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Power System Stability Improvement by LQR Approach and PSS Considering Electric Vehicle as Disturbance

Niharika Agrawal
Electrical and Electronics Engineering, SJB Institute of Technology, No.67, BGS Health & Education City, Bengaluru, Karnataka 560060
E-mail: niharika.svits@gmail.com

Mamatha Gowda
Electrical and Electronics Engineering, SJB Institute of Technology, No.67, BGS Health & Education City, Bengaluru, Karnataka 560060
E-mail: mahesh.mamatha@gmail.com

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Abstract: Low frequency oscillations result due to heavy loading conditions line faults, sudden change of generator output and also due to poor damping of interconnected power systems. There are different types of disturbances in the power system like sudden change of load, generation, faults, switching of lines. This hampers the power transmission capacity of the lines and the stability of the system There are significant impacts on the system stability during the charging and discharging operation of Electric Vehicle (EV). In the present work the charging operation of EV is considered as a load disturbance. The introduction of these vehicles in the system creates the problem of low frequency oscillation and endanger the system stability and security. In the present work the Single machine infinite bus system (SMIB) is first developed using mathematical modelling with consideration of EV disturbance. The LQR approach from optimal control theory is then applied in the system to damp the system oscillations, improving the system eigenvalues and enhancing the stability. The stability is seen in the system after LQR from various figures. In the second work the plotting of variation of different state variables is done using three different methods which are the transfer function model method, using code and then using state space representation of the system. The work is further extended by adding Power system stabilizer (PSS) to the system, again considering the EV disturbance. The time domain simulation results showed the improvement in stability using PSS device. Thus, in the present work the oscillations problems created due to the introduction of electric vehicles are solved by two methods. The first is implementing LQR approach from optimal control theory in the system and the second method is by adding PSS device in the same system.

Index Terms: Power System, oscillations, damping, frequency, transmission system, interconnection.

1. Introduction

Power system oscillations are created due to random variations of load, variation in generation schedule, interconnection of networks, heavy power transfer. These oscillations cause loss of synchronism, reduce the power transfer capacity of the system, endanger the secure operation of the system and cause instability. If they are not properly controlled it may lead to black-out. In the present work the EV has been considered as a disturbance like other disturbances such as sudden change in load, heavy power transfer etc which causes low frequency oscillations. The main objective of this paper is to design LQR based PSS to stabilize the system perturbed by the introduction of electric vehicle. The Electric Vehicle has been modelled as a first order system. This is done by changing the system eigen values with the proper design of Q and R weighting matrices. For solving the stability problems traditional PSS based on phase compensation technique have been used. In the present work the LQR based PSS is suggested which guarantees robustness to the system against uncertainties and disturbances. From the various figure it is seen that there is improvement in stability of the system after using LQR. The other objective here is to show the different methods of plotting the variation of state variables which are the transfer function method, coding method and by state space representation of the system. The variation of various state variables like rotor angle, rotor speed, internal voltage, field voltage is plotted after passing feedback gain matrix k to the system. The plotting of state variables by state space representation method is based on linearised dynamics of the system. This is done by developing the mathematical model of the system. The system is linearised around an operating point and represented by various equations.

2. Problem Statement and Related Work

Imbalance between the electrical power & mechanical power of machine is created because of faults and other disturbances which creates the power system oscillations. If they are not properly controlled it will lead to loss of synchronism. The system separation may also occur if these oscillations are not mitigated. PSS is used for damping power system oscillations which uses traditional lead-lag compensator. The most important and basic role of Power System Stabilizer is to supply a signal to the excitation system of synchronous generator. PSS create a damping torque in phase with rotor oscillations. Power System Stabilizer model consists of different blocks like gain, a washout high-pass filter, a lead -lag phase-compensation and limiter. The gain block introduces damping in the system. The function of the washout high-pass filter is to eliminate low frequencies and to allow the stabilizer to respond only to changes in speed. The function of phase-compensation block is to compensate the phase lag between the excitation voltage and the synchronous machine electrical torque. The PSS have been tuned using optimization technique for damping oscillations by SVC [1,2,3,4]. The LQG controller was designed using LQR and Kalman filter. The plant was considered with the process noise and the measurement noise. The H-infinity controller-based PSS was implemented for low frequency operating range of PSS. The Robust H2 control theory was developed for the excitation system and the speed governor control. The synchronising and damping coefficients involved in the model were discussed. [5,6]. This various work considered the problems of oscillations created due to short circuit, sudden change of generation or load, poor interconnection of networks but the disturbance created in the system due to the introduction of EV was not taken into consideration. Thus, in the present work, low frequency oscillations problems created due to charging of Electric Vehicles is considered and mitigated by two methods namely LQR approach and PSS device [7].

3. Modelling the SMIB Power System

The single machine infinite bus system with an excitation system of IEEE type ST1 is selected for this work. The different components of the schematic diagram of the system are a synchronous machine, exciter, transmission line, local load. The synchronous machine is connected by external impedance to the infinite bus. The synchronous machine model is developed using stator equations, network and rotor equations. Model 1.1 is used to represent the synchronous machine The Heffron-Philips model of the system is developed for LQR based PSS and the generator is equipped with PSS. Constant impedance type of load is taken into consideration. From the load flow analysis, the real and reactive power voltage magnitude and angle at the generator terminals are calculated. After that the initial conditions calculations are done for various system parameters. [8,9,10]. The SMIB system is linearized around an operating point for assessment of small signal stability and also to represent the power system in state space representation. For the application of LQR the controllability and observability of the system is checked using linearized state space representation and the system is found to be observable and controllable. From the block diagram of the system the Heffron-Philips transfer function model of fig 3a is developed which consists of different blocks relating the various system parameters line the rotor angle, rotor speed, internal voltage and field excitation voltage. The Vt and Eb denotes the terminal voltage and infinite bus voltage respectively. The Xt, XLand Xth are the transformer reactance the reactance of transmission line and the Thevenin's impedance at the receiving end of the system.

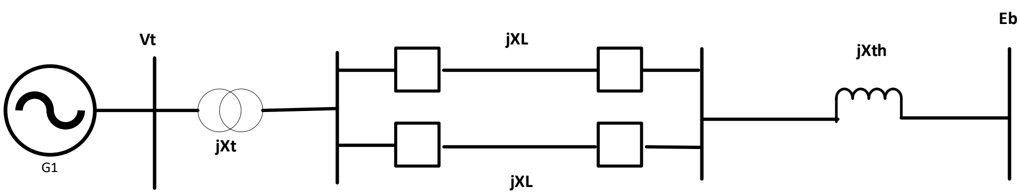

Fig.1. Single Machine Infinite Bus System

The linearised equations describing the system are given below: The equations for power, internal voltage -q axis and terminal voltage are given as below:

$$\Delta P_t = K_1 \Delta\delta + K_2 \Delta E_q^{'} \tag{1}$$

$$\Delta E_q = K_3 \Delta E_q^{'} + K_4 \Delta\delta \tag{2}$$

$$\Delta V_t = K_5 \Delta\delta + K_6 \Delta E_q^{'} \tag{3}$$

There are 6 constants K1 to K6 in the model are known as Phillips Heffron constants.

