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SENSOR-FAULT TOLERANT BASED GAIN SCHEDULING CONTROLLER FOR NETWORKED DC MOTOR SYSTEM

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Abstract— This work is concerned with the controller design of NDCMS. A fuzzy gain scheduling controller has been designed to overcome the sensor faults and also to manage the network delay and packet dropouts. Fuzzy gain schedulers allow the controller producing the optimal control action at different operating points. An algorithm has been used to execute the off-line tuning in each of operating point, and a fuzzy sub-system performs a fine tuning. This approach uses fuzzy gain scheduler to determine appropriate gains based on the system's operating conditions. Sliding-mode observer is used to find the rotor speed and unknown load torque for the networked system. To evaluate the feasibility and applicability of the sensor-fault-tolerant controller, numerical and experimental tests are carried out.

Keywords—Bilinear Matrix Inequality; Networked DC Motor System

1. INTRODUCTION

In networked control systems (NCSs), the control loops are closed via a communication network, i.e., the data exchange between different parts of the control loop is performed through the network. NCSs have several benefits in comparison with conventional control systems such as reduced system wiring, easy maintenance, and increase system agility. For those reasons, NCSs have been used in various fields such as dc motors, mobile sensor networks, remote surgery, automated highway systems, and unmanned aerial vehicles. Nevertheless, insertion of the communication network in control loop makes system analysis and design more complicated. This is arisen from some network inherent sophistications such as network-induced delays and packet losses.

In most control applications the most popular control algorithm is by far the PID controller with a fixed configuration and structural parameters determining the amount of proportional, derivative and integral action in the overall control law. When the controlled process is nonlinear, however, a fixed gain PID controller cannot produce satisfactory control performance in all process operating regions. The resulting gain scheduling of PID controllers technique over the years become one of the most popular methodologies to solve non linear control problems. The main advantage of conventional gain scheduling (CGS) is that controller parameters can be changed very quickly in response to changes in the plant dynamics, since no parameter estimation is required.

2. NETWORKED CONTROL SYSTEMS

A Networked Control System (NCS) is a control system where the sensing and actuation signals are exchanged among various parts of a single system or among many subsystems through communication networks. The significant feature of an NCS is that feedback and control signals are exchanged in the form of information packages through a network among the system's components. Four basic elements are used to establish the functionality of a typical NCS:

1. Sensors, to acquire information
2. Controllers, to provide decision and commands
3. Actuators, to perform the control commands
4. Communication network, to enable exchange of information.

This work proposes the modeling of a controller which is sensor fault tolerant and control network induced delays and packet dropouts. The paper is structured as follows. Section II gives the analysis of system. Section III describes the output result. Section IV shows conclusion and its future developments.

3. SYSTEM ANALYSIS

For modeling, stability analysis, and controller design for NCS many methods has already been proposed. It is stated that the NCS performance degrades when the network quality-of-service changes. Therefore, networked proportional–integral (PI) controller gains are adapted to compensate for these setbacks. NCS is modeled as a discrete-time switched system, and then, optimal stabilizing controller gain is selected using a heuristic search approach, so-called estimation of distribution algorithm (EDA). The controller gain is obtained by solving a set of LMIs. Measurement and actuation delays in NCSs are modeled by two mutually independent random variables with Bernoulli binary distribution. A sufficient condition for asymptotic stability and a necessary condition for zero steady-state tracking error for an NDCMS are obtained.

3.1 DISADVANTAGES

- High time consumption
- Highly disturbance sensitive
- Controller performance is low

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To overcome the disadvantages of above system a fuzzy gain scheduling method is proposed. A fuzzy gain scheduler has been developed to allow the controller producing the optimal control action at different operating points. An algorithm has been used to execute the off-line tuning in each of operating point, and a fuzzy sub-system performs a fine tuning. Based on the system's operating conditions, appropriate gains are determined using fuzzy gain scheduling. The fuzzy gain scheduler can be used to determine linear as well as non-linear action. A sliding-mode observer is used to find the rotor speed and unknown load torque for the networked system. Sliding mode control, is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal that forces the system to "slide" along a cross-section of the system's normal behavior. To evaluate the feasibility and applicability of the sensor-fault-tolerant controller, numerical and experimental tests are carried out.

