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PV and EV Generation to Reduce Frequency and Tie-line Power Fluctuations in Three Area Power using Soft Computing Techniques

Rakesh Kumar,
Department of Electrical Engineering Guru Kashi University, Bathinda, Punjab, India
R. K Bansal
Department of Electrical Engineering Guru Kashi University, Bathinda, Punjab, India
Surya Prakash
Electrical & Instrumentation Engineering Department, Thapar University, Patiala, India

Abstract

The main focuses in this paper in on load frequency control (LFC) process for interconnected three area Power systems with renewable energy system (RES). These areas are demarcated as Area I, Area II and Area III, consists of Thermal-Thermal and hydro Power Units. The Economic load dispatch mechanism into the LFC for economic division of load during load fluctruation is also incorporates. The frequency deviation in both the areas is sensed and proper controller is implemented to reduce the oscillations of the proposed system. Proportion integral derivative (PID) controller, selected to achieve this goal has optimum value of the integral gain. Hence, Fuzzy logic control (FLC) technique is used for the optimization of the system. For minor disturbances in the areas, Primary and secondary controllers are sufficient to minimize the frequency and tie-line power oscillations, as the response of governor mechanism is slow. But for major disturbance (RES) such as Photo-volatic (PV) and electric vechlie (EV) energy system, due to quick response and has very small time constant are used for improvement of the dynamic response of the system. By using (RES) power quality (PQ) of the system is improved. And the result shows that the presence of (RES) and high penetration EVSs improve PQ such as frequency and voltage fluctuation, voltage drop, harmonic distortion and power factor reduction.

Keywords: Load Frequency Control (LFC), Fuzzy Logic Controller (FLC), Proportion Integral Derivative (PID) Controller, Photo-Volatic (PV), Electric Vechlie (EV), Flexible AC Transmission System (FACTS)

1. Introduction

A power system is designed by different equipment connected at nominal and relied voltage. In healthy power system it is important to ensure reliable supply of electric power. To get the desired output, (LFC) mechanism play important role in the power system, as it keeps the frequency at nominal value, also keeps the net lie-line power with-in prescribed limits. In the literature survey, it is studied that the LFC mechanism consists of single area, multi-area or its various combination. FACTS (flexible AC transmission system) devices and storage devices are also widely accepted for stability and control mechanism in the power system. [1]

Some electronics switch devices like (SSSC) static synchronous services compensator.[2] Thyristor control phase shifter (TCPS) and Unified power flow controller(UPFC).[2] Redox Flow Battery(RFB) [3] etc. are used to improve the reliability and power transfer capability of the power system. PSO, and GA (Genetic Algorithm) evolutionary techniques are used in LFC mechanism to achieve the desired output [14]. In recent years, there is fast, innovation development towards the (RESs) Renewable energy sources, which are widely accepted for stability and control mechanism in the power system [15]. The stability analysis has been incorporated into the present work of the simulated system considering with and without the effect of the proposed control methodology. If the disturbance is persisting for the longest time, then only conventional controller or above reported control methodology for LFC of the discussed literature may not be sufficient to

reduce the mismatch between load demand and generation and resulting in the frequency deviation from its nominal value. The maiden attempt has been made in the paper for the LFC of three-area power system with co-ordination with (RESs) and electric-vehicle (EVs). Hence, PVs and EVS are installed in each area to support the LFC during load perturbation of the interconnected power system The work deals with the a suitable and efficient, coordinated Proportional Integral Derivative control scheme in coordination with PV and EV for the simulated interconnected power system. The optimum gain of PID controlled is optimized though Fuzzy logic technique. The proposed control arrangement suppresses the frequency oscillation and net lie-line power exchange effectively, which improves the LFC mechanism for the small load perturbation. The layout of the paper is as follow:- Section-1,contains introduction, Section-2, presents modeling of interconnected power system, Section-3, describe the linearized model of PV and Section-4, describe the linearized model of EV, the performance index and optimization of LFC through the Fuzzy logic procedure are given in section-5. Results and discussions are given in section- 6, and finally the paper is concluded in section-7.

2. Description and Modeling of the interconnected power system.

Mathematical Modeling of Inter-connected three area, power system has been used where Area-1, Area-2 and Area-3, consists of thermal-Thermal generation power unit and Area-3, consists of hydro generation power unit. The transfer function models of used inter-connected power system are discussed and developed in the IEEE committee report [16].The transfer function model of the simulated power system in given in the fig. 1.

