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An Intelligent and Non Integer Order Coordinate Control for LFC of Multi Area Power System Integrated with EVs

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Abstract: Nowadays to reduce carbon emissions every one looking forward to pollution free energy by integrating electrical power system with Electric Vehicles (EVs). This paper offers the participation of EVs for LFC of 3 region energy systems and every control area there is a EVs penetration to minimize frequency and Tie-Line oscillations of multi area power system. In this propose work a coordinated intelligent (Fuzzy) and Non Integer Order (FOPID) controller implemented for three area power system under sudden load disturbances and larger load demands. This new coordinated control methodology tested on multi area power system using MATLAB-Simulink and performance of proposed coordinated control strategy compared to FOPID and PID controllers.

Key words: Electric Vehicle (EV), Fuzzy controller, PID, FOPID

I. INTRODUCTION

Environment is polluting as the world is going to be developed most of the pollution is occurred by transportation and the fossil fuels are decreasing, the effect of global warming takes place. According to new data from the World Health Organization (WHO) released, shows that 90 out of 100 people breath air containing high levels of pollutants. The major cities like Delhi and Beijing are highly effected by pollution. This pollution control by the use of electrical vehicles. In India is developing market on the electrical vehicles (EV). India's largest automobile producer Tata cars signed a memorandum of Understanding (MoU) with the kingdom government of Maharashtra to set up 1,000 electric powered motors (EVs) and the primary elements at the back of the boom of electrical vehicle profits are authorities guide inside the shape of gives, subsidies, and tax rebates, growing environmental purchaser focus, enhancing charging infrastructure, and developing vehicle range. As in line with the survey via the use of the prevent of 2025 Indian authorities plains electric powered cars stood at about 20-25% of the whole motors. There are huge sort of electric automobiles are associated with the grid. a number of the EVs are rate at time and a few will discharge at some time those leads large disturbances in the grid and lot of frequency fluctuations are appear the grid for manipulate of this frequency we're capable of control the frequency in the aggregate of Fractional Order Proportional essential Differential Controller (FOPID) and cargo Frequency manage (LFC).There are many papers came into picture for the LFC with EVs, but in the combination of both Fuzzy Logic Controller (FLC)and FOPID is the better way to control the magnitude and frequency of the system.[18]

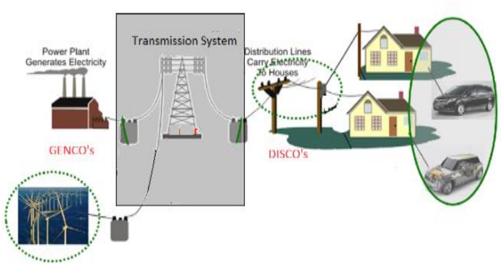

Fig.1 Overview of the system

PID manipulate is a well-set up way of using a tool in the route of a cause feature or degree. The mathematics in a PID control equation is complicated with more than one variables and constants interacting [15].Fuzzy appropriate judgment is recognition inside the have observe of synthetic Intelligence and is based totally at the charge of that statistics it actually is neither truly genuine nor fake. The data which people use of their ordinary lives to base intuitive choices and study stylish suggestions of thumb can and should be finished to those manipulate situations which call for them[22].

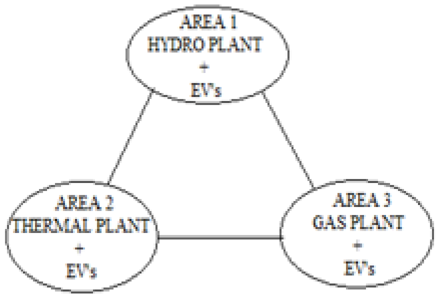

Fig.2: Three area system with EVs penetration

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Large number of EV's are connected to the grid, these EV's are ready to charge and discharge so the power plant should be large in size to supply this electricity demand by the EV's, it is a necessary to the owner should make agreement between the suppliers i,e. these EV' will charge for off peak time for 9pm to 6pm and discharge the EV's to the grid if it is necessary in on peak time. Therefore EVs are more better way for future electric demand [3]. On base of this many researchers are put their effort on the primary frequency control (PFC).