4. Methodology

4.1. Linearized Model

For the implementation of LQR approach and the PSS device in the system the following state space representation of the system is developed. The state matrix A is composed of variation in rotor angle, variation in rotor speed, variation in internal voltage q axis, variation in field voltage. The K_A and T_A are the exciter gain and time constants. The input signal to PSS is the deviation in rotor speed and the output signal is U from the PSS. From the state space representation of the system the eigen values can be determined from which the stability of the system is assessed. The K1 to K6 are the Heffron-Philips constants. U is the PSS stabilizing signal, The kA and TA are exciter gain and time constants, H are the damping and inertia constants. T'_{d0} is the open circuit d-axis time constant in sec. [11,12,13]. The model is linearised around a nominal operating point. Given a system in state space representation of the system $\dot{\mathbf{X}} = \mathbf{A}\,\mathbf{x} + \mathbf{B}\,\mathbf{u}$. The state vector is comprised of angle delta, speed, internal voltage and field voltage

$$\begin{bmatrix} \Delta\dot{\delta} \\ \Delta\dot{\omega}_m \\ \Delta\dot{E}'_q \\ \Delta\dot{E}_{fd} \end{bmatrix} = \begin{bmatrix} 0 & \omega_B & 0 & 0 \\ -\dfrac{K_1}{2H} & -\dfrac{D}{2H} & -\dfrac{K_2}{2H} & 0 \\ -\dfrac{K_4}{T'_{d0}} & 0 & -\dfrac{1}{T'_{q0}K_3} & -\dfrac{1}{T'_{d0}} \\ -\dfrac{K_A K_5}{T_A} & 0 & -\dfrac{K_A K_6}{T_A} & -\dfrac{1}{T_A} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta\omega \\ \Delta E'_q \\ \Delta E'_{fd} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \dfrac{K_A}{T_A} \end{bmatrix} U$$

4.2. Use of Linear Quadratic Regulator (LQR) for Stability Enhancement

LQR based controller is used for damping oscillations in power system. Due to disturbances and faults the safe operation of power system is difficult. Thus, strategies to control the system should be developed. LQR optimal control theory in combination with other controlling system elements is used for overcoming the problems of frequency oscillation in the power system. The foundation of LQR theory is minimizing a quadratic cost performance index. In this LQR technique there is a need to find an optimum control input *u* that puts limits or reduce the quadratic performance index or cost function J, *where* $J = \int_0^\infty (X^T Q X + U^T R U)$, In this function the Q and R are the weighting matrices for state matrix and control input which are always symmetric and square. They can be chosen as a diagonal matrix. The value of elements in matrices Q and R is related to its contribution in quadratic cost function. If the system is shown in state space representation like $\dot{X} = A\,x + B\,u$. The optimal control input u is defined as u = - K I. For the application of LQR approach the system should be observable and controllable. [14,15]

