule is formed[17].

A FLC's knowledge base consists of a database. The primary goal of the database is to supply the essential information for the fuzzification module, the inference engine, and the de-fuzzification module to operate effectively[18].

The defuzzification module executes the subsequent operations:

- Transforms the updated control output values into a control action that is not fuzzy.
- Executes a de-normalization of the output that translates the value range of fuzzy sets to the physical domain[18].

3.2 Fuzzy Logic Controller to Power System

3.2.1 Tuning of Fuzzy Logic controller

This proposed controller, which is based on Greg Viot's fuzzy cruise controller, is used to maintain a stable structured power system at specified frequency levels; as a result, it is constructed dual fuzzy inputs, *E* and *delE*, and one fuzzy output, the control output[19]-[20].

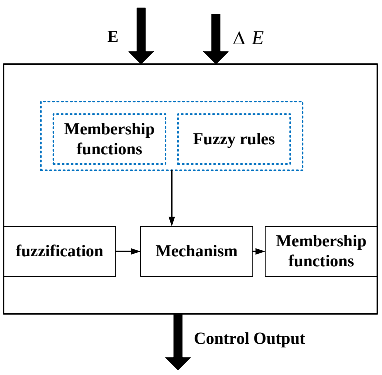

Figure 2: Block diagram representation of fuzzy controller

Two input variables (*E* and *delE*) and one output variable make up FLC in the proposed multistage FLPIDC[21]. The Multistage FLPID controller's pre-compensator outputs a control signal that is

$$Fpid = KpE + Ki\int E + Kd\frac{dE}{dt} \quad (7)$$

The Multi stage FLPIDC output control signal is

$$M_{output} = Fpid \quad (8)$$

Where Kp, Ki, and Kd - The parameters of a fuzzy-tuned PID controller.

The multistage FLPIDC file is created with the fuzzy toolbox. The Fuzzy Logic Controller file's FIS editor is created. Information pertinent to the multi-stage FLPIDC is displayed by the FIS editor. The rule editor adds FLC's rules [22].

The FIS editor is developed in the MATLAB software with two inputs and one output, such as *E*, *delE*, and *F*. (S). In that f_{is} file, the input 1 *E* range is taken to be between -0.1 and 0.1, the input 2 *del E* range is taken to be between -1.0 and 1.0, and the output *F(S)* range is taken to be between -1 and 1.5. Additionally, seven rules (shown in table 1) have been taken into account in the Fis editor[22].

3.2.2 Tuning of PID gain Values in Fuzzy Logic controller

The FLC is an example of a nonlinear controller that works well in both linear and nonlinear situations. FLC is demonstrated to be a linear PID controller under equilibrium or steady-state conditions. So, the overall tuning of the FLC can be accomplished to acquire the desired or ideal response by adjusting the FLC parameters as the linear equivalent of a traditional PID controller. The standard PID stabilizer's parameters serve as a starting point for fine-tuning the FLC. Hence, in FLC, gain values should be computed at the point of equilibrium, where they should be proportionate to the input E without a controller [23].

Gain values of PID in FLC represented as:

$$Kp = {Gp * H}/{2A(m-1)} \quad (13)$$

$$Ki = {Gi * H}/{2A(m-1)} \quad (14)$$

$$Kd = {Gd * H}/{2A(m-1)} \quad (15)$$

Where, *Gp*, *Gi*, *Gd* are gain values of PID controller
m is number memory functions
A is distance between the adjacent members to MFs

3.3 Defuzzification

When the output of a system is not perfect, it is sometimes easier to come to a clear answer if the output is modeled as a single scalar variable. The reverse of "fuzzification," defuzzification," lowers a fuzzy set to a single, distinct value. There are a number of approaches described in the literature, including centroid, center of sums, and mean of maxima; centroid has been added for enhanced results. The centroid methodology is also known as the area method or center-of-gravity method[24].

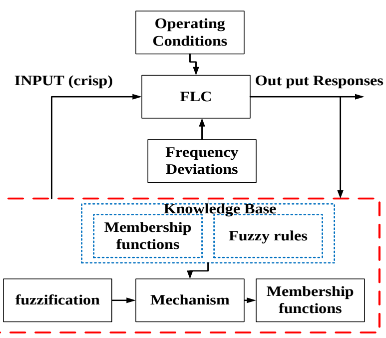

Figure 3: Analytical structure of FLC scheme

Figure 3 illustrates the analytical structure of the proposed fuzzy controller, which considers Symmetrical triangular MF partitioned uniformly within the shared Universe of Discourse for the control variables. [-1, +1] is chosen as the UOD of the input and output variables. Only expressions in the UOD range are derived[25]. The membership functions are positioned within the overlap area. In fuzzy sets of inputs and outputs, all MF members are of the same type. The centroid defuzzifier is used to obtain the final crisp output.

