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Comparative Analysis of Three Area Load Frequency Control with PI and PID Controller

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Abstract: With ongoing system restructuring, continuous change of dynamics/load and operating conditions, the uncertainty issue in electrical power system operation and control has increasingly become a challenge. Load frequency control is a challenging problem for utilities and needs to be maintained under slandered operating conditions despite the alteration in load demand or an imbalance between generation and load. It degrades the power system performance and even stability, which cannot be described in conventional transient stability and voltage stability studies. In the last two decades, many studies have focused on damping control and voltage stability and related issues, but there has been much less work on the power system frequency control analysis and synthesis. Therefore with concern to this major issue, study is done to understand the methodology and elements of load frequency control. For this several models are designed with primary and with primary & secondary control both. The designing aspects are concerned to maintain the tie line power constant in two and three areas. To achieve the better dynamic performance conventional PI controller is replaced by PID controller working in secondary control loop. Shorter overshoot and lesser settling time with zero steady state frequency deviation are observed. Tuning of controller is done by Ziegler-Nichols method and Routh array. The proposed method was implemented in MATLAB/Simulink and maintains the stability of the system frequency by balancing the total generation and total loads with tie line load constraints.
Keywords: Load Frequency Control, Area Control Error, PID Controller, ZN method, Tie-Line Loading

I. INTRODUCTION

In an interconnected power system, where a number of generating stations are running in parallel, it is necessary that the frequency of the system should remain constant. In steady state the mechanical power input to the generators balances with the electrical load plus losses in the system. Constant frequency is also necessary as it affects the speed of various motors in a system which may affect quality of the product in the industries. In the power systems the load demand is never steady and changes continuously with time. The load demand depends upon the consumers which are independent to use the electricity in the way they like.

As soon as the system loads increases the generator feeds the additional load by losing their kinetic energy and so their speed decreases reducing the system frequency. The reduction in the frequency in turn reduces the speed of the motor in the system and so the motor output which is proportional to the speed drops. This reduces the system loads such that the system load and input to the generators balance at some lower frequency. Reverse happens when the system load reduces. Therefore in order to keep the system frequency constant the input to the generators, steam input to the thermal generators and water input to the hydro-generators, must be continuously regulated to meet the load demand variations. It is required to regulate the frequency within a specified narrow limit around the rated frequency; therefore control of frequency by controlling input to the generator is necessary. The input to the generators is generally controlled by the action of the governor which is an essential part of all types of generators.

The most critical component in a generator control system is the controller. It is designed in such a way that the concerned parameter has frequency and tie line power flowing as to maintain at the desired value [9].

There were several approaches proposed to optimize the gain constants with considering the uncertainties of the power system [2] i.e. generating rate constraints [6], valve speed limit to handle the nonlinearities in the power system. Decentralized PID controller based on Kharitonov's theorem and stability boundary locus [10] was proposed to take care of uncertainties in each control area. Laurent series expansion methods were suggested to tuning the controller parameters and with simulation achieves better damping for frequency and tie-line power flow deviations. Plotting the stability boundary locus in the $K_P - K_I$ plane and then computing the stabilizing values of the parameters of a P-I controller proposed in [8] and with the time delay in [11]. Internal model control method is proposed in [12] with the additional degree of freedom to cancel the effect of undesired poles of disturbances.

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II. CONTROL AREA CONCEPT

The control in the three area system is like the two area system. The integral control loop which is used in the single area system and two area system can also be related to the three area systems. Due to change in load there is change in the steady state frequency (Δf) so we need another loop apart from the primary loop to make the frequency to the initial value, before the load disturbance occurs.

The integral controller which is responsible for making the frequency deviation zero is put in the secondary loop. Three area interconnected system consists of three interconnected control areas. There is flow of tie line power as per the changes in the load demand due to the interconnection made between the control areas.

Thus the overall stability of the system is maintained at a balanced condition in spite of the constant variations in the load and load changes.

III. ANALYSIS OF MODELLING AND SIMULATION OF THREE AREA SYSTEM

A. *Three Area System with PI Controller*

Three area interconnected systems with PI controllers are given in Fig. 1. Fig. 2 presents the settling down of frequency to a finite value which is less than the actual frequency. Fig. 3 shows the power change due to tie-line on account of the deviation in the load. Here stability is improved with interconnection. We have taken the values of the different parameters as shown in Table I for modelling the Simulink model and its successful operation to obtain the desired results.