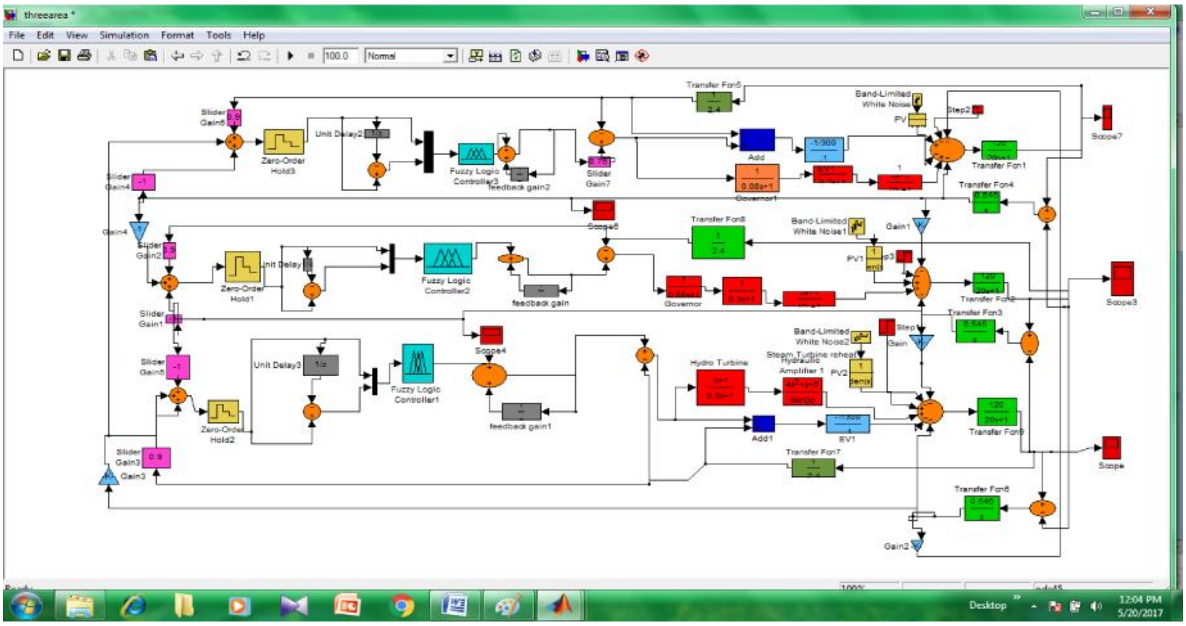

Fig.1 Transfer function model of PV and EV in Three Area Power system.

The (RESs) supports the secondary controller of LFC during their lag time, so dynamic performance of the system can be improved during the transient condition. Therefore, the EV unit has been installed in both the interconnected areas and the input signal of the EV is the area control error of the corresponding area. The proposed control strategy and its investigation are carried out in the detail for improvement of the LFC as well as the dynamic performance of the simulated task system.

3. Literalized model of the PV (Photo-Voltaic)

The basic physical structure of PV system consists of series/parallel combination of PV arrays and a power conditioning unit. These two components directly convert sunlight to DC power and then converts DC power to AC power and maintain the maximum efficiency of the PV operation[18]. To provide proper interface

between the grid-connected PV system, frequency, voltage level matching and phase sequence must be satisfied. The applied control strategy of the PV system in the study is based on a PI controller and pulse-width modulation (PWM), as shown in fig.2. [19].

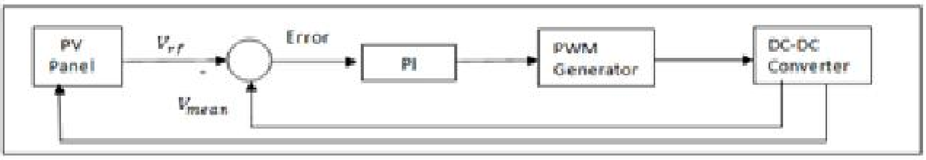

Fig2 Block diagram of the PV system

Where the PV panel block generates the reference voltage as a function of injected current, solar irradiance and panel temperature. Which is compared with the measured terminal voltage, the measured change in voltage (error) is passed through PI controller to obtain the appropriate PWM duly cycle and generate the switching signal of the DC/DC converter, using IGBT switches, which converts unregulated DC voltage to a regulated DC output voltage. The power is then injected into the system by using a coupling transformer at the desired voltage level. [20]

4. Linear zed model of EV(Electric Vehicle)

Growing concern about global warming and energy security aspects associated with road transport system has directed more public interact to EVS. The main difference between EVs and conventional vehicle is that, the required toque in EVs is supplied through an electric motor, powered either solely by a battery or in combination with an internal combination engine referred to as hybrid-electric vehicle. The impact of EVs on system performance depends on the changing Scenario [21]. To investigate the effect of high penetration EVs in this study, charging is assumed at remote spots called charging stations (Similar to petrol filling stations) under a fast charging mode [22]. The important factor in modeling EVs include charging time and charging power level. In this study, each EV is assumed to consume 10 KW of electricity on average, and each can reach full-charge levels within 10 min to 15 min through a 330 V DC fast changing board in the EVS[23].