Table 1: Fuzzy Rules

E / delE	NegL	NegM	NegS	Z	PosS	PosM	PosL
NegL	PosL	PosL	PosL	PosM	PosM	PosS	Z
NegM	PL	PosM	PosM	PosM	PosS	Z	PosS
NegS	PosM	PosM	PosS	PosS	Z	NegS	NegM
Z	PosL	PosM	PosS	Z	NegS	NegM	NegL
PosS	PosM	PosS	Z	NegS	NegS	NegM	NegM
PosM	PS	Z	NegS	NegM	NegM	NegM	NegM
PosL	Z	NegS	NegM	NegM	NegL	NegL	NegL
NegL -negative large				PosL-positive large			
NegM-negative medium				PosM-positive medium			
NegS-negative small				PosS- positive small			
				Z- zero			

4. RESULTS AND DISCSSION

The Simulink model of a hybrid power system is simulated using the parameters of the proposed multi-stage FLPIDC for LFC against various load disturbances. The load frequency control, created using the self-tuning FLPIDC for the two-area system, keeps the system frequency, two-area powers, and tie line powers at their rated levels.

Using FLPIDC for LFC and PID for various load changes, the dynamic responses of frequency change and power generation change were examined.

For variations in frequency and power of the two-area system, all performance requirements settling time, overshoot, and steady-state error are some examples—are thought to be minimized.

In simulation experiments, it is assumed that the system will encounter step changes in input power and step load disturbances of 0.01, 0.02, 0.03, and 0.05 in pu. *figures 4 to 7* depict the reactions of the PID approach with various schemes to variations in frequency, delPm1, delPm2, and tie line power.

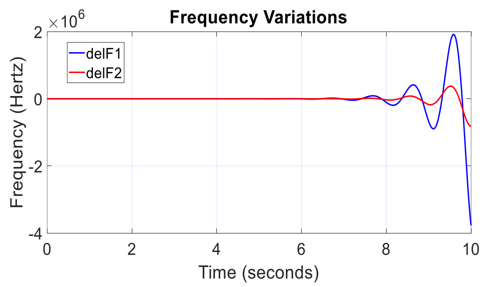

Figure 4: Frequency variations without PID scheme in two area system

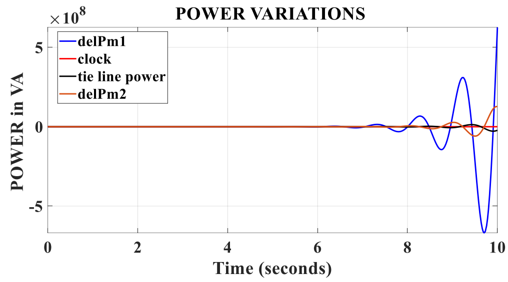

Figure 5: Power variations without PID scheme in two area system

Case 1: Two area control without scheme

The frequencies and power variations of two area systems in the *figure 4 & 5* at 1000MVA loads, represents without any control technique, here power system cannot be stable. Therefore, in multi-area system, frequency and power variations are more when load changes or may be turned-off.

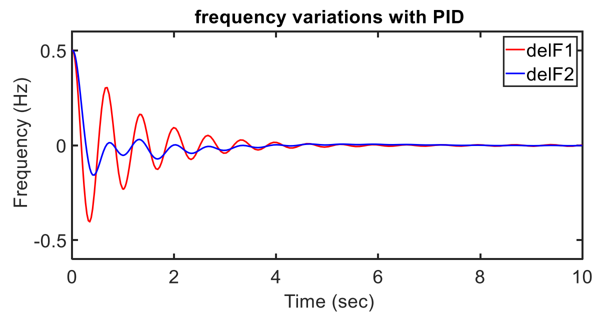

Figure 6: Frequency with PID scheme in two area system

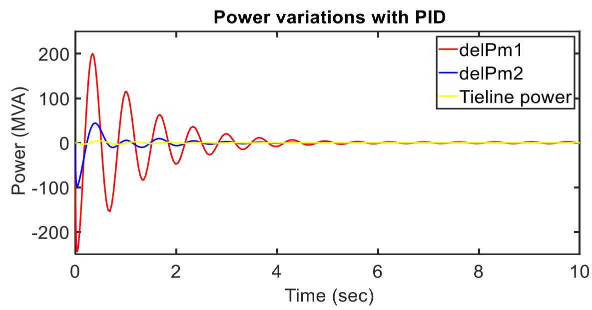

Figure 7: Power variations with PID scheme in two area system

Case 2: Two area control with PID Technique

Figure 6 & 7 represents load frequency control with PID scheme, in which frequency of two area systems settled after 5.8-5.9 sec at 1000 MVA load, while the powers settled after 5.6628 and 5.791 seconds, respectively. At 5.8 sec, the tie-line power became stable.