Table I: System Parameters For Three Area System With Pi Controller

Name	Area 1	Area 2	Area 3
K_{sg}(Gain of speed governor)	1	1	1
T_{sg}(Time constant of speed governor in sec.)	0.80	0.20	0.30
K_t(Gain of turbine transfer function)	1	1	1
T_t(Time constant of turbine in sec.)	0.30	0.50	0.60
H(Inertia constant)	10	5	4
D (pu MW /Hz)	1	0.60	0.80
R(Speed regulation)	15	20	16
ΔP_D(Alteration in load Demand)	1	0	0

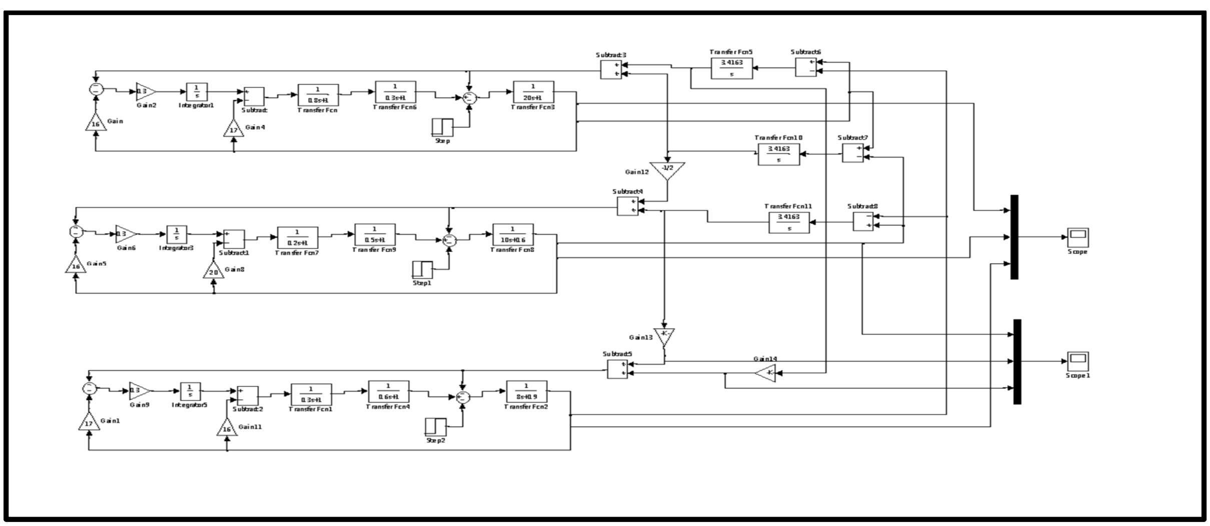

Fig.1: Simulink Model of Three Area System with PI Controller

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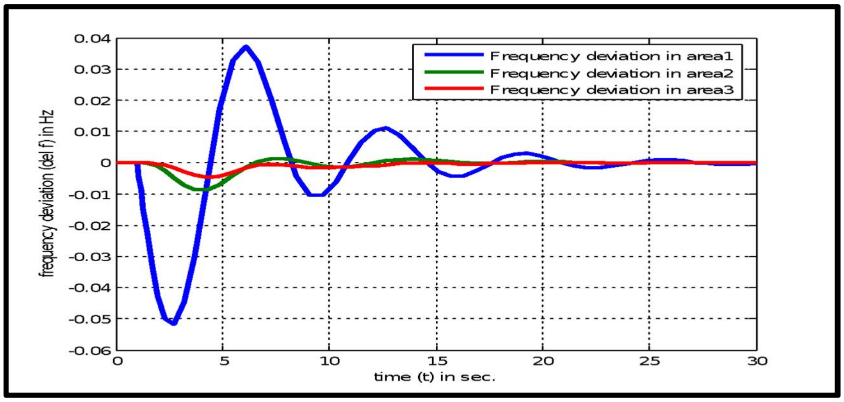

