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DEVELOPMENT OF A PID CONTROL SYSTEM IN DISTRIBUTED GENERATION FOR IMPROVEMENT OF VOLTAGE STABILITY USING MODEL REDUCTION METHOD

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ABSTRACT: Voltage stability is the ability of a power system to maintain synchronism when subjected to a severe disturbance such as fault, loss or addition of a large load, and loss of generation. Unlike small-signal stability, in Voltage stability a large-signal disturbance is considered. Therefor nonlinear differential equations of the system should be employed to represent the system.

The methodology used was the model reduction method for performing the load flow analysis of the bus system. Stable operations of a power system depends on the ability of system generators to meet active and reactive power demand of the loads. As a result, it is important to accurately represent the load to capture the dependence of it real and reactive power on the system variables, e.g bus voltage. Therefore, load modelling plays an important role in Voltage stability analysis. In this work, a software tool was developed to implement the simulation algorithm in MATLAB 8.1. The software was capable of representing several load and generator models and can handle the PSS/E native file format.Evaluation of result was done based on the Delta angle of generators , Speed deviation of generators, Field circuit flux of generators, Bus voltages and Internal delta angles with respect to time

Keywords: Bus Voltage, Fault, Field Flux, Generator, Stability, Voltage**.**

1.0 INTRODUCTION

The most widely used controller in the process industries is Proportional integral derivative (PID) controller, as it can assure satisfactory performances with simple algorithm for a wide range of processes. It is important to note that cost benefit ratio obtained through the PID controller is difficult to achieve by other controllers. It is found that 97% of the regulatory controllers use PID algorithm (Giusto, 2006). The Internal Model Control (IMC) provides a progressive, effective, natural, generic, unique, powerful, and simple framework for analysis and synthesis of control system performance. Because of the easiness and improved performance of the IMC based tuning rule, the analytically derived IMC-PI/PID (IMC-PID) tuning methods have attracted the attention of industrial users over the last decade (Bergen et al, 2010). The well-known IMC-PID tuning rule has the advantage that a clear compromise between closed loop performance and robustness to model uncertainties, is achieved by a only one user-defined tuning parameter.

If the oscillatory response of a power system during the Voltage period following a disturbance is damped and the system settles in a finite time to a new steady operating condition, we say the system is stable. If the system is not stable, it is considered unstable. This primitive definition of stability requires that the system oscillations should be damped. This condition is sometimes called asymptotic stability and means that the system contains inherent forces that tend to reduce oscillation (APPRAEZ, 2012).

In stability assessment the critical clearing time (CCT) is a very important parameter in order maintain the stability of power system. The CCT is maximum time duration that a fault may occur in power system without loss of stability. Fault clearing time is set randomly. If the fault clearing time (FCT) is more than CCT then the relative rotor angles will go out of step and the system will lose stability (Liu, 2003).

1.2 AIM

The aim of this project is to use reduction method to improve performance of PID controllers in voltage distributed generation

1.3 OBJECTIVES

1. To develop first- or second-order plus delay model. The effective delay in this model may beobtained using the proposed half-rule.
2. To Derive PID Equations based on First order

3. To implement first or second order equation using FOPTD Model which will be used as a predictive model in IMC structure
4. To filter the disturbance rejection rate using lead/lag filter structure to optimize the performance of system for load disturbance rejection.
5. Perform robustness analysis by incorporating perturbations into the plant (predictive) model parameters and evaluate performance of the closed loop system in terms of integral error criteria.

1.4 SCOPE

PID controllers are widely used in industrial plants because it is simple and robust. So the control engineers are on look for tuning procedures. This paper gives the review of some soft computing techniques which are used for PID tuning. Soft computing techniques make easy of the tuning of parameters of controller to get desired response

2.0 REVIEW OF RELATED WORKS

Classical research on Voltage stabilization of power systems has relied on the use of aggregated *reduced network* models that represent the system as an n–port described by a set of ordinary differential equations. Several excitation controllers that establish Lyapunov stability of the desired equilibrium of these models have been reported.