Technology agencies and (GENCOs) and distribution groups (DISCOs) made a bilateral agreement and positioned up the agreement to independent gadget operators (ISO). The two businesses GENCOs and DISCOs is tough assignment to maintain reliability and safety with factor of view [1]. But numerous researchers given integer order (IO) cannot deliver the better effects whilst the physical parameters like GDB, saturation limits, and charge constraints are present. In contemporary-day days, fractional order (FO) controller is playing hundreds interest due to its stepped forward flexibility for adjustment of device dynamics. it is been hired for AGC of thermal structures below deregulated environment [19].the prevalence of FO controller is due to its extra tuning knobs which encompass fractional order of integrator (λ) and fractional order of the differentiator (μ). Inside the issue of debate, in this paper LFC of multi vicinity gadget which incorporates 3 gadgets in integration of EV's fleets is evaluated under deregulated device [5]. The version that is developed on this paper consists of realistic parameters like GRC, GDB, for thermal tool and open conversation hyperlinks. The mixture of fuzzy common experience controller (FLC) and Fractional order necessary-spinoff (IλDμF) controller with clear out is carried out to the model to rectify the area control mistakes (ACE). And the consequences are in comparison with PID and FOPID controllers.

Flower pollination set of guidelines (FPA) is one of the better set of policies that's utilized in modern-day days, the ones set of rules is mimics the behaviour of the FPA in the nature [24]. Pollination is the natural phenomenon; it performs a number one function in replica of flower flora [1]. The smooth clarification of FPA is given in [25]. Many researchers given the prevalence of FPA. The layout of LFC scheme of smart grid covered with EV's is given in [1].

II. MODELLING OF POWER SYSTEM FOR LFC

In this paper we have consider that three area system one thermal power plant and second is of hydro power plant and the third is of the gas plant, all this three plants are interconnected and every plant is having some number of EV's connections to charge and discharge it depends up on the necessary of the respective EV. Each EV is connected to the grid.

When one of the DISCO is necessary of more power than that the GENCO and EV's are supplied than the other GENCO is ready to supply the amount of the power to balance the grid. For example if area 2 DISCO is require more power than the area 2 GENCO and EV's. The require amount of the power is taken from other two areas. The value of upper limit and lower limit values as taken 5 MHz and -5 MHz respectively. The droop coefficient of EV model is taken 2.4Hz/p.u.MW.

The battery Where N_{EVi} value depends up the number vehicles connected to the grid, for simulation we considered that 200 number for area-1, 300 for area-2 and 500 for area-3 system.

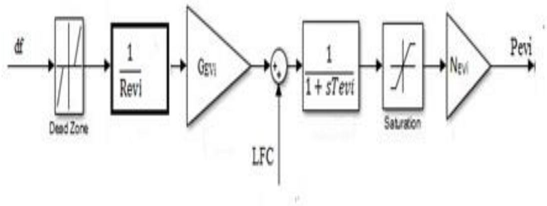

Fig.3 Simulation model of Electric Vehicle

For analysis, the charging and discharging can pass as plenty as 50 kW or perhaps greater throughout fast start. In each each vicinity, charging and discharging EVs are associated with the mitigate the mismatch at some point of agreement violation wherein NEvi is the shape of electric powered vehicles associated with the tool as stated above.

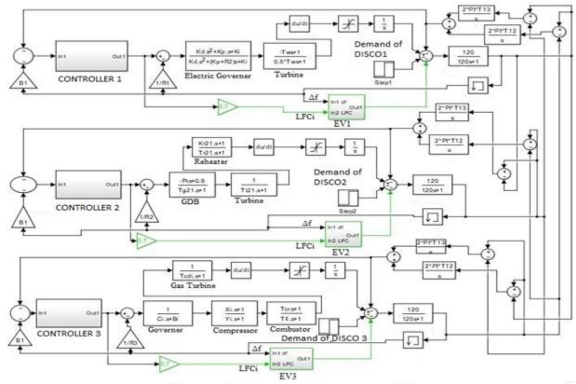

Fig 4: Transfer Function typical _diagram of three region power classification with EVs

III. DESIGN OF COORDINATED CONTROL METHODOLOGY

In this paper a coordinated control methodology with both Fuzzy Logic Controller (FLC) and Fractional Order Propositional Integrator Derivative (FLC+FOPID) proposed. Fuzzy controller is the realistic controller and FOPID is the mathematical approach controller so the combination of both the controller will give the better results. The two controller connection is shown in figure below and the output the controller is connected to the system as shown in the fig.4.

Fig.5 is the connection of two controllers i.e FLC and FOPID are connected in the cascade, than the performance of the controller is increased and gives the better performance and stability of the system is increased

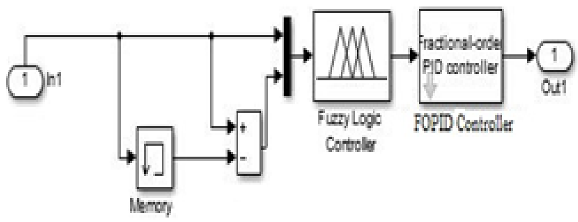

Fig.5 the simulation diagram of the both Fuzzy Logic and FOPID controllers

Fuzzy Logic Controller:

Fuzzy controller is a manage method primarily based mostly on fuzzy commonplace enjoy.