Fig.2: Frequency Deviation vs. Time for Three Area System with PI Controller

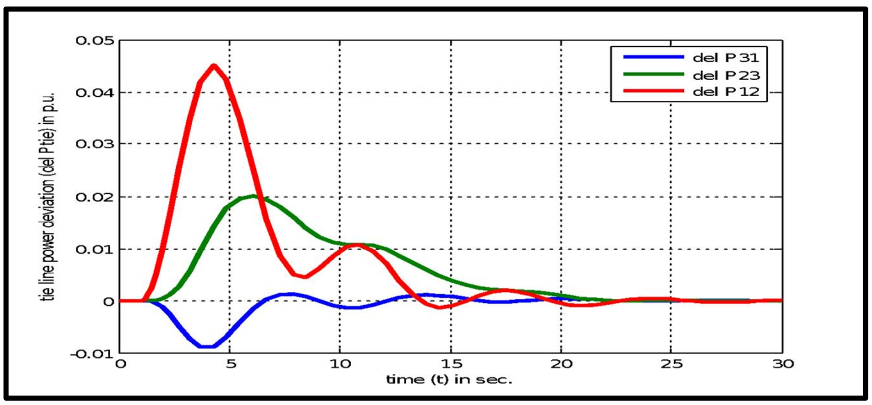

Fig. 3: Tie Line Power Deviation vs. Time for Three Area System PI Controller

B. Three Area System with PID Controller

The model for the three area system with PID controller is shown in Fig. 4. The results of the variation in frequency as well as tie line power output with respect to time are being shown in Fig. 5 and Fig. 6. The system operates in a similar way to that of the two area system, taking into consideration the changes in the load. We have taken the same values of the particulars as shown in Table I for modelling the Simulink model and its successful operation to obtain the desired results.