These nonlinear controller design techniques include feedback linearization Kolesnikov (2002), damping injection, as well as, the more general, interconnection and dampingassignment passivity–based controlOrtega (2006) Aggregated models erase the identity of the network components and impose an unrealistic treatment of the loads. In this paper, we abandon the aggregated n–port view of the network and consider the more natural and widely popular structure–preserving models (SPM), first proposed in Bergen et al. (2010). Since these models consist of differential algebraic equations (DAE) they require the development of some suitably tailored tools for controller synthesis and stability analysis. Another original featureof the present work is that we do not aim at Lyapunov stability, but establish instead a global convergence result.

In Giusto (2006) SPM were used to identify—in terms of feasibility of a LMI—a class of power systems with nonlinear (so-called ZIP) loads and leaky lines for which a *linear time–invariant* controller renders the overall *linearized* system dissipative with a (locally) positive definitestorage function, thus ensuring stability of the desired equilibrium. Unfortunately, a full–fledged *nonlinear* analysis of the problem was not possible due to the difficulty in handling the complicated interdependence of the variables appearing in the algebraic constraints of the DAEs. The Lyapunov function in that paper is obtained by adding a quadratic term in the rotor angle to the classical energy function of Milano (2005). This quadratic term is needed to compensate for a linear term (in rotor angle) appearing in the energy function of Milano (2005) and render the new storage function positive definite. To obtain our global convergence result we observed in Jiang (2009) that removing the linear term from the energy function of Milano (2005) and increasing the quadratic term in bus voltages yields a function whose time derivative can be *arbitrarily assigned* with a globally defined static state feedback. Furthermore, although this new function is not positive definite, it is *bounded from below* and has some suitable radial unboundedness properties—features that are essential to establish boundedness of trajectories. However due to the complexity of the calculations, the energy function used describes only the synchronous machines. Goal of this work is to show that, by exploiting the resultsin Jiang (2009), it is possible to construct a globally convergent controller that renders attractive the ball centered on the stable equilibrium point, with an energy function that describes the entire electric network. The only critical assumption required to establish this result is that theloads are constant impedances in Jiang (2009).

It is worth mentioning that the Voltage stabilization problem (in the sense of the definition given in Ademoye(2011) does not coincide with the problem of stabilization of power system at the *desired* operating point. From a practical point of view the solution of the latter problem ispreferable but its realization just after some fault can cause the large control efforts acting on the system. Therefore, one can use the controller which provides Voltage stabilization, *i.e.*, prevents the system from loss of synchronism, as an intermediate control law and then solve the problem of power system stabilization at the desired operating point which better fits the current electric power demand and supply.

Power system engineering deals with the large-scale production, transmission and distribution of electrical energy. Deregulation and an increasing exchange of electricity between countries has led to greater demands being imposed on system stability, system protection and security, see for instance (Kolesnikov,2002)
The synchronous stability of multi-machine systems describes synchronism of an operating process for power-angle of a distribution system, which would play an important role in the study of Voltage stability of power systems. Devendra(2013) proposed a quantification theory in the

establishment of quantitative criterion which can be used to identify and to control the synchronous stability of multi machine power systems. (Devendra, 2013) gave a further explanation for it.

3.0 METHODOLOGY

3.1 Design of the PID Controller

A design method for PID controller cascaded with lead/lag filter obtained using IMCtechnique using improved IMC filter structure was suggested for disturbance rejection. The suggested method willprovide good performance for disturbance rejection for lag dominant processes. It is well-known that a well-designed control system should meet the following requirements besides nominal stability, it should possess Disturbance attenuation, Set point tracking and, Robust stability and/or robust performance. The first two requirements are traditionally referred to as 'Performance' and the third, 'Robustness' of a control system

3.2 Development of algorithm for Classical Voltage stability study:

Step1: Read the bus data i.e. bus codes, impedance, line charging admittance and the scheduled generation and loads of the given system.

Step2: The Y bus matrix is calculated from the lines, transformer, STATCOM data and shunt element data and the load flow solution prior to the disturbance is calculated by using Newton-Raphson iterative method.