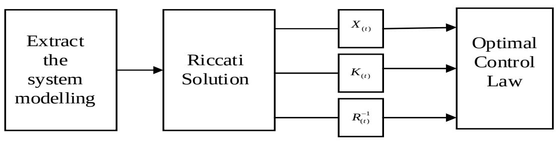

Fig.2. LQR Approach

5. Simulation Diagram

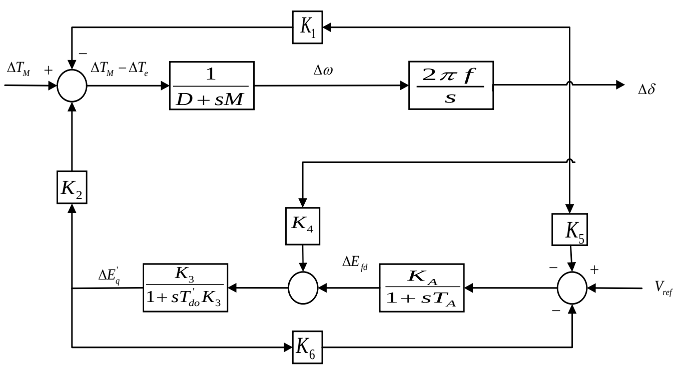

Fig.3. a. Heffron-Philips model of System

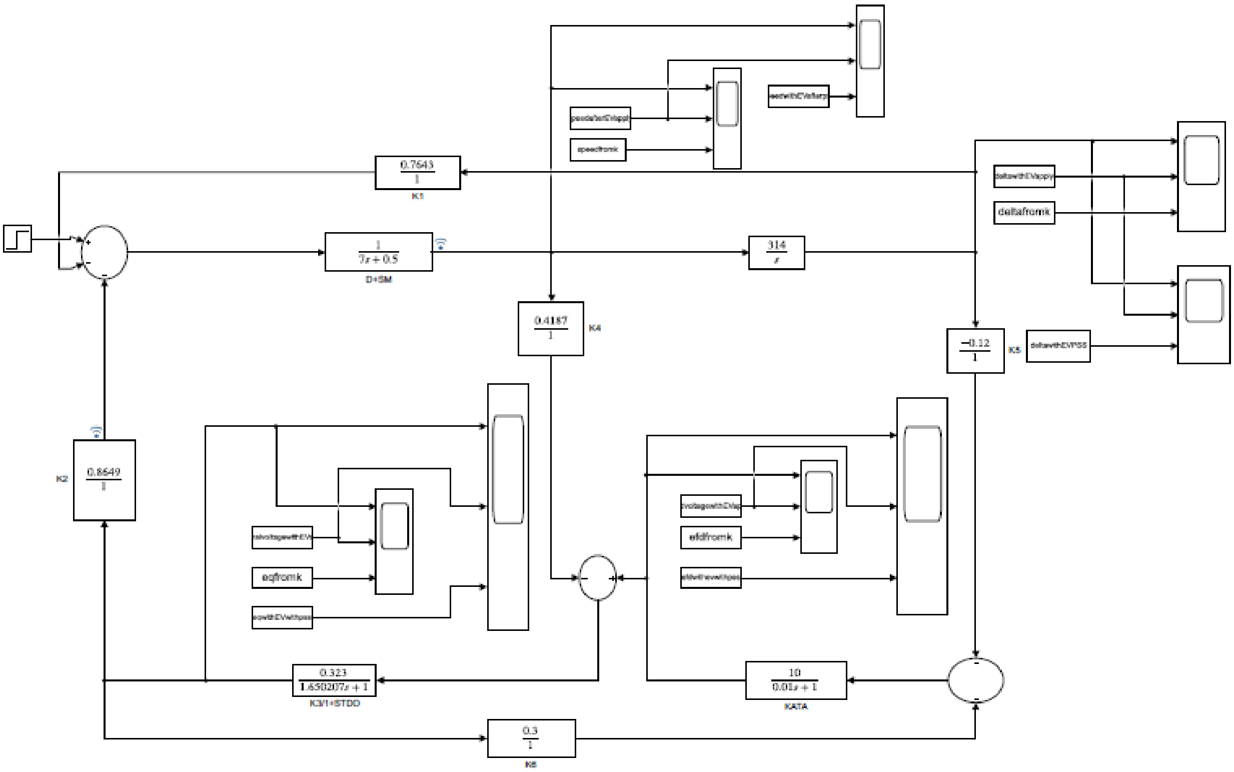

Fig.3b. SMIB alone

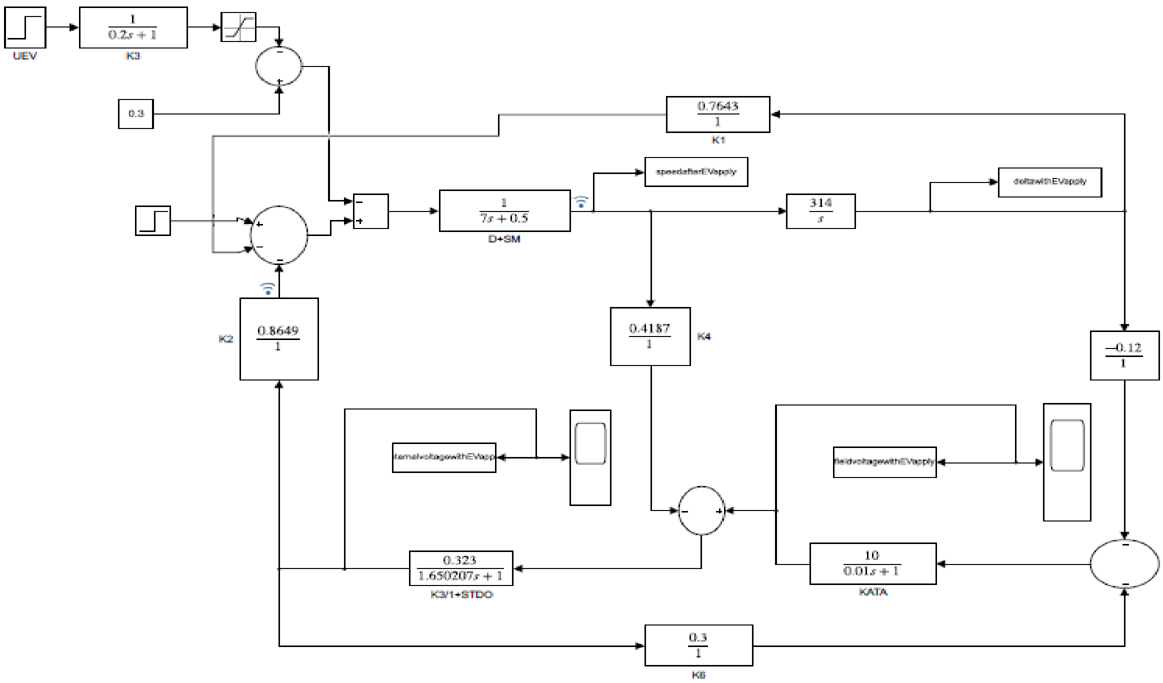

Fig.4. SMIB with EV

The simulation block diagram of the power system is given in figure 3a. The MATLAB simulation of the same system is shown in figure 3b. Figure 4 showed the system with application of EV disturbance and the figure 5 showed the LQR based System. Fig 5 included the linearized state space dynamics block of MATLAB. The K constants are calculated based on the derivation of equations of the system. The ABCD matrices of the system are given below. The values of the ABCD matrices are calculated based on the state space modelling of the system. The A, B, C, D are the state, control, the output and the feed forward matrix respectively. [16,17,18] The Q and R are chosen as shown.

$$A = \begin{bmatrix} 0 & 377 & 0 & 0 \\ -0.1092 & -0.0714 & -0.1235 & 0 \\ -0.0819 & 0 & -0.6059 & 0.1957 \\ 120 & 0 & -300 & -100 \end{bmatrix} \quad B= \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1000 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad D = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad Q= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad R= [1]$$

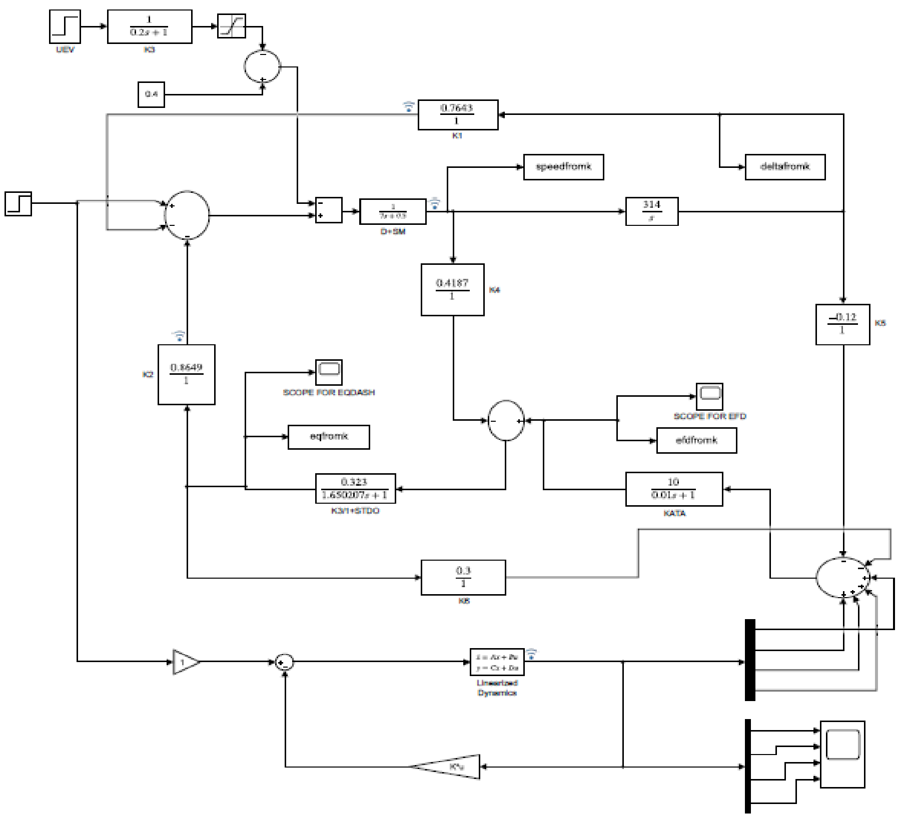

Fig.5. SMIB With EV With LQR

The feedback gain k matrix is found from LQR and given below:

$$K = \begin{bmatrix} 0.6156 & -4.6518 & 0.7300 & 0.9051 \end{bmatrix}$$

The system A matrix is calculated again after passing feedback gain k matrix to the system and is given

$$\text{by ALQR} = 1.0e{+}03 * \begin{bmatrix} 0 & 0.377 & 0 & 0 \\ -0.0001 & -0.0001 & -0.0001 & 0 \\ -0.0001 & 0 & -0.0006 & 0.0002 \\ -0.4956 & 4.6518 & -1.0300 & -1.0051 \end{bmatrix}$$

6. Result Analysis and Discussions.

6.1. Plotting variation of state variables using transfer function model of system considering three cases. They are the Single machine infinite bus system, System with EV disturbance and System with LQR taking EV disturbance.