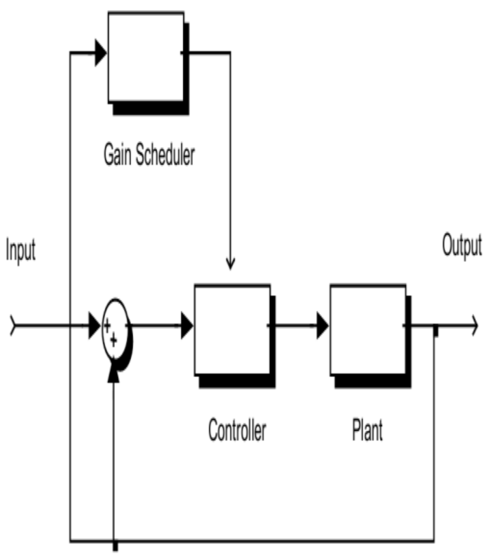

Fig.1 Example of Gain Scheduling

Fig.1 shows an example of gain scheduling system. The gain scheduling system consists of a gain scheduler, controller and a plant. The gain scheduler output has been feed to the controller. The system output is given as feedback to the input.

3.2 ADVANTAGES

1. Controller performance is higher.
2. Low cost.
3. The proposed approach is capable of dumping the adverse effects of time-varying delays and packet dropouts

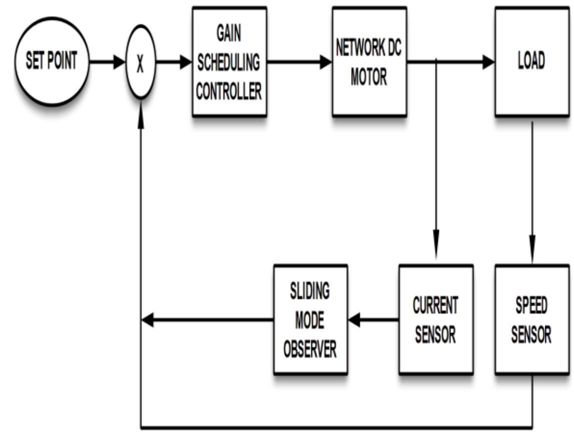

Fig.2 Block diagram

The block diagram is shown in the Fig.2. It consists of a gain scheduling controller, network DC motor, Sliding mode observer and sensors. Both speed and current sensors are used to determine the speed and current of the system. To increase the speed of the response and also to eliminate the steady state error the combination of proportional and integral terms are important. Sliding mode control, is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal that forces the system to "slide" along a cross-section of the system's normal behavior.

4. RESULTS AND DISCUSSIONS

4.1 SIMULINK MODEL FOR FAULT TOLERANT DC MOTOR SPEED CONTROL

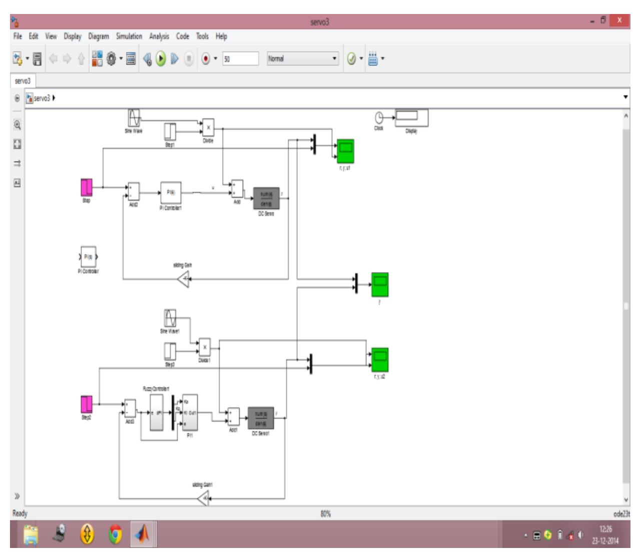

Fig.3 Simulink model for fault tolerant DC motor speed control

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Fig.3 shows the stimulation model for fault tolerant DC motor speed control system. Here tuned PI controllers and fuzzy PI controller have been considered. First section shows the PI controller with tuning and output has been taken. Second shows the controller with fuzzy PI controller, its output also taken. Then both the output has been compared with the set value.