Step 3: If there is any switching action we have to modify the system data first and also, solve the network performance equations, calculate machine currents I_{ti} and the machine terminal powers P_{ti}, Q_{ti} for all buses by using eq (3.1 and 3.2) respectively, otherwise go to **step4**

$$E_p^{k+1} = -\sum_{q=1}^{p-1} YL_{pq} E_q^{k+1} - \sum_{q=p+1}^{n} YL_{pq} E_q^{k} - \sum_{t=1}^{m} YL_{pt} E_t^{1} \qquad \textbf{(3.1)}$$

$p = 1,2,..........n.$

$p \neq f$ (When fault on bus f)

$$I_{ti} = (E_t^1 - E_{ti}) \frac{1}{r_{ai} + jx'_{di}} \qquad \textbf{(3.2)}$$

i=1, 2, 3…

$$P_{ti} - jQ_{ti} = I_{ti} E_{ti}^{*} \qquad \textbf{(3.3)}$$

i=1, 2, 3… m

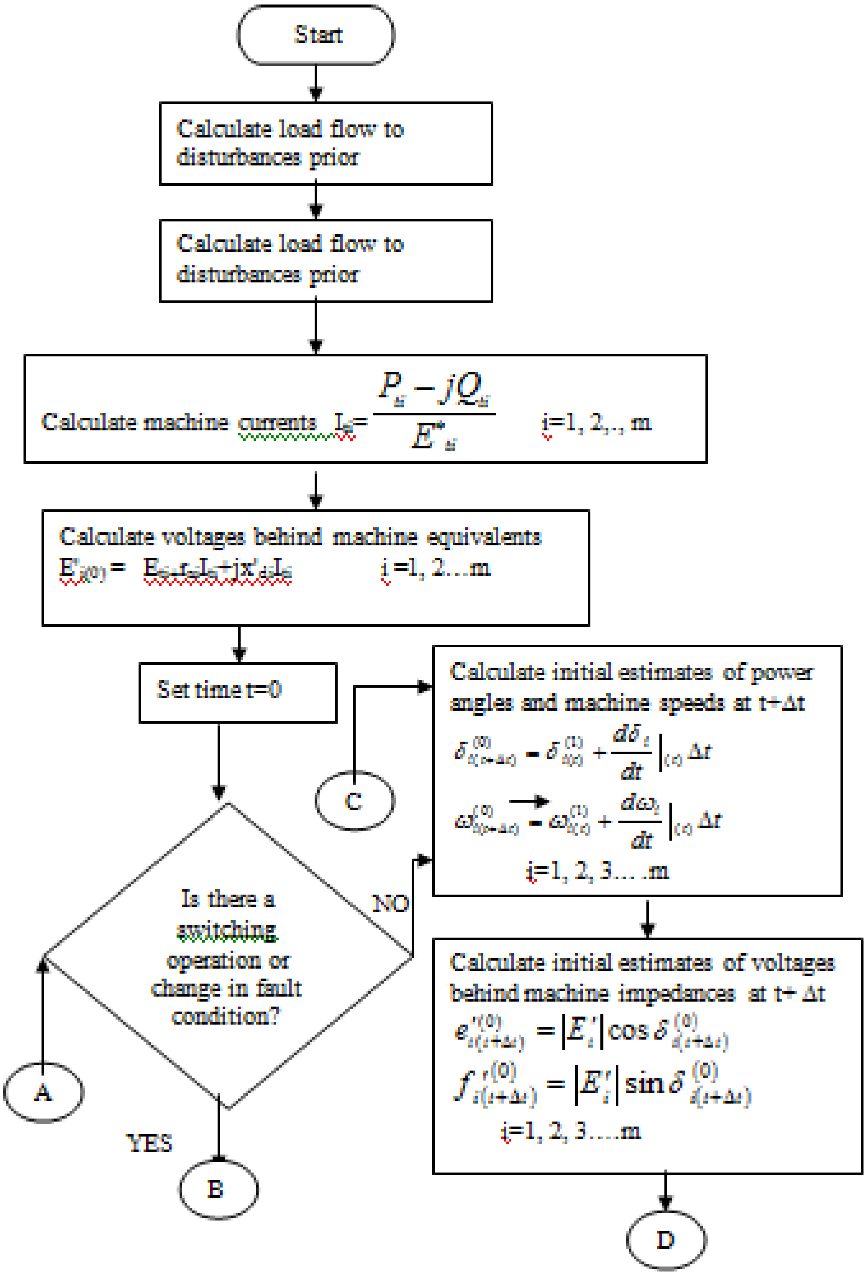
Step 4: Compute the inertial estimates of power angles, machine speeds and inertial estimates of voltages behind machine impedances all of them at t + Δt