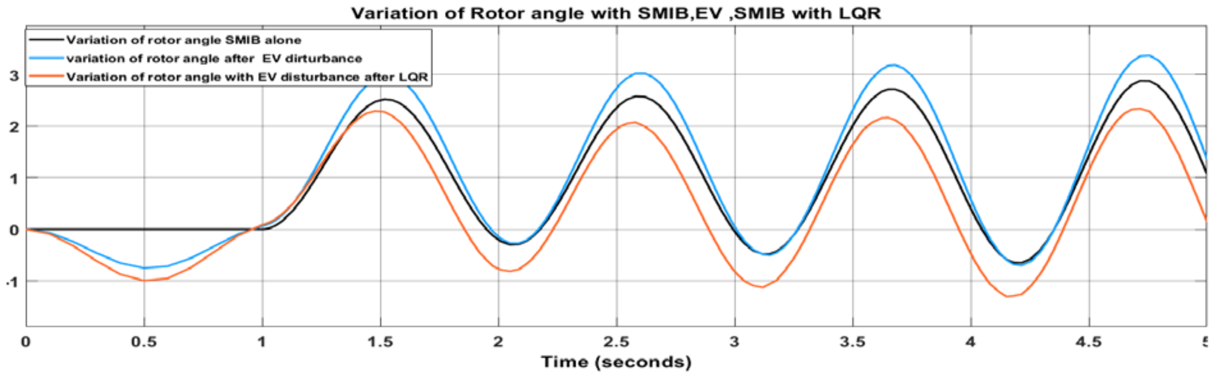

Fig.6. Variation of rotor angle

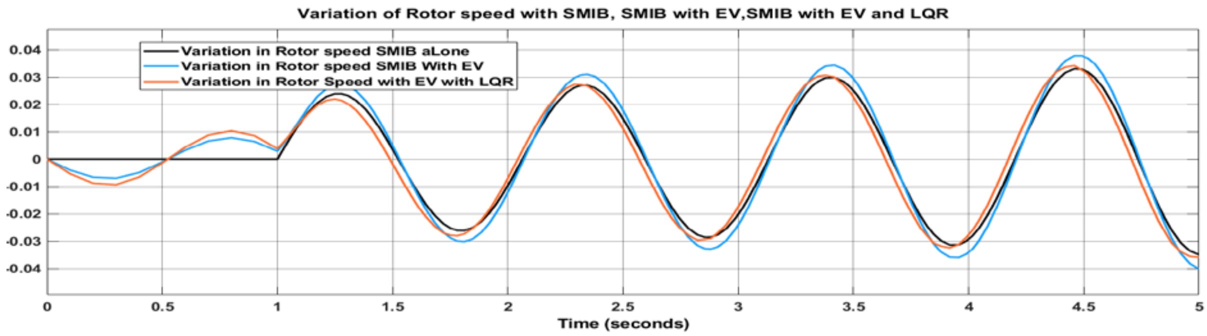

Fig.7. Variation of Rotor Speed

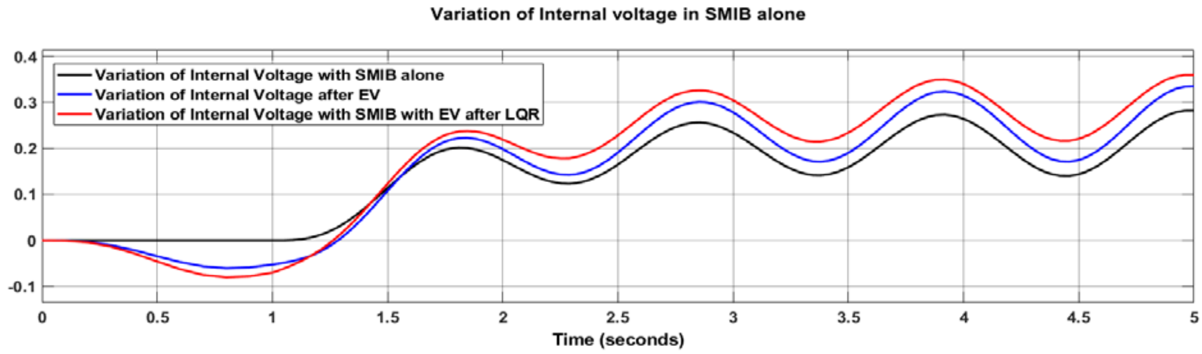

Fig.8. Variation of Internal voltage

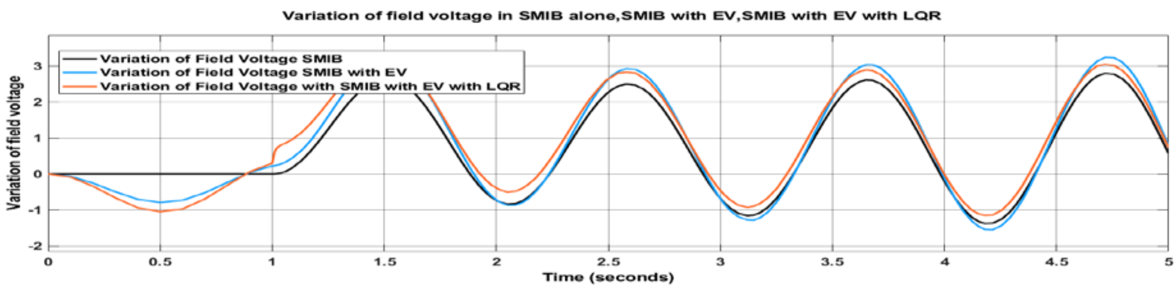

Fig.9. Variation of Field Voltage

From the figures (6.7,8,9) the variation of rotor angle, rotor speed, internal voltage and field voltage by SMIB alone, by applying Electric vehicle disturbance, with SMIB with EV and applying LQR. On the application of EV as load disturbance the variation is increased which is settled when feedback gain matrix k is passed to the system. The weighting matrix Q puts limits on the variation of state variables. The R matrix puts limits on control effort. The cost function of LQR is composed of both the variation of state variables and control effort so both the state variables and control effort are minimized. The improvement in system stability is seen from the various graphs.

6.2. Plotting step response, state variables without LQR using Code

The system transfer function is developed using all the four state variables using the command sysnolqr=ss (A, B, C, D) and tfnolqr=tf(sysnolqr). They are found to be tfnolqr = From input to output...

```
                -9112
 1: -------------------------------------------
   s^4 + 100.7 s^3 + 167.7 s^2 + 4146 s + 5623
               -24.17 s
 2: -------------------------------------------
   s^4 + 100.7 s^3 + 167.7 s^2 + 4146 s + 5623
         195.7 s^2 + 13.97 s + 8057
 3: -------------------------------------------
   s^4 + 100.7 s^3 + 167.7 s^2 + 4146 s + 5623
   1000 s^3 + 677.3 s^2 + 4.121e04 s + 2.113e04
 4: -------------------------------------------
   s^4 + 100.7 s^3 + 167.7 s^2 + 4146 s + 5623
```

These are the transfer function of the system from input to output. The step response of the system is plotted and shown in fig 10. This step response is without any controller like LQR and PSS. The plot showed that the variables are unstable. The time domain simulation results showed the variation of various state variables. The state variables take more time to settle.