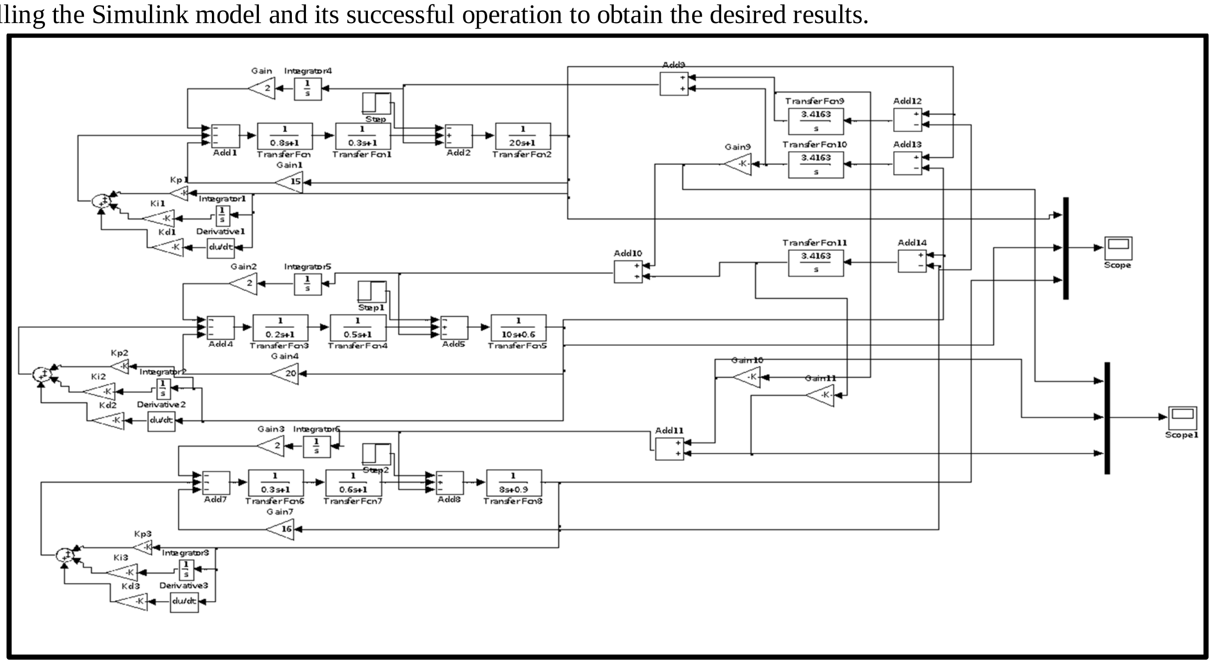

Fig. 4: Simulink Model of Three Area System by Using Secondary Loop

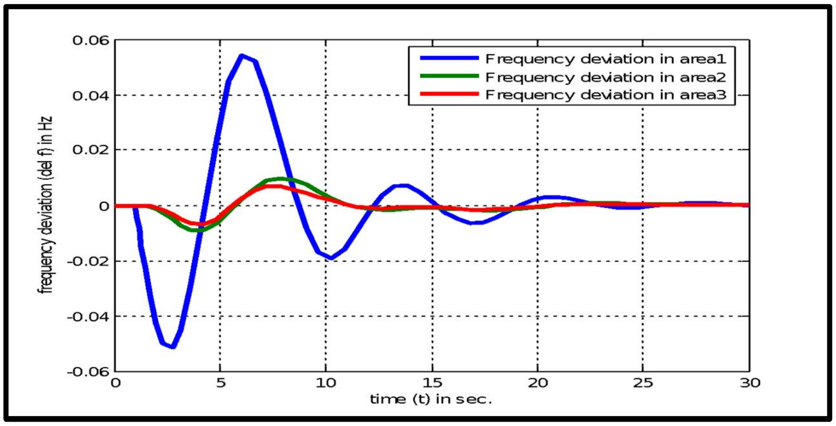

Fig. 5: Frequency Deviation vs. Time for Three Area System with PID Controller

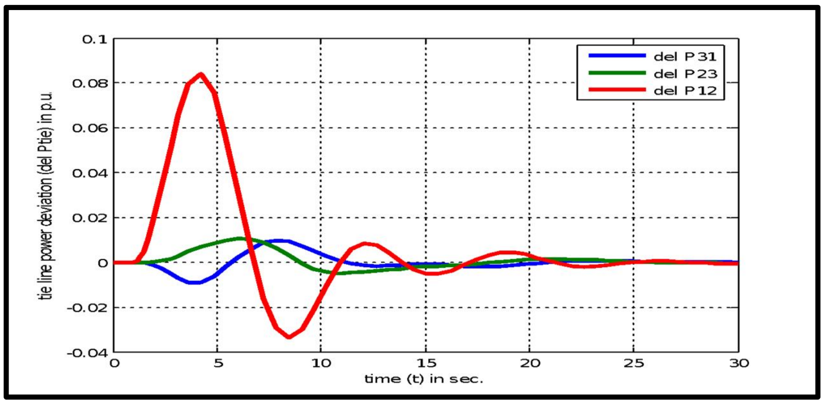

Fig. 6: Tie Line Power Deviation vs. Time for Three Area System with PID Controller

Moreover variation in frequency is made to be zero by using a secondary loop in both single area networks in addition to two area networks. We also see that the three area system also operates in a similar manner like that of two area systems and flowing power in a tie line which drifts from their contractual constraints between various areas are back to normal in steady state within a few seconds.

IV. ANALYSIS OF MODELLING AND SIMULATION OF THREE AREA SYSTEM WITH PID CONTROLLER

It's a general approach to the control system design problem that first we select the configuration of the overall system by introducing controllers and then choose the parameters of the controllers to meet the desired performance specifications. Practically most controllers require a trial and error parameter adjustment to achieve at least an acceptable performance if it is not possible to satisfy exactly all the performance specifications.

The gain constants of the controller optimized by Zeigler-Nichols method give better dynamic performance. So an approach is made to optimize the K_{pi} , K_{di} and K_{Ii}, where i represents the area no. or electricity board of different regions interconnected with a tie-line, by ZN method. The optimized values are shown in Table II.

Table II: Optimized Gain Constants For Three Area Network

Gain Constants	Area 1	Area 2	Area 3
K_p	49.8919	31.7702	16.8774
K_d	18.5373	7.7359	5.3614
K_I	33.5703	32.6391	13.2823

Fig. 4 shows the designed model with tuned PID controller. Frequency deviation and tie line power variation with respect to the time are depicted in the following figures from Fig. 7 to Fig. 12. Fig. 7, 9 and 11 shows the frequency deviation when the disturbance is applied for simulation in area 1, area 2 and area 3 respectively. Fig. 8, 10 and 12 shows the tie line power deviation following the sudden power mismatch about the generator load model in area 1, area 2 and area 3 respectively reduced and settles faster by the introduction in PID controller in feedback, also the tie line deviation and settling time is reduced and better dynamic response is obtained.