Fig.3 shows the block diagram of EV.

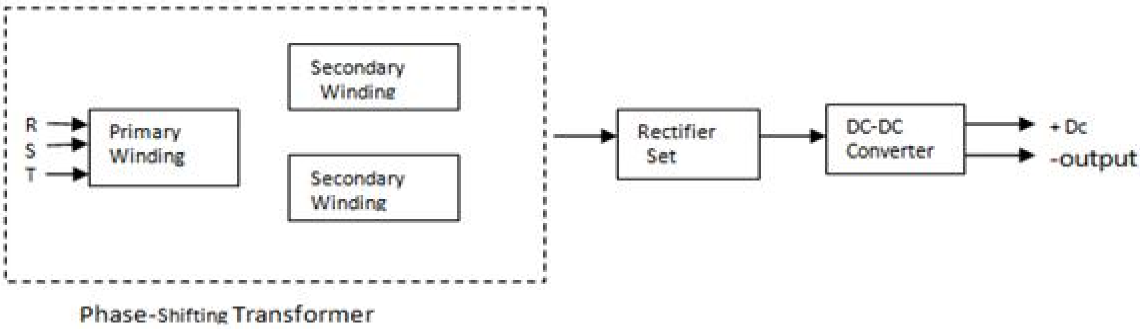

Fig.3 Block diagram of the EVS

The described EVs can be modeled as a dynamic DC load connected to the grid through a AC/DC power convertor which includes a phase-shifting power transformer, a set of rectifier and one set of DC-DC full bridge converter to provide the pre-determined DC voltage level, as show in fig 3. The main importance of phase-shifting power transformer is to mitigate current harmonic and increase the system power factor, and the rectifier and DC-DC convertors are fed through the secondary winding of transformer.

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5. Optimization of an integral controller gain through fuzzy approach.

First of all, the objective function is defined for the studies system ie. the performance index of the system which is the combination of the frequency deviation of both interconnected areas(Δf_1, Δf_2) and net tie-line power flow (ΔP_{tie}) of the interconnected power system. Hence, integral square Error (1SE) acts as an objective function for the optimization purpose of an integral controller gain of the proposed interconnected power system.

In this paper three fuzzy-PID controllers are used, 1st and 2nd for thermal units, 3rd one for hydro unit. Many of the previous research works in different areas related to fuzzy-PID controller dealt with selection of input and output scaling factors of the controller with several hit and trail runs. The performance of the controller mainly depends on the selection of these parameters and it is very difficult to get the optimum values using hit and trial method. The main contribution of the work is to design a fuzzy-PID controller with optimized input and output scaling factors. This paper proposes a fuzzy-PID controller, and finally the superiority of the proposed fuzzy-PID controller is proved in the result and discussion section.

The structure of the fuzzy-PID controller of thermal unit is shown in Fig.4.and Fig.5 It has two inputs, area control error and change in area control error and one output. The input scaling factors are k_1 and k_2 and output scaling factors are K_3 and K_4 . Similarly the controller for hydro unit have four scaling factor each. Zolfagharian et al. [24] have designed a multi-objective genetic algorithm based active fuzzy controller to reduce noise and vibration of automobile wiper system. In this article fuzzy-PID controller are the proposed for optimization.

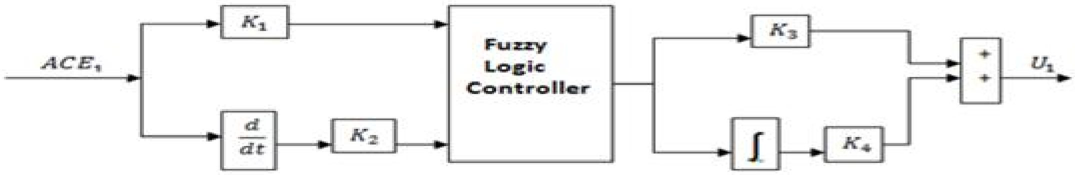

Fig.4. Fuzzy-PID Controller of area -1.