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Certainly fuzzy right judgment can be defined easy as computing with phrases in preference to numbers and is defined clean as manage with sentence in place of equations. FLC can encompass empirical suggestions, and this is particularly beneficial in operator plant. It's far the sensible controller, Fuzzy not unusual experience is implemented with great achievement in several control software program. Nearly all of the customer products have fuzzy manage. Some of the examples embody controlling your room temperature with the help of air-conditioner, manipulate on website online traffic lights, washing machines, massive monetary systems, and so on. The FLC is format through the usage of some of the pointers as the synthetic intelligence primarily based totally on that hints the output of the machine is extra realist.

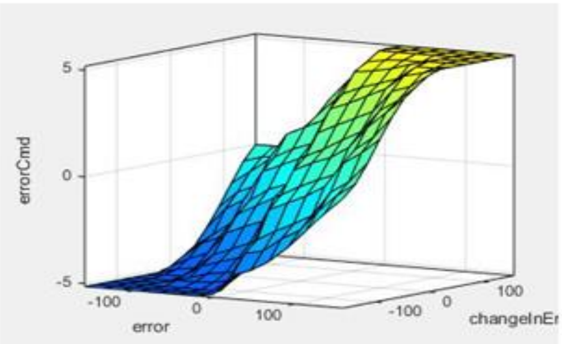
The control method is isolated in a rule base in opposition to an equation primarily based definitely description. A rule based totally controller is easy to recognize and smooth to hold for a non-professional stop-consumer. An identical controller may be applied using conventional strategies. FLC designed based definitely certainly totally on the recommendations, the tips are given in fig.6

FLC is designed through the usage of the triangular membership feature. By using way of the use of FLC we are able to get higher output than the previews one, because it has many versions we're able to get advocate rate.

Fuzzy logic resembles the human decision making methodology. It deals with vague and imprecise information

E / Δe	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

(a)



(b)

Fig. 6 (a) Rule table of fuzzy logic controller, (b) is cube of FLC

Fractional Order Controller:

The Fractional-order came into picture that to extend the integration and differentiation's integer order of controller. The Fractional-order will provide more adjustable time and frequency responses for the control system allowing fulfilment of better as well as robust performance. So a fractional-order PID controller will always give better response than integer-order PI and PID controllers if it is properly tuned whatever may be the type of plant (integer or fractional). It is true that by application of fractional-order controller will give more adjustable time and frequency responses for the control system [4]. A fractional-order PID controller can have as much as 5 DOF which means that you can satisfy more than 3[4]. By considering all the advantages FOPID will give much better results than the PID controller.

The Riemann-liouville classification for insignificant derivative is specified by the _equation (1)

$$ {}_aD_t^{\alpha} f(t) = \frac{1}{\Gamma(n-\alpha)} \frac{d^n}{dt^n} \int_a^t (t-\alpha)^{n-\alpha-1} f(\tau) d\tau \quad (1)$$

wherein n-1 ≤ α < n, n is a integer and Euler's gamma characteristic is Γ (.). The given equation is fractional essential, equation (2)

$$ {}_aD_t^{-\alpha} f(t) = \frac{1}{\Gamma(\alpha)} \int_a^t (t-\tau)^{\alpha-1} f(\tau) d\tau \quad (2)$$

Where D_t^{α} is the fractional operator? The equation (3) shows that the Laplace transformation of Rieman-Liouville definition for the fractional derivative.

$$L\{{}_aD_t^{\alpha} f(t)\} = s^{\alpha} F(s) - \sum_{k=0}^{n-1} s_a^k D_t^{\alpha-k-1} f(t)\, |_{t=0} \quad (3)$$

in which L{f(t)} indicates the regular Laplace transformation For n-1 ≤ α ≤ n. right here we're capable of recollect the initial scenario as zero, the overall device dynamic behaviour may be defined via using the use of differential equations collectively with fractional derivatives supply upward push to fractional order of s.