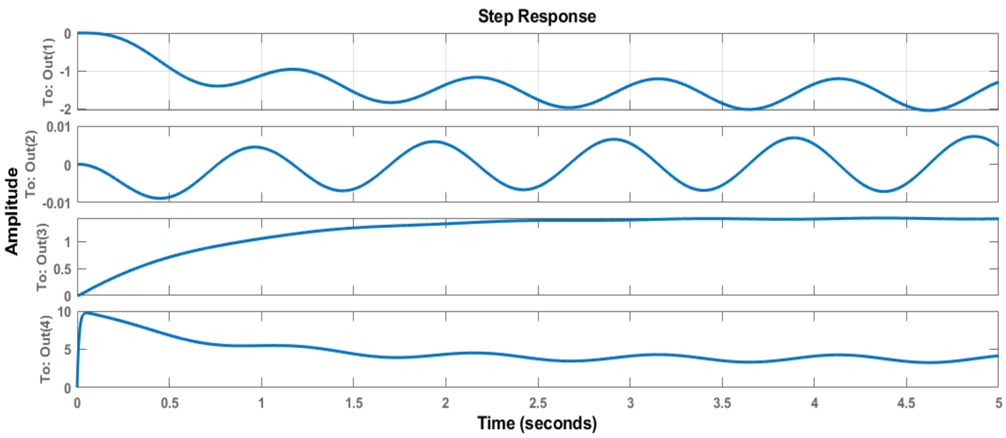

Fig.10. Step Response of the system without LQR

Plot of variation of state variables without LQR using Code

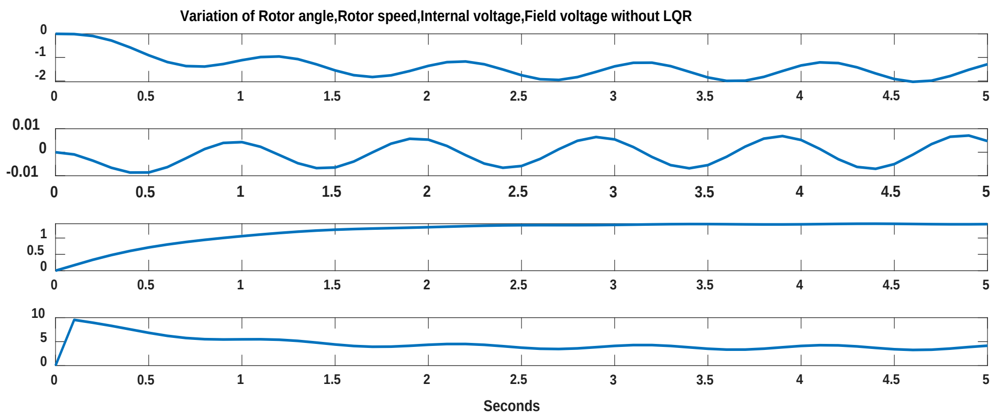

Fig.11. Variation of state variables without LQR

6.3. Plotting step response, state variables with LQR using Code

The feedback gain matrix K is passed to the system using K=lqr (A, B, Q, R) and ALQR=A-b*K. The system transfer function is developed using all the four state variables using the command syslqr=ss (ALQR, B, C, D) and tflqr=tf(syslqr). They are found to be

```
tflqr =     From input to output...
                        -9112
  1:  -------------------------------------------------
      s^4 + 1006 s^3 + 923.5 s^2 + 4.157e04 s + 2.502e04
                        -24.17 s
  2:  -------------------------------------------------
      s^4 + 1006 s^3 + 923.5 s^2 + 4.157e04 s + 2.502e04
                195.7 s^2 + 13.97 s + 8057
  3:  -------------------------------------------------
      s^4 + 1006 s^3 + 923.5 s^2 + 4.157e04 s + 2.502e04
         1000 s^3 + 677.3 s^2 + 4.121e04 s + 2.113e04
  4:  -------------------------------------------------
      s^4 + 1006 s^3 + 923.5 s^2 + 4.157e04 s + 2.502e04
```

The step response of the system step(syslqr) is

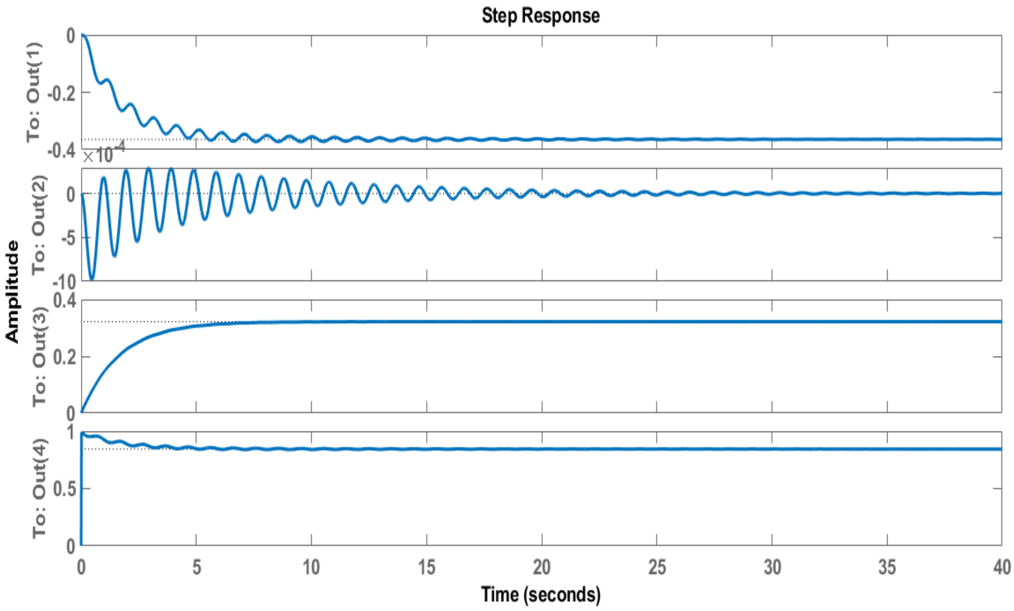

Fig.12. Step Response of the system with LQR

Plotting state variables using LQR

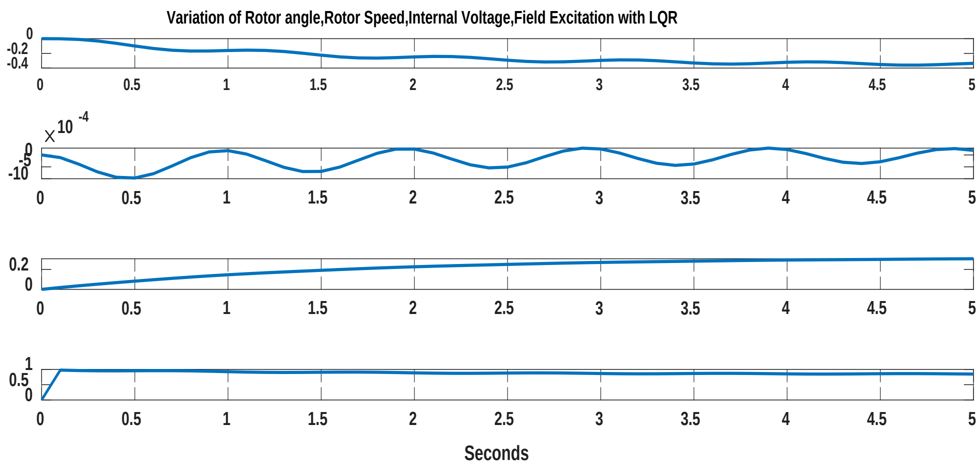

Fig.13. Variation of state variables with LQR with code

The step response of the system is improved using LQR After passing feedback gain matrix k to the system the variation in state variables is lessoned. The LQR system assure the robustness and both the stability of the system and performance is improved. The advanced control technique used by LQR settles the variation in state variables. LQR approach also consider the modelling errors, neglected dynamics and system uncertainties. The system eigen values are shifted to the left half of the complex s-plane indicating performance improvement. The system is tested against Electric vehicle as a perturbation.