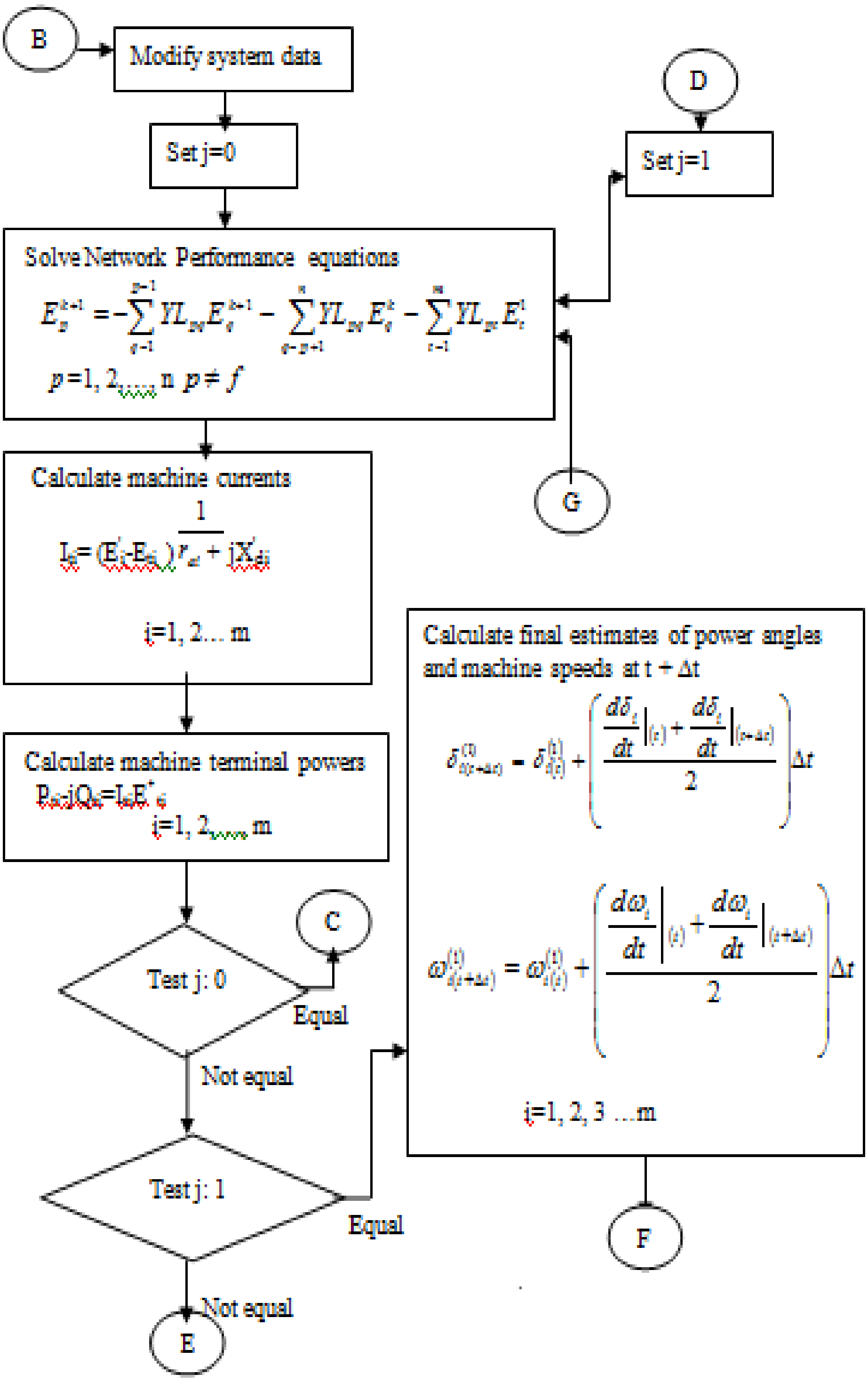
Step 5: Solve the network performance equations and calculate machine currents $I_{ti}$and calculate the machine terminal powers P_{ti} and Q_{ti} for these machines by using equations (3.1), (3.2)and(3.3).