The fractional derivative or vital s^{α} may be approximated through a switch function proposed through the usage of Oustaloup. And that need to be the in the pre-distinct frequency kind of [ωl, ωh] the use of recursive distribution of poles and zeros is given equation (4)

$$S^{\alpha} = K \prod_{n=1}^{N} \frac{1+(s/\omega_{z,n})}{1+(s/\omega_{p,n})} \quad (4)$$

Within the above equation 'adequate' is represents as a adjustable benefit, at the same time as k=1, the gain is 0 db for a 1 rad/s frequency. The kind of zeros and poles 'N' is selected in advance. be aware that decrease values of N consequences right into a bargain masses plenty much less complex approximations however motive ripples in each benefit and segment behaviours. Ripples can be eliminated with the useful resource of manner of manner of growing the price of N. Frequencies of poles and zeros are given through equations (5)–(9).

$$\omega_{z,1} = \omega_l \sqrt{\eta} \quad (5)$$

$$\omega_{p,n} = \omega_{z,n} \varepsilon, \quad n = 1, \ldots, N \quad (6)$$

$$\omega_{z,n+1} = \omega_{p,n} \sqrt{\eta}, \quad n = 1, \ldots, N-1 \quad (7)$$

$$\varepsilon = (\omega_h/\omega_l)^{v/N} \quad (8)$$

$$\eta = (\omega_h/\omega_l)^{(1-v)/N} \quad (9)$$

The general transfer function of single degree of FOPID controller is shown in the below equation.[2].

$$G_c(s) = K_p + K_i/s^{\lambda} + K_d s^{\mu} \quad (10)$$

$$G_c(s) = K_i/s^{\lambda} + K_D s^{\mu} \quad (11)$$

IλDμ controller has four impartial tuning knobs on the equal time as five in case of PIλDμ. Because of its inherent capabilities, PIλDμ controller allows to hold the tool balance in evaluation to conventional controller. However, in PIλDμ controller, the D parameter will uplift the disturbances substantially below noisy environment it honestly is because of non-save you switching within the load problem.

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Therefore, immoderate frequency noise may be reduce thru which encompass a easy out to the Dμ parameter. Ultimately, the output of the proposed controller takes the form given with the beneficial useful resource of the usage of (12).

$$G_c(s)=K_i/s^{\lambda}+(K_D s^{\mu} N_F)/(1+(N_F/s^{\mu})) \quad (12)$$

wherein in NF is the smooth out coefficient and termed as IλDμF controller. proper right right right here, ACE signal, i.e., frequency deviation and scheduled tie-strength deviation is handed via the analog clean out confirmed in equation (13).

$$K_{I1}^{min} \le K_{Ii} \le K_{I1}^{max} \text{ and } K_{D1}^{min} \le K_{Di} \le K_{D1}^{max}$$
$$\lambda_1^{min} \le \lambda_i \le \lambda_1^{max} \text{ and } \mu_1^{min} \le \mu_i \le \mu_1^{max}$$
$$N_{F1}^{min} \le N_{Fi} \le N_{F1}^{max} \quad (13)$$

where K_{Ii}^{min},K_{Di}^{min}, are the minimum (min.) values of the controllergains and $K_{Di}^{max}K_{Di}^{max}$, are the maximum (max.) value of the controller gains. $\lambda_i^{min,}\mu_i^{min}\lambda_i^{max}$, μ_i^{max} are the min.and max. value of order of integral and derivative gains.the derivative filter coefficients are of $N_{Fi}^{min}$and N_{Fi}^{max} are the min. and max. values. 0 and 1 are the min. and max. values of the gain and fractional order. 0 and 100 are the NFi, min and max values. By using the fraction on the powers of integer and differentiator the FOPID controller gives the better results than normal PID controller.

TABLE.1 Gains of PID, FOPID and FLC+FOPID

Areas		Optimal values of PID and IDF Parameters					
		K_{Pi}*	K_{Ii}*	K_{Di}*	λ_i*	μ_i*	N_F*
PID	Area1	0.197	0.678	0.403	-	-	57
	Area2	0.174	0.378	0.932	-	-	81
	Area3	1.088	0.511	0.015	-	-	112
FOPID	Area1	0.173	1.972	0.982	0.321	0.0032	100
	Area2	0.197	0.001	0.001	0.289	0.0854	65
	Area3	0.211	0.064	0.064	0.195	0.1121	100
FLC and FOPID	Area1	0.107	0.490	0.490	0.864	0.0368	100
	Area2	0.181	0.501	0.501	0.942	0.0716	79
	Area3	0.163	0.174	0.451	0.842	0.2116	82

IV. SIMULATION RESULTS

Simulink models are developed using MATLAB 2014b under various operating conditions and larger load demands to obtain output frequency response and Tie line power oscillations.