6.4. Simulation Diagram for plotting state variables without and with LQR using State Space Representation

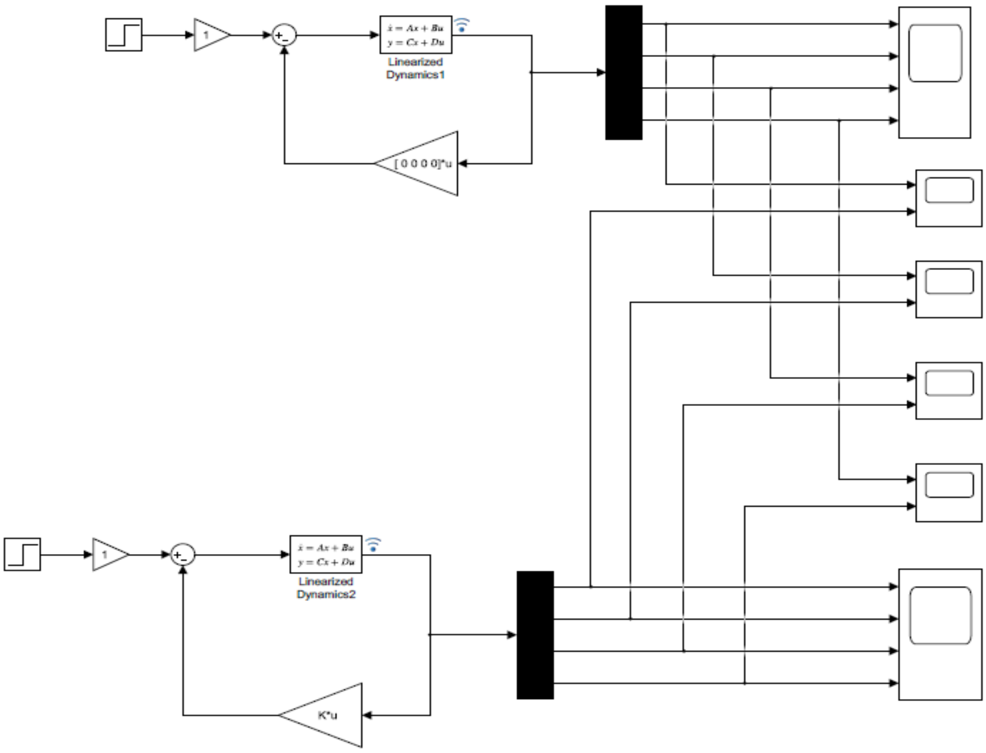

Fig.14. State Space Representation of the system

A. Plotting state variables using State space representation

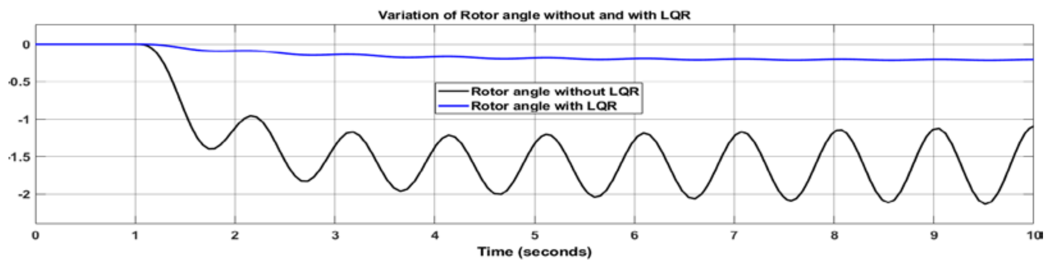

Fig.15. Variation of rotor angle without LQR and with LQR

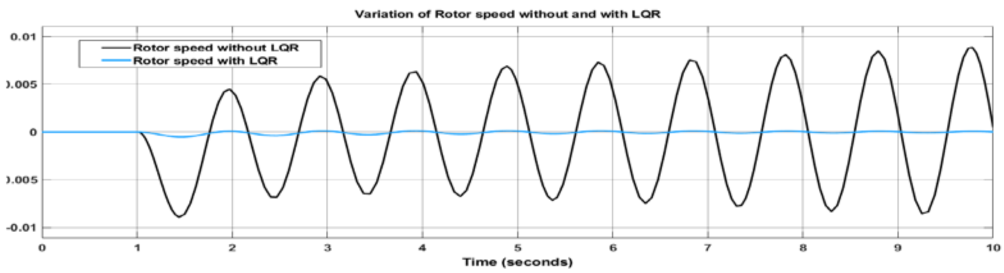

Fig.16. Variation of rotor speed without and with LQR

Fig 14 showed the state space representation of the system. Both the system without LQR and with LQR is shown in fig 14 using linearized state space dynamics of the MATLAB. The comparison of various state variables is done without and with LQR and shown in figures (15,16,1,7,18). The state variables are settled on passing k to the system. The analysis is made with the application of Electric vehicle as a disturbance. The system eigen values are shifted to more negative of the s-plane. The LQR based system damp the low frequency oscillations and improved the system performance.