4.2 OVERALL SYSTEM PERFORMANCE

In Fig.4 below shows the overall system performance.

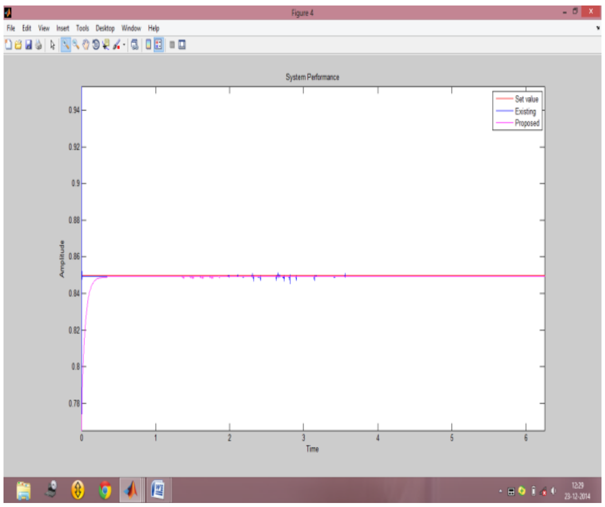

Fig.4 Overall system performance

The set value is indicated by red, the existing system output is shown in blue color and the proposed system output is shown in pink. The existing system value first overshoot and then reach set value but it oscillate. While for proposed system the response almost reaches the set value.

4.3 DYNAMIC SET POINT TRACKING USING TUNED PI CONTROLLER

A set point value has been given. And the output is determined for controller with tuned PI and fuzzy PI. This helps to determine the controller performance in both cases.

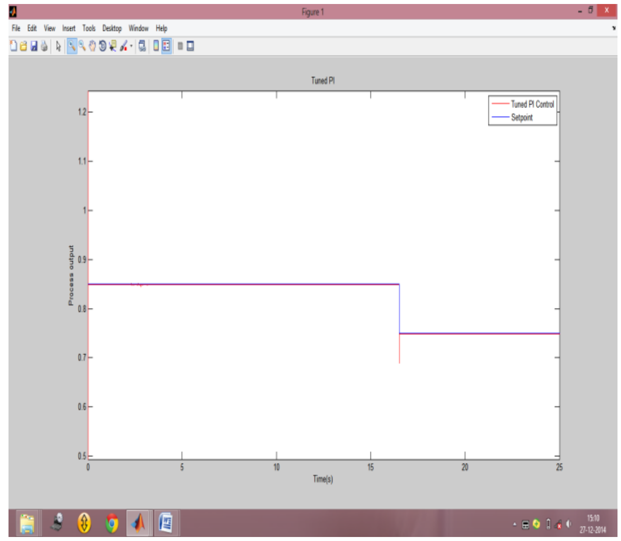

Fig.5 Dynamic set point tracking using tuned PI Controller

Fig.5 shows the dynamic set point tracking using a PI controller with tuning. The set point is indicated by blue color. Initially the set point value is assign as 0.85 and rated speed value 0.75. The red color indicates response output, it initially overshoot the output signal and slowly reach the set point value. The fault is applied after 18 second, and then the controller response is too low.