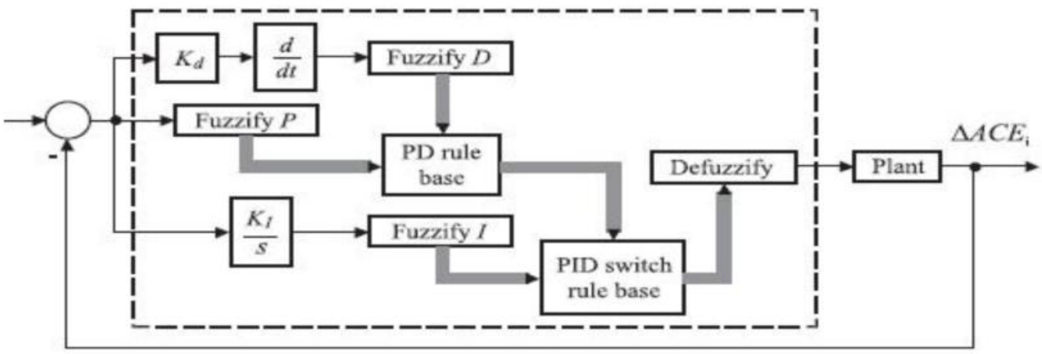

Fig. 5. The proposed multi-stage fuzzy PID controller.

Five membership functions are used namely negative big (NB), negative small (NS), zero (Z), positive small (PS) and positive big (PB) for both the inputs and output. Triangular membership function are used for both the input and output because it is simple and used less computation time.

The input and output variable of fuzzy logic controller have five membership functions and therefore there is a need of 25 rules for generating fuzzy output. These rules play very important role in performance of fuzzy logic controller and therefore in this paper these rules are investigated comprehensively by studying the dynamic behavior of the system. The very popular Mamdani interface system is used in fuzzifying the inputs and combining the fuzzified inputs with the fuzzy rules. The output of the fuzzy system is a fuzzy value and

therefore must be converted to a real value using a suitable defuzzification technique. In this paper, the most effective centre of gravity (COG)' method of defuzzification is used to convert the fuzzy value to real value.

Now the fuzzy controller is used for getting his optimized value of the integral gains of an integral controller. With the help of the fuzzy rules, the optimized value of the integral gain of an integral controller in obtained to achieve the desired output with the proposed LFC scheme. Corresponding system performance parameters like peak line. Peak value, rise time, setting time and the value of performance index for ISE or obtained and shown in the Table.

6. Result and discussion of the simulated test system.

The simulation of this proposed controller is carried out using the MATLAB/Simulation toolbox. All the parameter of this studied system have been given in appendix-A. As mentioned in section 5, the fuzzy logic techniques have been successfully applied to line his integral controller through the ISE performance index. All the analysis has been done at the load change of 0.01 PV in both the areas and result of the small signal stability in the case of with and without proper controller in given in follow.

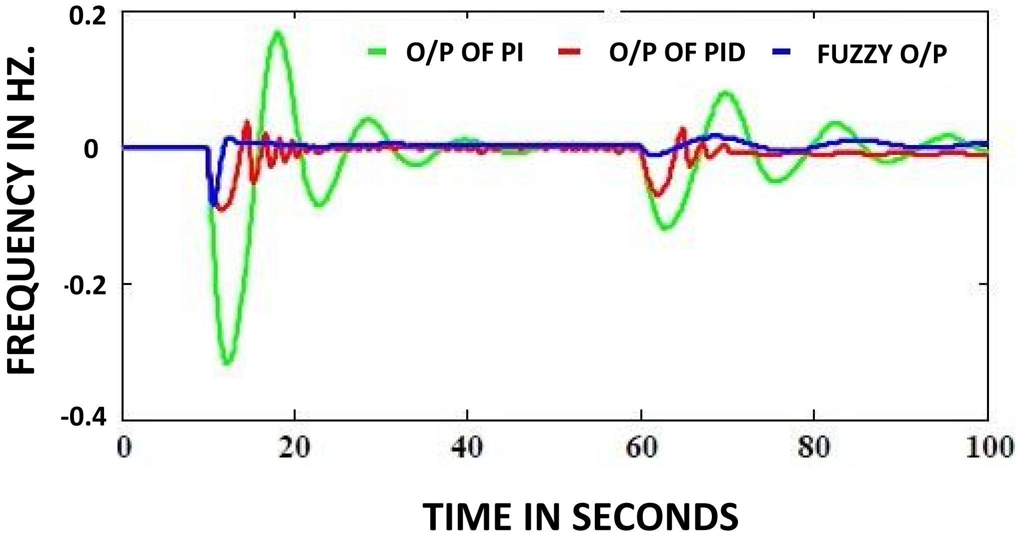

Table.1 Dynamic performance characteristics of the studied system with proposed control scheme.