Step 6: Calculate final estimates of power angles and machine speeds and also find the estimates of voltages behind the machine impedance at t + Δt by using the equations (2.36), (2.37), (2.38) and (2.39), and solve the equation (3.1),(3.2)and(3.3)

Step 7: Advance the time t + Δt to t and test for the time limit, if it is less than T_{max}then go to step3 otherwise print results.

3.3Development of the Flow Chart for Modified Euler's method




B
Modify system data
Set j=0
D
Set j=1
Solve Network Performance equations
$E_p^{k+1} = -\sum_{q=1}^{p-1} YL_{pq} E_q^{k+1} - \sum_{q=p+1}^{n} YL_{pq} E_q^{k} - \sum_{r=1}^{m} YL_{pr} E_r^{1}$
$p = 1, 2, \ldots, n \quad p \neq f$
G
Calculate machine currents
$I_{di} = (E_i' - E_{di}) \frac{1}{r_{ai} + jX_{di}'}$
$i = 1, 2 \ldots m$
Calculate machine terminal powers
$P_{di} - jQ_{di} = I_{di} E^*_{di}$
$i = 1, 2, \ldots, m$
C
Test j: 0
Equal
Not equal
Test j: 1
Equal
Not equal
E
Calculate final estimates of power angles and machine speeds at t + Δt
$\delta_{i(t+\Delta t)}^{(1)} = \delta_{i(t)}^{(1)} + \left(\frac{\left.\frac{d\delta_i}{dt}\right|_{(t)} + \left.\frac{d\delta_i}{dt}\right|_{(t+\Delta t)}}{2} \right) \Delta t$
$\omega_{i(t+\Delta t)}^{(1)} = \omega_{i(t)}^{(1)} + \left(\frac{\left.\frac{d\omega_i}{dt}\right|_{(t)} + \left.\frac{d\omega_i}{dt}\right|_{(t+\Delta t)}}{2} \right) \Delta t$
$i = 1, 2, 3 \ldots m$
F

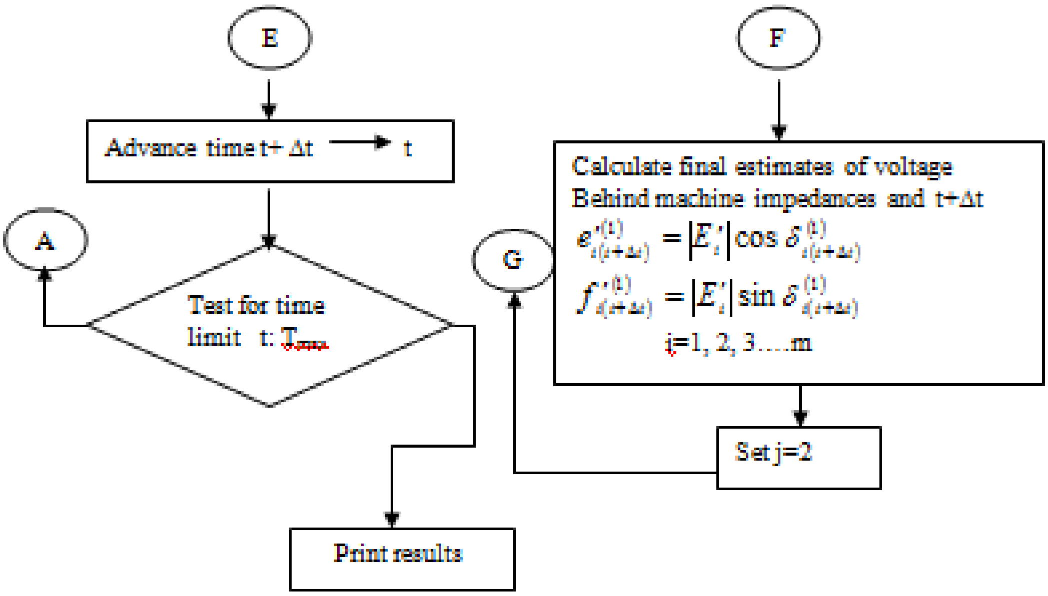


Figure 3.1:Flow Chart for Modified Euler's method

3.4Development of the Voltage Stability Algorithm using Model Reduction

The procedure used for the implementation is as follows

Step 1: Each synchronous machine is represented by a constant voltage behind xd (neglect salience and flux change)

Step 2: Input power remain constant

Step 3: Using prefault bus voltages, all load in equivalent admittances to ground

Step 4: Damping and asynchronous effects are ignored

Step 5: δmech = δ(machine belongs to the same station swing together and are said to be coherent, coherent machine can equivalent to one machine. solution to multi-machine syste

Step 6: Solve initial power flow and determine initial bus voltage magnitude and phase angle.