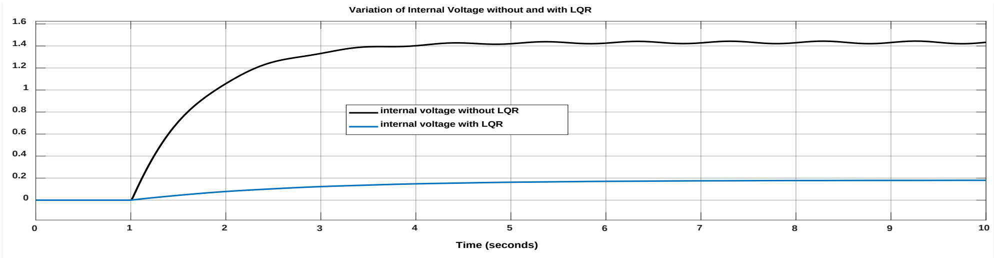

Fig.17. Variation of internal voltage without and with LQR

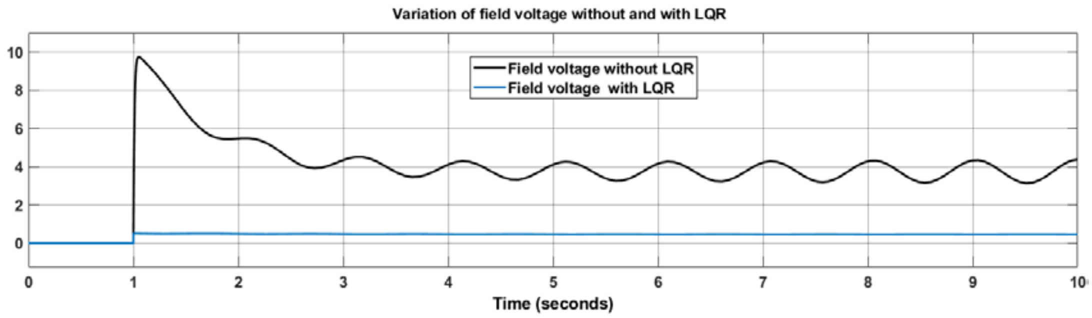

Fig.18. Variation of field voltage without and with LQR

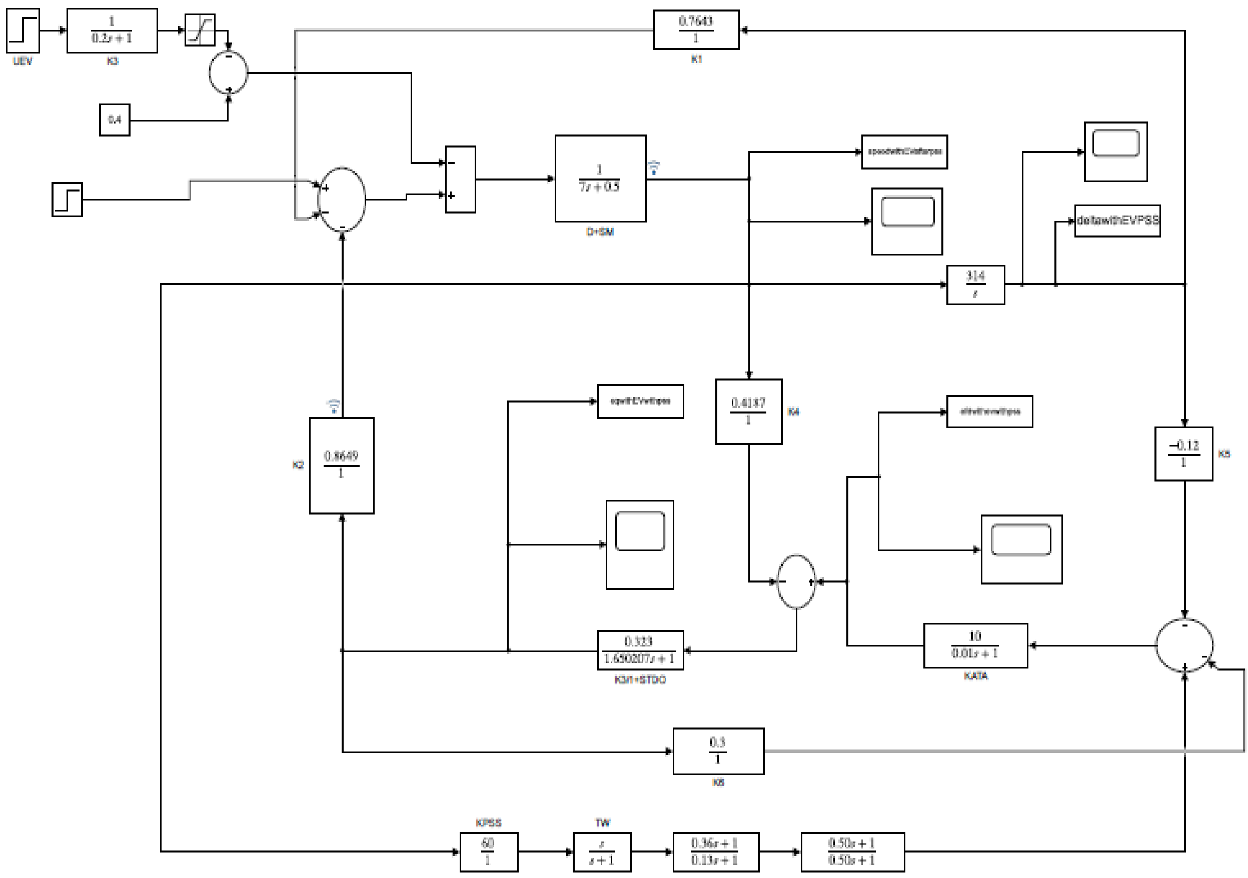

Fig.19. Simulation Diagram with PSS considering EV

6.5. Stability Improvement using PSS.

The equilibrium between the two torques which are the synchronising torque and the damping torque is disturbed due to disturbances. AVRS were used in the system for the problems of low frequency oscillations but it did not provide the required damping torque due to high gain and fast acting nature. It provided sufficient synchronising torque but lacked the damping torque. So, PSS was added with AVR to provide the necessary damping torque to the system and mitigate the problems due to low frequency oscillations. The stability improvement of the system after application of EV as a disturbance is also done with PSS. The values of the parameters of PSS parameters T1 to T4 are respectively 0.36,0.13.0.50,0.50. PSS are very effective for damping local modes of oscillations. These oscillations are created due of swinging of one machine against the rest of the system. The other modes of oscillations are interarea mode, torsional mode of oscillations. The AVR with high gain provide synchronising torque but may not provide the correct damping torque. So, PSS is used with AVR to provide the damping torque and damp out the power oscillations.

A. Plotting variation of state variables using PSS considering EV as a disturbance.

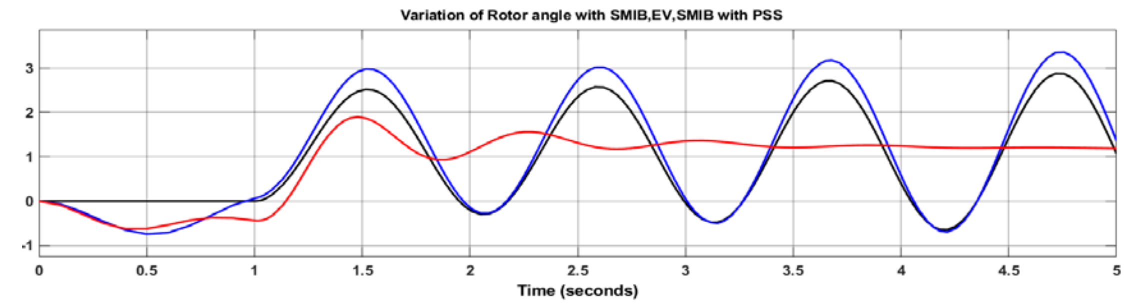

Fig.20. Variation of rotor angle

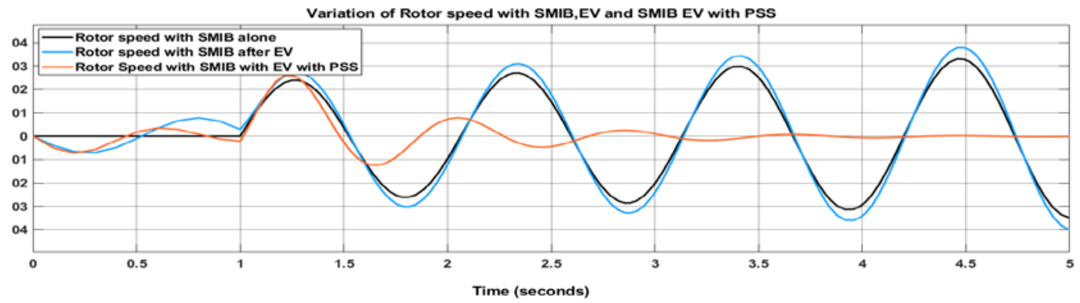

Fig.21. Variation of rotor speed

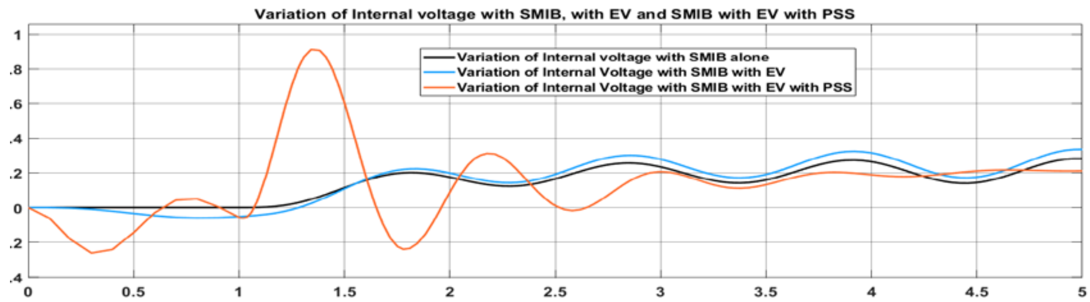

Fig.22. Variation of internal voltage – q axis

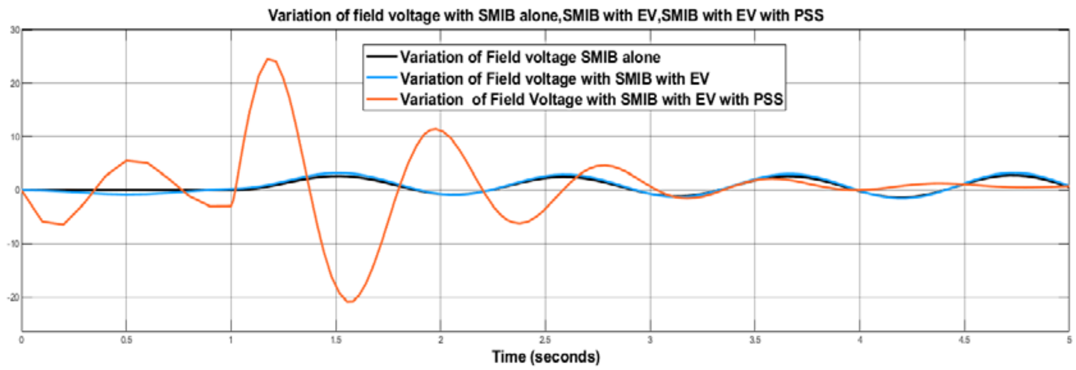

Fig.23. Variation of field voltage

The power system stabilizers are used in the next approach here to damp the system oscillations. The Electric vehicle is applied as a disturbance. On using PSS, the variations are compared with different cases and are shown in figures 20,21,22,23. Oscillations of low frequency often exist in power system due to faults, disturbances and sudden changes of load. By estimating the synchronizing and damping coefficients the PSS damp these oscillations. The speed deviation signal is used as an input to the system.