4.4 DYNAMIC SET POINT TRACKING USING FUZZY PI CONTROLLER

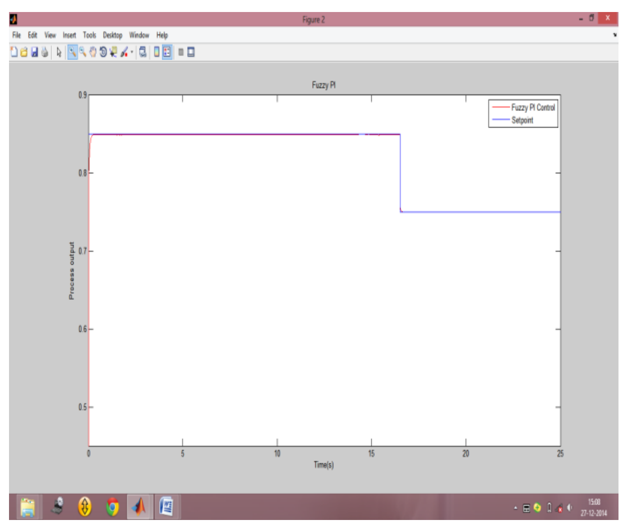

Fig.6 Dynamic set point tracking using fuzzy PI Controller

Fig.6 shows the dynamic set point tracking using a fuzzy PI controller. The set point is indicated by blue color. Initially the set point value is assign as 0.85 and rated speed value 0.75. The

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tuned PI controller output is shown using red color. When compared to the unturned output, the tuned controller outputs almost reach the set value.

4.5 ERROR PLOT

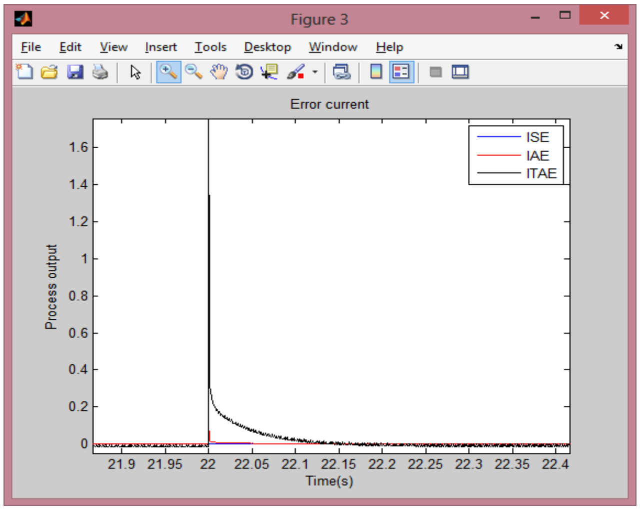

Fig.7 Error plot

1. ISE → Integral Square Error
2. IAE → Integral Absolute Error
3. ITAE→ Integral Time absolute Error

Table.1 Performance of Tuned PI Vs Fuzzy PI Controller

Step Performance	Tuned PI controller	Fuzzy PI controller
Rise Time	1.9932e-04	4.0481e-04
Settling Time	16.5020	16.5008
Settling Min	0.4806	0.6757
Settling Max	1.4234	0.8497
Overshoot	89.9740	13.4002
Undershoot	0	0
Peak	1.4234	0.8497
Peak Time	6.1918e-04	14.5008

5. CONCLUSION AND FUTURE ENHANCEMENTS

A robust sensor fault tolerant networked dc motor in the presence of network-induced delays, packet dropouts, and unknown load torque has been developed. The speed sensor fault has been rectified using a sliding mode observer or, in other words, speed sensor less scheme is also used here. Furthermore, the disadvantages of an optimal PI controller are rectified using a better controller. The controller used for the improvement of the system is a gain scheduling controller. As a future enhancement a fuzzy gain scheduling method is proposed. A fuzzy gain scheduler has been developed to allow the controller producing the optimal control action at different operating points. An algorithm has been used to execute the off-line tuning in each of operating point, and a fuzzy sub-system performs a fine tuning. It provide high response time, error rate is low and high step performance. The network induced delay and packet drop out has been considerably reduced. Simulation and experimental verifications show that the proposed observer/controller is capable of dumping the adverse effects of unknown and time-varying delays and packet dropouts.

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