Step 7: Swing solution of multi-machine system

$$\frac{H_i}{\pi f_o}\frac{d^2\delta_i}{dt^2} = P_{mi} - \sum_{j=1}^{m} |E_i'|\,|E_j'|\,|Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) = P_{mi} - P_{ei} \qquad \textbf{(3.4)}$$

- Y_{ie} are the element of the faulted reduced bus admittance matrix

Step 8: Solve the State variable model of swing equation using Matlab

$$\frac{d\delta_i}{dt} = \blacktriangle w_i, \quad i = 1, k, n \qquad \textbf{(3.5)}$$

$$\frac{dw_i}{dt} = \frac{\pi f o}{H_i}(P_{mi} - P_{ei}) \qquad \textbf{(3.6)}$$

$$I_i = \frac{S_i^*}{V_i^*} = \frac{P_i - jQ_i}{V_i^*},\ E_i' = V_i + jX_d' I_i \qquad \textbf{(3.7)}$$

Step 9: Calculating load equivalent admittance

- $y_{io} = \frac{P_i - jQ_i}{|V_i|^2}$ **(3.8)**

Step 10: Generate the Nodal equation of the system

$$\begin{bmatrix} 0 \\ I_m \end{bmatrix} = \begin{bmatrix} Y_{nn} & Y_{nm} \\ Y_{nm}' & Y_{mm} \end{bmatrix} \begin{bmatrix} V_n \\ E_m' \end{bmatrix} \qquad \textbf{(3.9)}$$

Step 11: Classical Voltage stability study is based on the application of three phase fault

$$P_{mi} = P_{ei} = Re\{E_i^* I_i\} = \sum_{j=1}^{m} |E_i'|\,|E_j'|\,|Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \qquad \textbf{(3.10)}$$

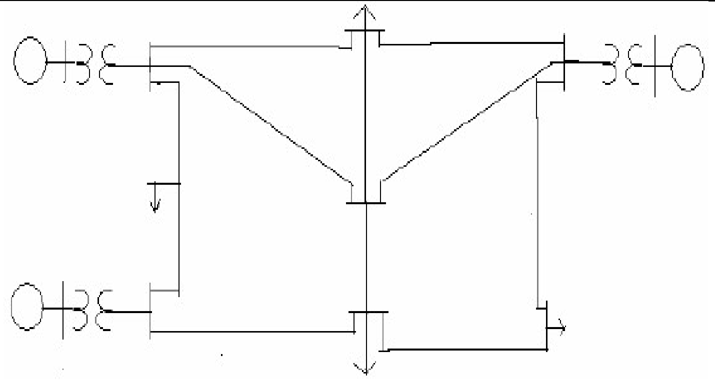


Fig 3.2: Diagram for distribution stability

4.0 RESULTS AND DISCUSSION

Table1: Power Flow Solution by Model Reduction Method

```
 Bus   Type    |V| (pu)   /_V (deg)   Pg (MW)    Qg (MVAR)   Pd (MW)    Qd (MVAR)
  1     PQ    1.0412       -2.69       0.00        0.00        0.00        0.00
  2     PQ    1.0041       -0.95      -0.00        0.00      280.00      200.00
  3     PQ    0.9927      -37.88      -0.00        0.00      320.00      240.00
  4     PQ    0.9805      -42.99       0.00        0.00      320.00      240.00
  5     PQ    0.9980      -30.79      -0.00        0.00      100.00       60.00
  6     PQ    0.9951      -34.31      -0.00        0.00      440.00      300.00
  7     PQ    1.0493       -4.42      -0.00       -0.00        0.00        0.00
  8     PQ    0.9995      -36.09       0.00        0.00        0.00        0.00
  9     Sl    1.0400        0.00     509.12       -0.00        0.00        0.00
 10     PV    1.0200        1.85     500.00      173.97        0.00        0.00
 11     PV    1.0100      -36.74     200.00      176.80        0.00        0.00
 12     PV    1.0200      -30.92     300.00      135.63        0.00        0.00
```