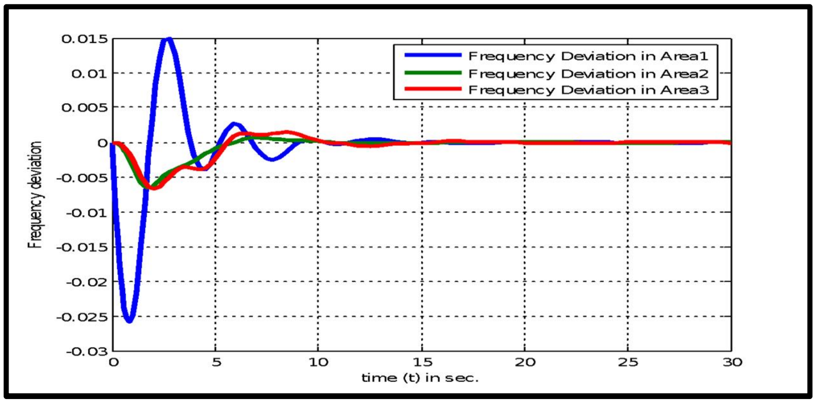

Fig. 7: Frequency Deviation vs. Time Plot Following Sudden Load Disturbance in Area 1

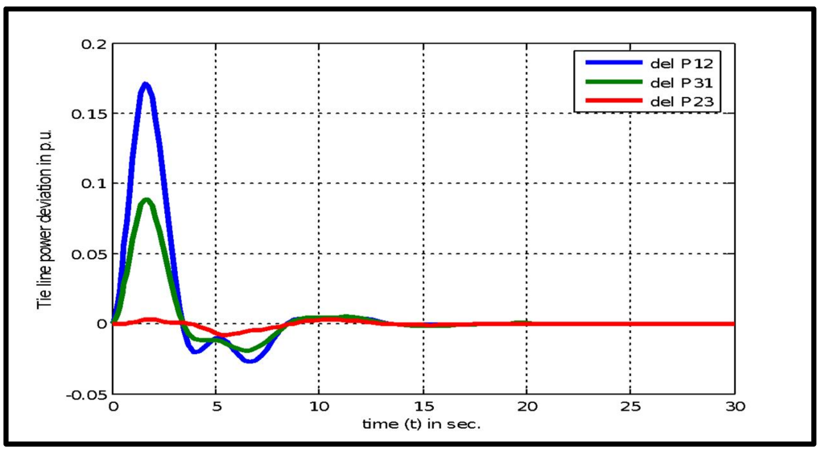

Fig. 8: Tie Line Power Deviation vs. Time Plot Following Sudden Load Disturbance in Area 1

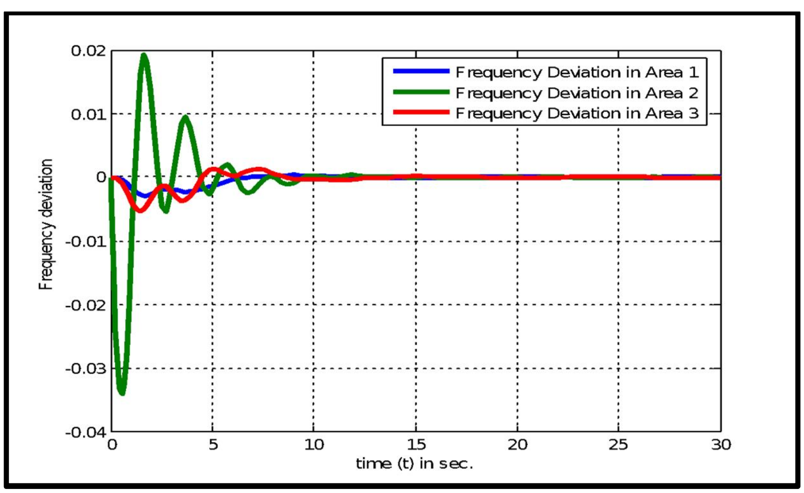

Fig. 9: Frequency Deviation vs. Time Plot Following Sudden Load Disturbance in Area 2