	With optimal control scheme	**With proposed controller**	**Percentage improvement**
Value of the PID gains of both area	Proportional gain = 4 Integral gain =1.18 Derivative gain =0.5	K1 = 0:699 K2 = 0:325	-
Value of the performance index		ISE= 0.0002	
Characteristics of the frequency Deviation (Δf_1) of area 1	Peak Amplitude: 0.0311 pu RiseTime: 0.1345 s PeakTime: 1.9400 s Settling Time: 27.12 s	Peak Amplitude: 0.0053 pu Rise Time: 4.18e_04 s Peak Time: 1.781 s Settling Time: 22.03 s	8.46 99.77 8.62 21.55
Characteristics of the frequency deviation ($\Delta f2$) of area 2	Peak Amplitude: 0.0223 pu RiseTime: 0.1122 s PeakTime: 1.8000 s Settling Time: 29.21 s	Peak Amplitude: 0.0078 pu Rise Time: 0.017 s Peak Time: 0. 569s Settling Time: 23.25 s	66.54 85.10 67.43 22.17
Characteristics of tie-line power flow deviation (ΔP_{tie}) of the interconnected power system	Peak Amplitude: 0.0080 pu RiseTime: 0.1411 s PeakTime: 1.9000 s Settling Time: 37.83 s	Peak Amplitude: 0.0026 pu Rise Time: 0.1072 s Peak Time: 0. 191 s Settling Time: 37.41 s	60.11 23.35 85.48 1.09

Table. 2. Percentage improvement of the system with energy storage device simulation study.

Value of change	With energy storage system	Without energy storage system	Percentage improvement
Maximum frequency deviation of Area-I	-0.0998	-0.745	86.53
Maximum frequency deviation of Area-II	-0.0571	-0.491	88.37
Maximum tie-line power flow deviation of the system	-0.0190	-0.1594	88.08

Table 3. Comparison results for PI,PID and FUZZY LOGIC controllers with 0.01 step change in steady state and peak overshoot aspects of considered system .

Controller	Steady state	Peak over shoot
PI	X=31.53,Y=0.17	X=2.802;Y=0.00007
PID	X=21.73,Y=0.000042	X=1.95;Y=0.00004
Fuzzy PID	X=17.17Y=0.0027	X=0.218 Y=0.0003

Table 4. Comparison results for PI,PID and FUZZY LOGIC controllers with 0.01 step change in steady state and peak overshoot aspects of considered system. For three areas interconnected thermal system.

Controller	Steady state	Peak over shoot
PI	X=3.63, Y=0.019	X=11.28; Y=0.0107
PID	X=34.57, Y=0.600114	X=10.67; Y=0.0012
Fuzzy PID	X=29.17, Y=0.0127	X=0.841 Y=0.0104

Appendix A .Parameters of this studied system.

1. Thermal power system

Coefficient of re-heat steam turbine = k_{r1} = k_{r2} = 0.3, Re-heat time constants = T_{r1} = T_{r2} = 10 s, Turbine time constant = T_{t1} = T_{t2} = 0.3 s, R_{thi} Speed governor regulation = R_{thi} = R_{thi2} = 2.4 Hz/puMW, Speed governor time constant =T_{g1} = T_{g2} = 0.8 s and Water time constant = T_{w1} = T_{w2} = 1 s, GRC = 0.0017 pu, Dead band = 0.006 pu.

2. Hydro power system.

Speed governor rest time = T_{R1} = T_{R2} = 5s s, Transient droop time constant = $T_{R\ 1}$ = $T_{R\ 2}$ = 28.75 s, Main servo time constant = $T_{G\ 1}$= $T_{G\ 2}$ = 0.2 s, and Speed governor regulation = R_{hy1} = R_{hy2} = 2.4 Hz puMW.

3. Power System.

Gain of the power system = $K_P = K_P$ =120Hz/pu, Time constant of the power system= $T_P = T_{P\ 2}$= 20s, Participation factor representing economic load dispatch ($p_1 = p_2 = o.46966, p_1 = p_2 = 0.37814, p_1 = p_2 = 0.15220$) , Bias factor $= B_1 = B_2 = 0.425$ puMW/Hz, Integral gains of the controller ($K_1 = 0.6999 \& K_2 = 0.325$).

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