7. Conclusion and Future Scope

From the graphs of various controllers, it is seen that there is improvement in stability after plotting state variables using three different methods. The results can be seen in the plot of variation of rotor angle, speed, internal voltage and field excitation voltage with and without different methods. After applying LQR approach to the SMIB system the oscillations take less time to settle. There is less overshoot in the variation of various parameters. Thus, in the proposed work the disturbance created due to Electric vehicle is settled. Then PSS is implemented in the Single machine infinite bus system again taking EV disturbance. The PSS is effective in damping the oscillations and the robustness is assured by LQR. The LQR approach assure that the system designed in robust and efficient for improving the stability. The significance of LQR approach is that it considers both, the state variables and control effort. Q matrix is used for improving the performance index and R is used to minimize the control effort. The nonlinear simulation results showed that the two methodologies (LQR approach and the use of PSS device) are effective in damping the system oscillations and increasing the system stability. This confirms the potential of the proposed research work for the optimum utilization of the control strategy based on LQR and PSS. The present work can be extended to multimachine power systems. Thus, both methods, the LQR approach and PSS device ensured the stability of the system against the disturbances and uncertainties created due to electric vehicles. The power quality of the system is improved using PSS device as the oscillations are now mitigated. The challenges due to introduction of EV in the grid system are properly met. Suitable modelling of the EV disturbance as a first order system has been done and added to the system This work can be extended to multi machine systems. The PSS can be optimized with different optimization algorithms. The power electronics-based FACTS device TCSC can be coordinated with the system to mitigate both the interarea and local modes of oscillations.

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References

[1] Abolfazl Jalilvand, Mohammad Reza Safari Tirtashi," Design of Output Feedback Controller for PSS and TCSC by GA to improve the Damping of Power System Oscillations, "International Conference on Power and Energy, IEEE, pp.178-182,2010.

[2] M.W. Mustafa. MIEEE, Nuraddeen Magaji, Z. bint Muda," TCSC Control of Power System oscillation and Analysis using Eigenvalue Techniques International Journal of Engineering & Technology IJET-IJENS Vol.09, Issue-10, pp. 37-43, December 2009.

[3] Rajasekhara Reddy Naguru, G V N Yatendra Babu, and Vaskar Sarkar," A Comparative Study on LQR and *H∞* Control for Damping Oscillations in Power System Network Considering Different Operating Points, IEEE ,2014.

[4] Nuraddeen Magaji, Mukhtar F. Hamza, Ado Dan-Isa, "Comparison of GA and LQR Tuning of STATIC VAR COMPENSATOR for damping Oscillations," International Journal of Advances in Engineering & Technology, Vol. 2, Issue 1, pp. 594-601, Jan 2012

[5] Ali M. Yousef, Mohamed Zahran, Ghareeb Moustafa," LQG Controller for Enhancement Power System Operation, "Journal of Electrical Engineering, pp.1-12. January 2015.

[6] Ali M Yousef, Ahmed M. Kassem, "Power System Stabilizer based on Robust H Infinity Controller for Low Frequency operating Range, "Research Journal of Applied Sciences, Engineering and Technology, Vol.4, Issue-10,2012, pp 1376-1385.

[7] G.Magdy, G. Shabib, Adel A. Elbaset, Thongchart Kerdphol, Yaser Qudaih,Yasunori Mitani ,"A New Coordinated Fuzzy-PID Controller for Power System Considering Electric Vehicles," Energy and Power Engineering, Vol. 9,2017,pp. 425-435

[8] Kwang M. Son, Jong K. Park, "On the Robust LQG Control of TCSC for Damping Power System Oscillations, IEEE Transactions on Power Systems, Vol. 15, Issue- 4, pp.1306-1312, November 2000.

[9] Ajasa, Abiodun Afis, Sebiotimo, Abdul-Azeez Arisekola," The Use of MATLAB in the Solution of Linear Quadratic Regulator (LQR) Problems, Computing, Information Systems, Development Informatics & Allied Research Journal, Vol. 5 No. 4. pp.15-32, December 2014,

[10] Naresh Kumari, A. N. Jha, Nitin Malik," Performance Comparison of PSO Based State Feedback Gain (K) Controller with LQR-PI and Integral Controller for Automatic Frequency Regulation," WSEAS TRANSACTIONS on Power Systems, Vo.11, pp.299-308,2016.

[11] Lotfollahzade, S.J. Seyed-Shenava, A. Akbarimajd, J. Javidan," Design LQR and PID Controller for Optimal Load Sharing of an Electrical Microgrid," International Research Journal of Applied and Basic Sciences, Vol, 4, Issue-3, pp. 704-712,2013.

[12] Reza Sedaghati, Khodakhast Isapour, Mohammad Bagher Haddadi and Navid Mehdizadeh Afroozi," Enhancement of Power System Dynamic Performance using Coordinated Control of FACTS Devices," Indian Journal of Science and Technology, Vol

7(10), pp.1513–1524, October 2014.

[13] S.K. Tso, J. Liang, Q.Y. Zeng, K.L. Lo and X.X. Zhou,” Coordination of TCSC and SVC for stability improvement of power systems, “Proceedings *of* the 4th International Conference on Advances in Power System Control, Operation and Management, pp 371-377, November 1997.

[14] P. Sunilkumar,” Transient Stability Enhancement of Power System Using TCSC,” International Journal of Electrical and Computer Engineering, Vol.2, No.3, pp. 317-324, June 2012.

[15] Sasongko Pramono Hadi, Hatta Imaduddien Wiennetou, Rian Fatah Mochamad, International Journal of Engineering & Computer Science, Vol.13, Issue No-1, pp.23-30.

[16] Harsha Anantwar, B.R. Lakshmikantha, Shanmukha Sundar, "Optimized Controller Design Using an Adaptive Bacterial Foraging Algorithm for Voltage Control and Reactive Power Management in Off-Grid Hybrid Power System", International Journal of Image, Graphics and Signal Processing, Vol.11, No.1, pp. 33-43, 2019.

[17] Naveen kumar bhimagavni, PV Kumar," Extension of Refinement Algorithm for Manually Built Bayesian Networks Created by Domain Experts", International Journal of Wireless and Microwave Technologies, Vol.8, No.1, pp. 25-33, 2018.

[18] Neha Kapoor, Jyoti Ohri, "Improved PSO tuned Classical Controllers (PID and SMC) for Robotic Manipulator", International Journal of Modern Education and Computer Science, vol.7, no.1, pp.47-54, 2015.

Authors’ Profiles

Niharika Agrawal received B.E and M.E Degree in Electrical Engineering from SGSITS Engineering College, Indore. She has worked as Assistant Professor in Electrical Engineering and has teaching experience of 10.5 years. Currently she is working towards the Ph.D. degree at SJB Institute of Technology, Bangalore from Visvesvaraya Technological University, Karnataka, India. Her research interest includes Power System, Renewable Energy, Microgrids, Soft Computing, Control Systems and Power Quality

Dr. Mamatha M. Gowda has received Bachelor Degree from Mangalore University, Masters from Bangalore and Doctorate from Prairie View A & M University, Texas, USA in the field of Electrical Engineering. She has 17 years of Teaching Experience and 5 years of industrial experience. Currently she is working as a Professor in the Department of EEE at SJB institute of Technology, Bengaluru, Karnataka, India. Her area of research interest are Power Electronics, Motor Drives and Controls, Renewable Energy, Power Systems and Control Systems.

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