4.1 Delta angle of generators vs. time

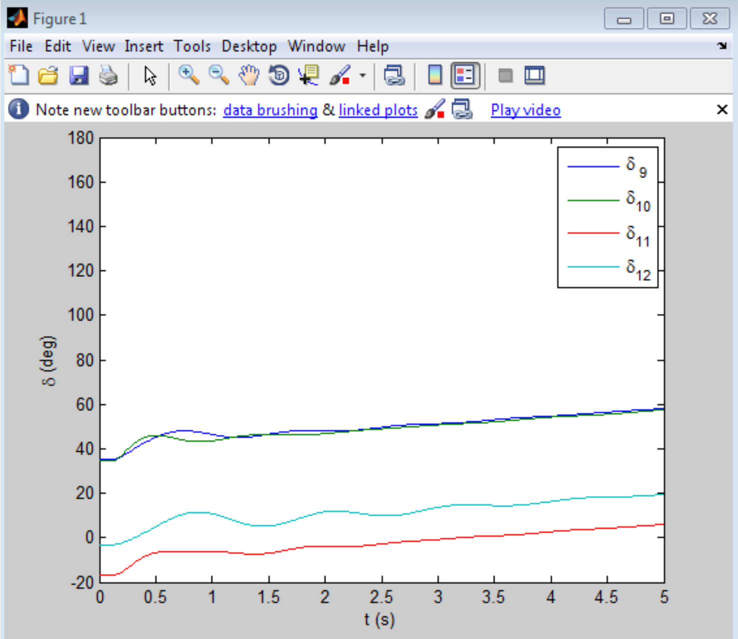


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Fig 3: angle of generators with time for a three phase machine

4.2 Speed deviation of generators vs. time

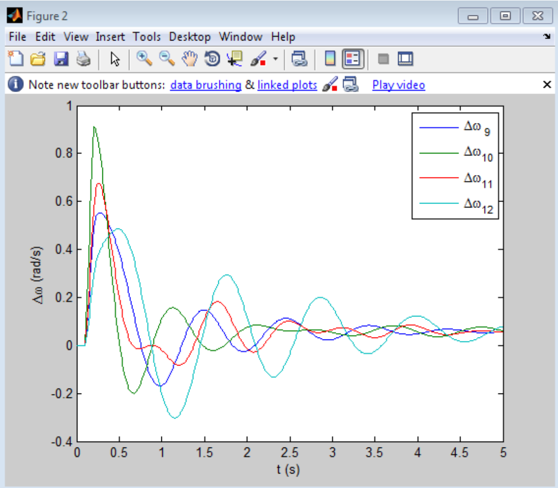

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Fig 4: speed deviation of generators with time for a three phase machine

4.3 Field circuit flux of generators vs. time

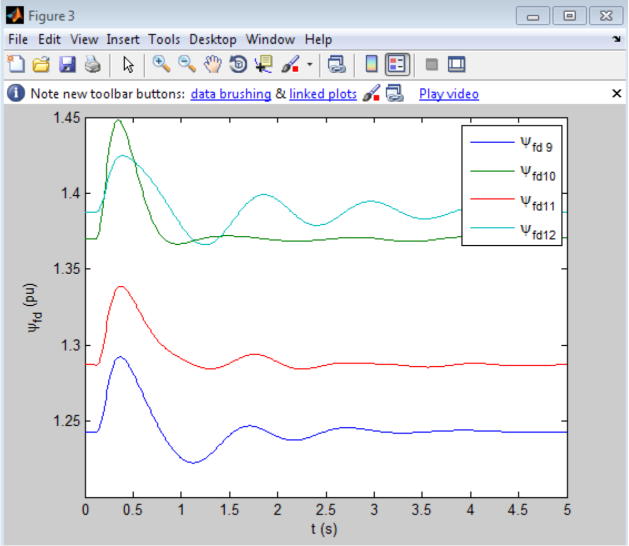

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Fig 5: Field circuit flux of generators with time for a 3phase