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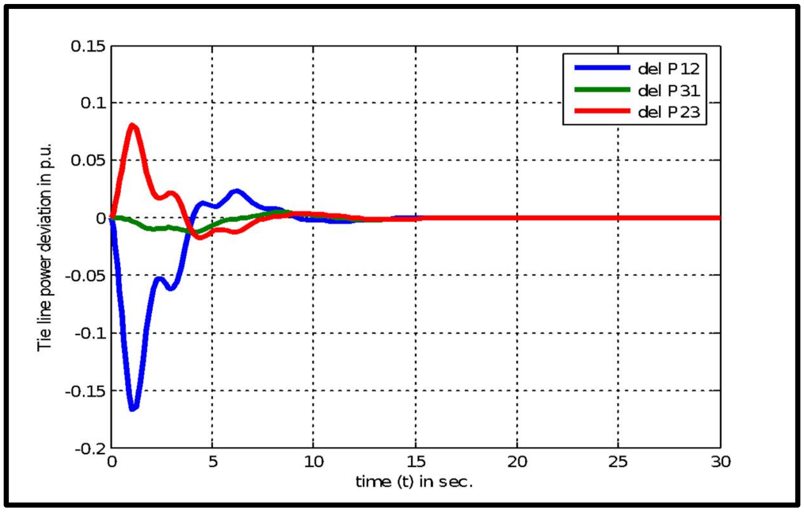

Fig. 10: Tie Line Power Deviation vs. Time Plot Following Sudden Load Disturbance in Area 2

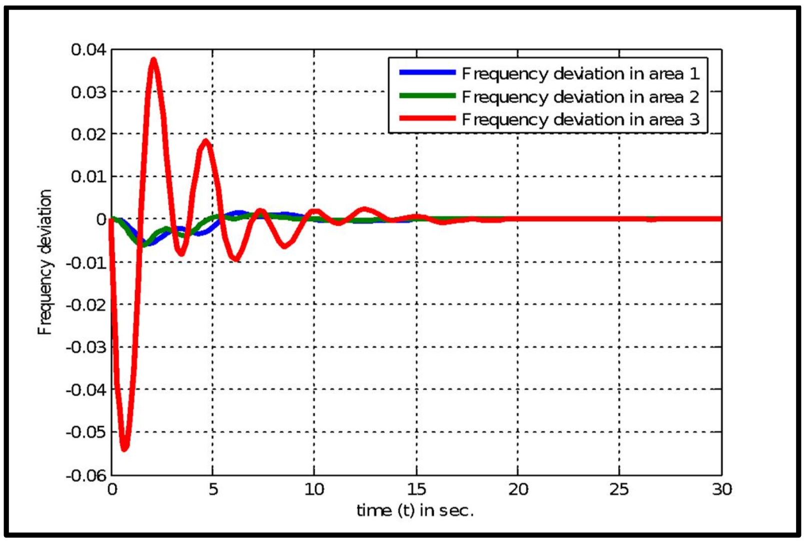

Fig. 11: Frequency Deviation vs. Time Plot Following Sudden Load Disturbance in Area 3

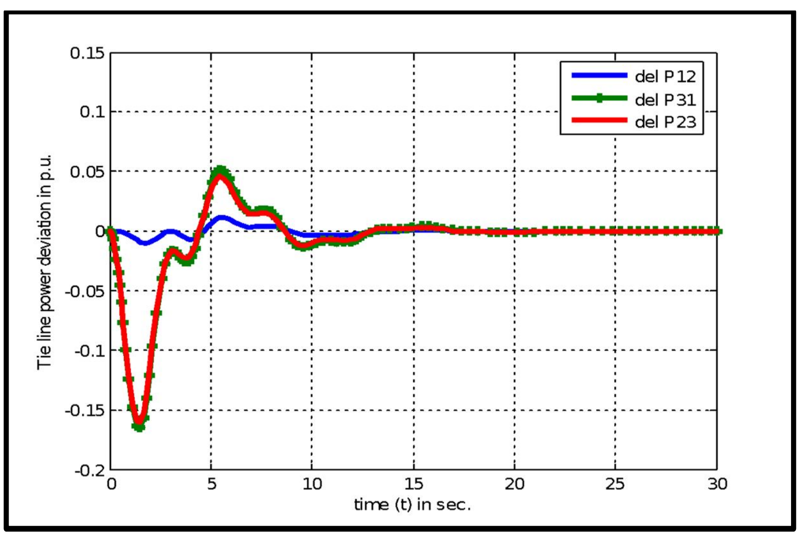

Fig. 12: Tie Line Power Deviation vs. Time Plot Following Sudden Load Disturbance in Area 3

V. CONCLUSIONS

In this paper an approach is made to design a PID controller connected in feedback configuration in individual area of three area networks which represent the interconnected power system and the objective is to control the speed and power flowing in the transmission line. The result shows that not only the steady state but also the transient response of the system is improved in all the cases of wherever the fault occurred.

