ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE) Vol 2, Issue 5, May 2016

Design of Redundant Actuators for TRMS

[1] Vidya S Rao, [2] Raviraj Maiya U, [3] Rubina Arora
Instrumentation and Control Engineering
Manipal Institute of Technology, Manipal University, India

Abstract: **-- A Twin Rotor MIMO System (TRMS) is a dynamic model, which is similar in behaviour with helicopter system with significant cross-coupling. Actuator failure in helicopter system may cause huge risks to life and property. Thus, a redundant system is required. Therefore, there is a need for a system, which can direct the control action to the other analogous system so that damages can be eluded. In this paper, redundant motors are used in parallel with the actual motors to avoid this damage and maintain the system stability.**

***Index Terms*—T**RMS**,** Redundant actuators, DPDT switch, H infinity observer controller.

I. INTRODUCTION

TRMS as the name suggests is a MIMO system, which means it has two inputs and two outputs. Its behavior resembles helicopter system with significant cross coupling in longitudinal and lateral axis. Working on a complex helicopter system is a strenuous task therefore TRMS is used which is simplified version of helicopter system in hovering mode. Hovering mode of helicopter is used for rescue operation and package delivery during disasters. So it is very important to make sure that helicopters used for these operations work in extreme conditions of climate since it can damage the parts of helicopter such as sensor, actuators etc. Safety is essential for the systems like helicopter system actuator failure may cause huge risk to life and property. In this paper, implementation of redundant actuators for both main and tail rotors connected in parallel with actual actuators can circumvent any possibility of damage to the helicopter parts. [1]

II. LITERATURE REVIEW

A dynamic model for the two-degree-of-freedom Twin Rotor MIMO System (TRMS) is extracted using a black box system identification technique [2]. For this TRMS model, H infinity controller is designed which is observer based controller which can sustain uncertainties and external disturbances [3]. Uncertainties like actuator failure and sensor failures may cause instability to the TRMS. These uncertainties are well handled by the reliable H infinity observer controller which is already designed in [3][4]. Therefore, during actuator failure to take the control signal coming from the H infinity observer controller, there is a need for redundant actuators, which is explained in detail in this paper.

PCI DAC CARD

PCI1711 has sixteen channel single ended analog inputs, 12-Bit ADC with 100 KHz sampling rate. It has programmable gain and two 12-Bit analog output channels. For TRMS with redundant system it requires four analog output pins but it has only 2 pins which are already in use for actual motors. Therefore, soft switch is not implemented instead hardware switch is used. [5]

Actuators

Maxon A-max motor of 18V, 6W, 30 mA is a graphite brushed DC motor which can run at a speed of 8300 RPM. Redundant motor should be of similar specification. [6]

Snubber Circuit

There is a snubber circuit to filter the control signals coming to the motor. Similarly, we need a snubber circuit for redundant actuators also.

Redundancy Technique

The redundancy technique used in this paper is parallel (stand-by) redundancy which is used in mechanical devices such as motors.

III. METHODOLOGY

a. TRMS Redundant System Setup

To place the redundant motors on TRMS there should be a supporting mechanism for the motors. These redundant motors should be connected in such a way that shaft of these motors are connected to the already existing rotors of actual motors.

1) Construction: To connect redundant motor to the rotor of actual motor a 10mm hexagonal iron bar with one side drilled with a hole of (3/16)" to fit the shaft of redundant motor. A threaded hole perpendicular to the main hole so that proper torque is delivered to the rotor. On the other side, 1" length of the bar is reduced to the screw of (3/16)". A supporting system for the redundant motor is made with the help of aluminium sheet cut into strips of 14cmX1cm and a C-clamp to hold the motor of diameter 22mm with screw to tight it.

Fig. 1. 10mm Hexagonal bar

Fig. 1. C- Clamp to hold the motor

Fig. 3. supporting mechanism for redundant motor

b. DPDT

A Double Pole Double Throw (DPDT) switch is a switch that has 1 input and 2 outputs. Each of the terminals of a double pole double switch can either be in 1 of 2 positions. This makes the double pole double switch a very versatile switch. With 1 input, it can connect to 2 different outputs or reroute a circuit into 4 different modes of operation. A Double Pole Single Switch is actually two single pole double (SPDT) switches. [7]

Fig. 4. DPDT Switch

Simulation for TRMS under actuator failure condition

In this it is assumed that the actuator is faulty. The set point r_pitch and r_yaw for Pitch and Yaw inputs respectively are given as step input with unit radian. y_pitch and y_yaw, are the measured outputs taken from the TRMS block with gain. The control inputs u_pitch and u_yaw from the H infinity controller are fed to the TRMS Block. yhat_pitch and yhat_yaw are the estimated outputs from the H infinity observer. Using, multiport switch in the Simulink we are failing the actuator by cutting down the control signal for a desired time instant.[3][8]