4.4 Bus voltages vs. time

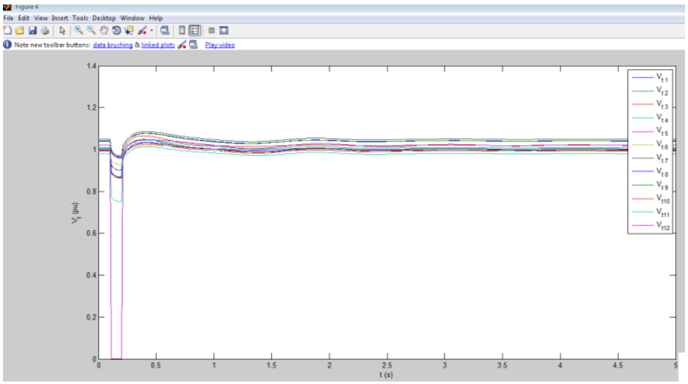

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Fig 6: Bus voltages with time for a three phase

4.5 Internal delta angles vs. time

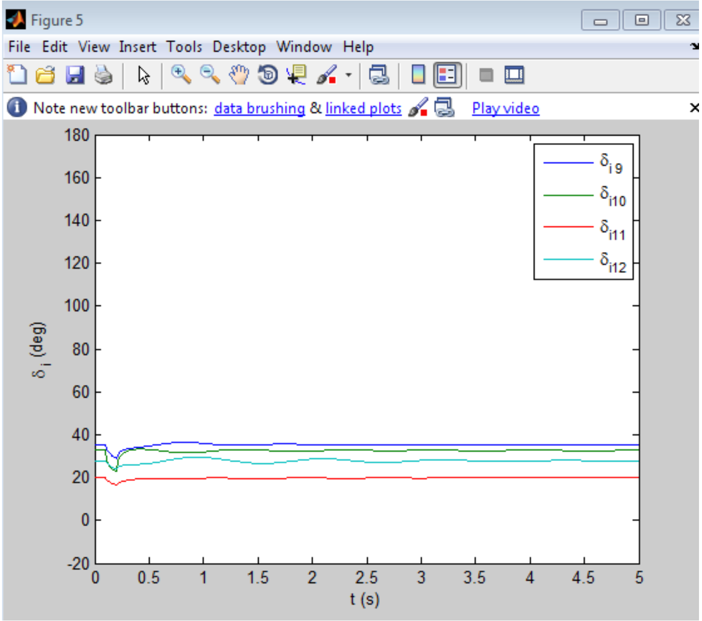

Fig 7: Internal delta angles with time for a three phase

Fig.3and 4 are showing the variation of the angle δ and the angular velocity of the rotor, while Fig.4 and 5 show the variations of the field flux and Bus Voltage of the generator in time for the system. we find that the angle δ of the rotor continues to increase following an increasing pace; it does not pass through a maximum and increases indefinitely

At the default, the electrical power drops to zero, the rotor accelerates and the generation is getting greater than the pow-er (Fig.6). We can also note from (Fig.7) that the power storing the kinetic energy of rotation continues to oscillate rapidly and indefinite way, this can be easily explained by the fact that the mechanical torque is higher than the electrical torque. Then a large amount of energy has been accumulated by the generator what put the rotor in over speed after elimi-nation of the fault.

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

A design method for PID controller cascaded with lead/lag filter obtained using IMCtechnique using improved IMC filter structure was suggested for disturbance rejection. The suggested method will provides good performance for disturbance rejection for lag dominant processesIt is well-known that a well-designed control system should meet the following requirements besides nominal stability, it should possess Disturbance attenuation, Set point tracking and, Robust stability and/or robust performance. The first two requirements are traditionally referred to as ‘Performance’ and the third, ‘Robustness’ of a control system

5.2 RECOMMENDATION

In addition to real time analysis, there are other areas where Voltage stability analysis couldbecome an integral part of daily power system operations such as system restoration analysis , economic / environmental dispatch and expansion planning .Furthermore, the optimisation and application of advanced toolssuch as ANN and fuzzy logic, is also much easier as there arecorresponding toolboxesavailable within MATLAB

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