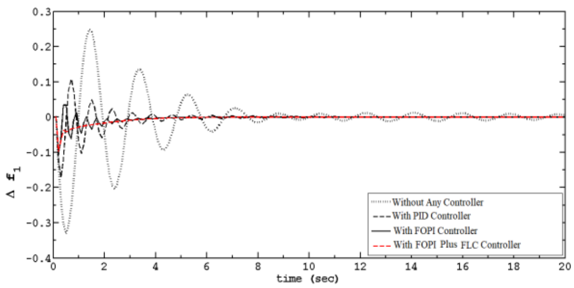

Fig-7: Frequency response of Control Area-1

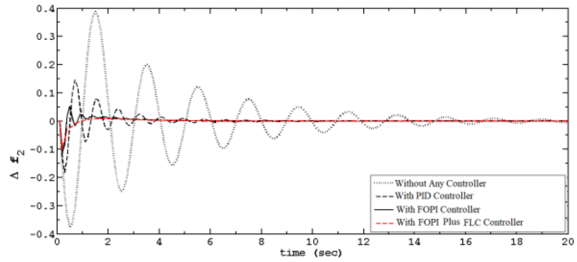

Fig-8: Frequency response of Control Area-2

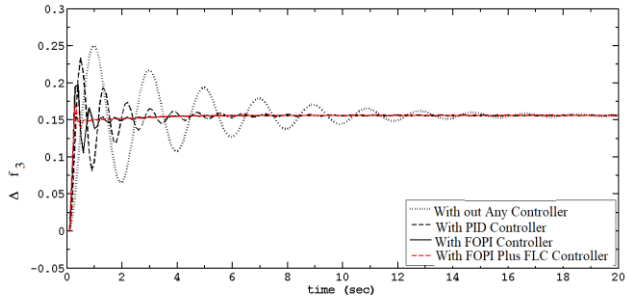

Fig-9: Frequency response of Control Area-3

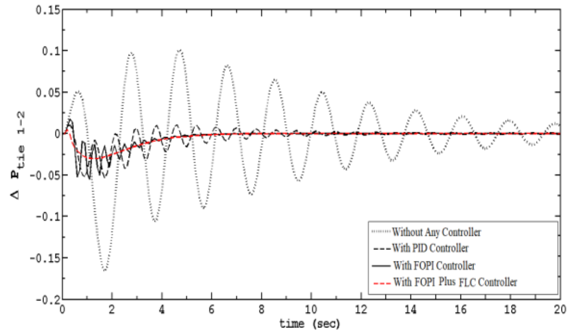

Fig-10: Tie line power deviations of Control Area One and Two.

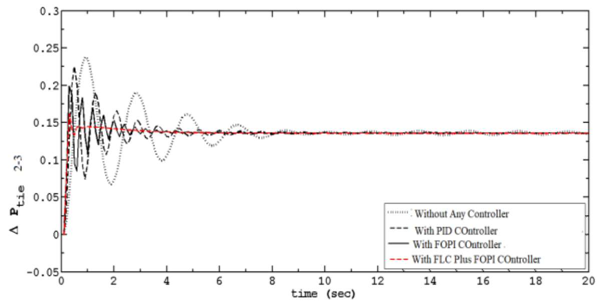

Fig-11: Tie line power deviations of Control Area Two and Three

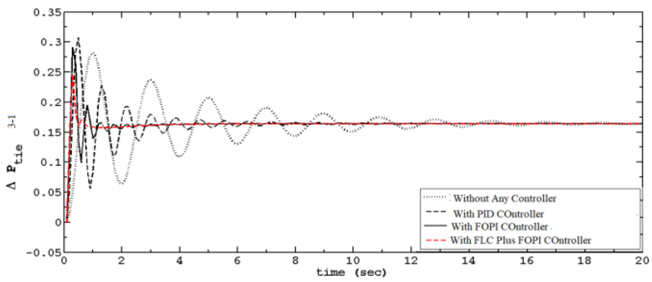

Fig-12: Tie line power deviations of Control Area One and Three

V. CONCLUSION

A Coordinated Control strategy implemented for three area power system under sudden load disturbances and control parameter variations. Simulations are performed and effectiveness of the coordinated control strategy tested on three area power system with EVs penetration. Simulation results shows that this control strategy gives better dynamic response compared to FOPID controller, PID controller and without any controller. This paper gives the better results with coordinate control methodology both Fuzzy logic controller (FLC) and Fractional Order PID (FOPID) controller [FLC+FOPI] compared to FOPI, PID and without any controller for LFC of multi area power system with EVs penetration.

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