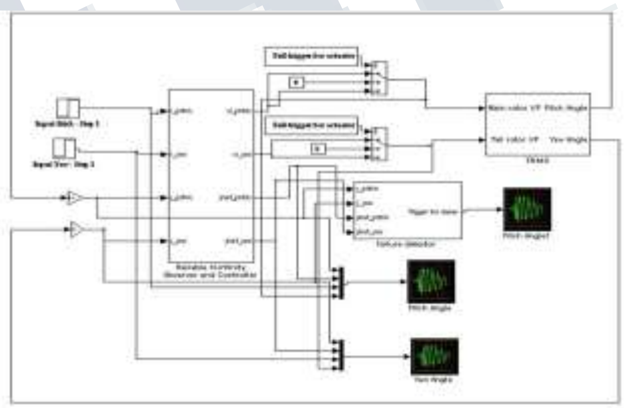

Fig. 5. Simulation for actuator failure

c. Simulation for TRMS with redundant system

In this, it is assumed that actuators are faulty. Therefore, redundancy technique is applied to the system. The set point r_pitch and r_yaw for Pitch and Yaw inputs respectively are given as step input with unit radian. y_pitch and y_yaw, are the measured outputs taken from the TRMS block with gain. The control inputs u_pitch and u_yaw from the H infinity controller are fed to the TRMS Block. yhat_pitch and yhat_yaw are the estimated outputs from the H infinity observer. Here the control signal of actual actuator is monitored continuously. Whenever failure is occurred, the control signal directly goes to the redundant actuator maintaining the stability of the system until the actual actuators restart. [3][8]

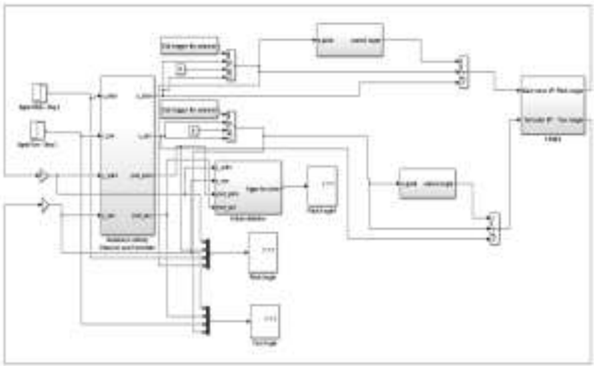

Fig. 6. Simulation for TRMS with redundant system

d. Real time Implementation for TRMS under actuator failure condition

1) Real Time implementation using soft switch: Implementation of TRMS with redundant motor was done using multiport switch (soft switch) as shown in the fig 7. But due to availability of only 2 analog output signal pins which are already used by actual motors so we can't connect to redundant motors. Therefore, it is implemented using hardware DPDT switch.

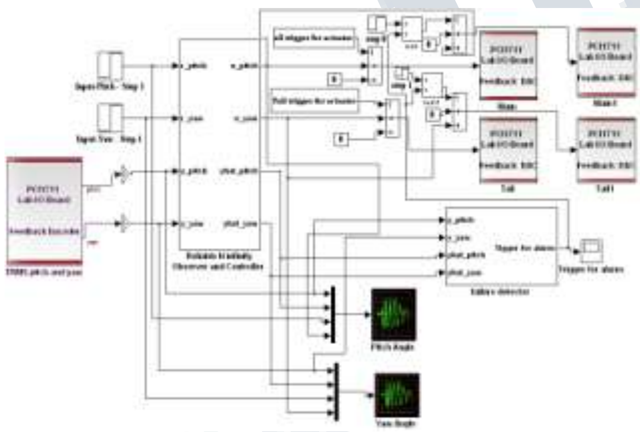

Fig. 7. Real time implementation using soft switch

2) TRMS under actuator failure condition (using DPDT):

In this it is assumed that the actuator is faulty. The set point r_pitch and r_yaw for Pitch and Yaw inputs respectively are given as step input with unit radian. y_pitch and y_yaw, are the measured outputs taken from the Feedback Encoder. The control inputs u_pitch and u_yaw from the H infinity controller are fed to the feedback DAC system. yhat_pitch and yhat_yaw are the estimated outputs from the H infinity observer. So, in this case DPDT switch is implemented because soft switching isn't possible. By failing the power to the motors actuator failure is happening.