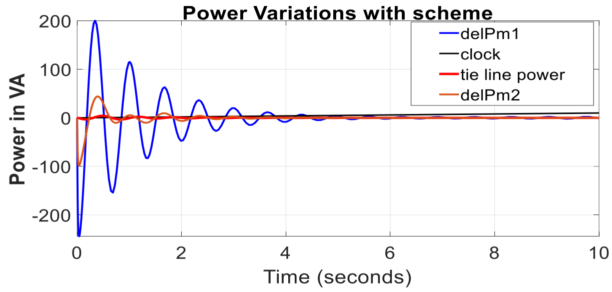

Figure 8: Frequency variations with FO-PID scheme in two area system

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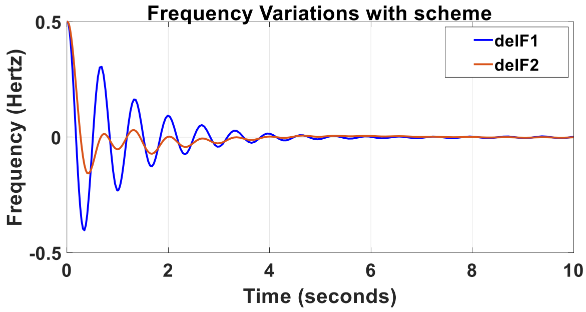

Figure 9: Power variations with FO-PID scheme in two area system

Case 3: Two area control with FO-PID Technique

Figure 8 & 9 represents load frequency control with FO-PID scheme, in which frequency of two area systems settled after 5.79-5.9 sec at 1000 MVA load, while the powers settled after 5.69628 and 5.791 seconds, respectively. At 5.78 sec, the tie-line power became stable.

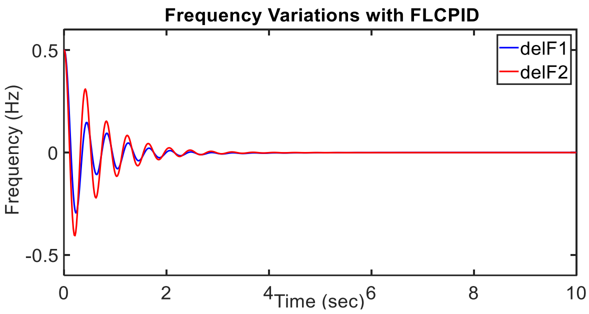

Figure 10: Frequency variations with FLPIDC scheme in two area system

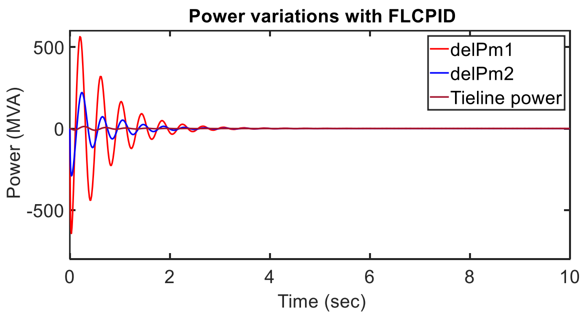

Figure11: Power variations with FLPIDC scheme in two area system

Case 4: Two area control with Proposed Technique (FLPIDC)

Figure 10 & 11 represents load frequency control with PID-PSO scheme, in which the frequencies of two-area systems had a settling time of 2.9334 seconds and 2.9376 seconds from at 0.01 p.u. load, and the powers had a settling time of 3.6802 seconds and 4.7851 seconds. Tie-line strength stabilised at 3.9931 seconds. The PID-PSO method is therefore more efficient.

5. CONCLUSION

The FLPIDC technique is researched for various load disturbances and is designed for LFC of the two-area system. The suggested FLPIDC is crucial at larger load disturbances because it effectively reduces deviations in the power system's dynamic responses and returns it to stable operation. The proposed controller demonstrates its superiority, offers reliable control, and upholds the system's dependability under a variety of loads and disturbances.

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