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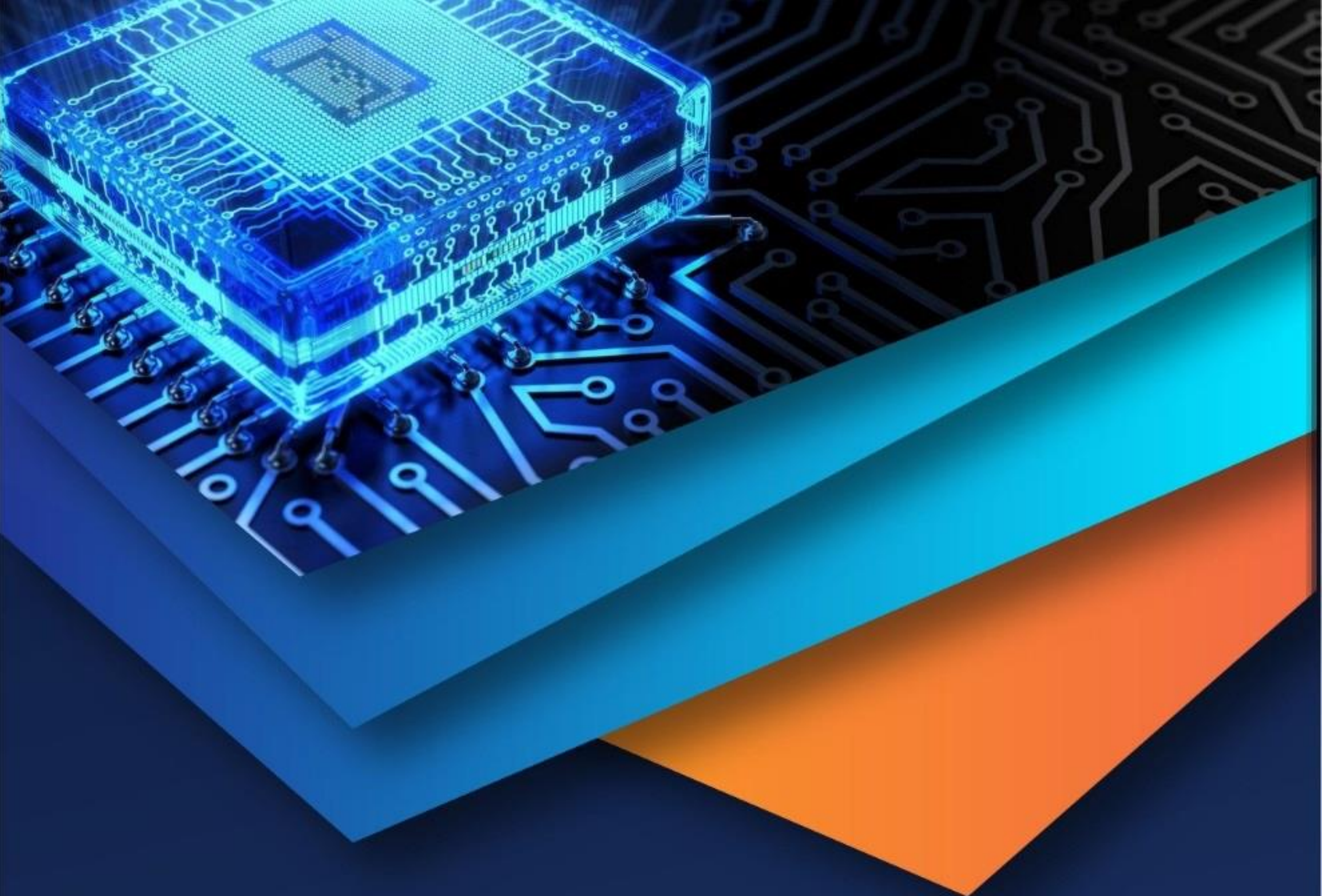

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