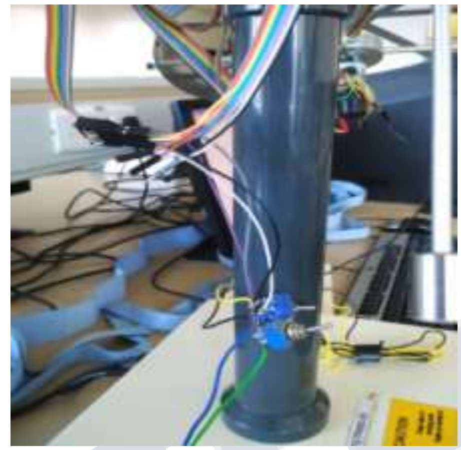

Fig. 8. DPDT switch connections

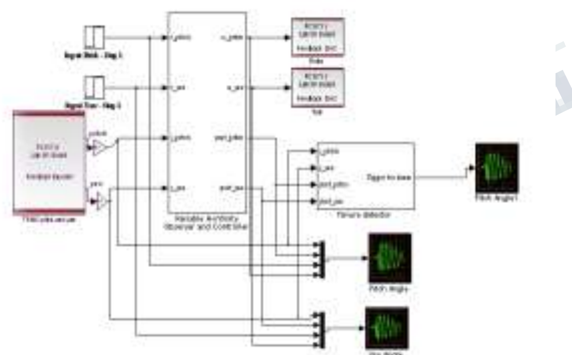

Fig. 9. Real time implementation for TRMS with normal condition

e. TRMS with redundant system:

In this case both actual and redundant motors are attached to the rotor. Using DPDT switch the actual motors are failed and the redundant motors are made to run during the failure. There will be 2 kinds of failure.

i. Partial failure in which any one of the actuators will be failed.

ii. Complete failure in which both main and tail actuators will fail. The setup is made so that it can work in the above failures.

Fig. 10. TRMS System with redundant actuators

The DPDT switch is connected to the motors as shown in the Fig 11. The middle terminals are connected to control signals coming from the controller. The other 4 terminals are connected to the actual and redundant motors.

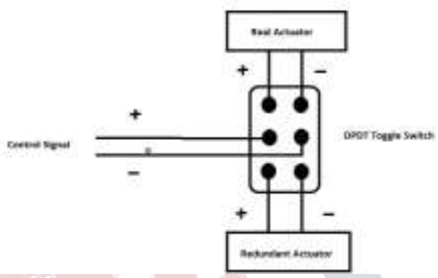

Fig. 11. DPDT connection diagram for the actual and redundant actuators

IV. GRAPHS AND RESULTS

A. Graphs for TRMS under actuator failure(simulation)

Simulated graphs for TRMS under actuator failure is shown in Fig.12 and Fig.13. Between 50s to 70s the actual actuator failure occurs, but due to the control signal from reliable H infinity observer controller, the TRMS output is stable as shown in Fig. 12 and Fig. 13.

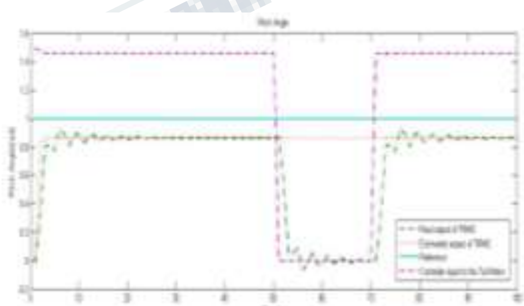

Fig.12. Result for pitch angle under actuator failure condition (simulation)

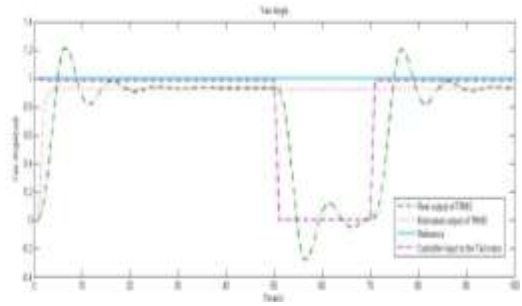

Fig. 13. Result for yaw angle under actuator failure condition simulation)

B. Graphs for TRMS with redundant system(simulation)

Simulated graphs for TRMS with redundant system is shown in Fig. 14 and Fig.15. In this case the actuators will fail from 50s to 70s. But due to redundant system the system does not go to instability.

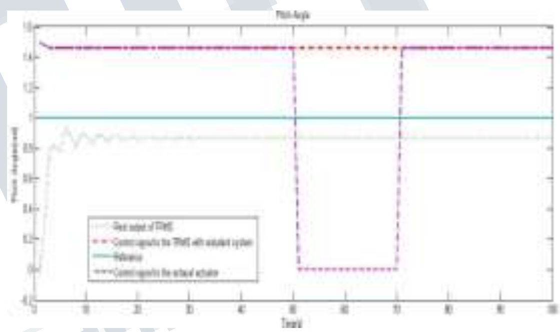

Fig. 14. Result for pitch angle of TRMS with redundant system simulation)

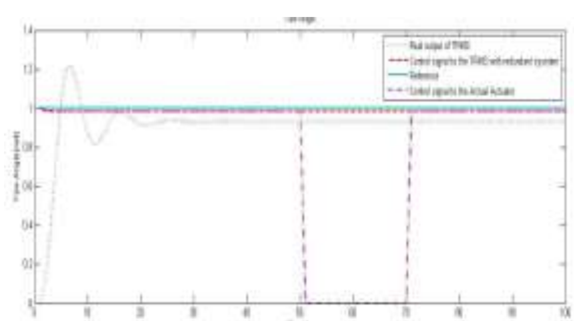

Fig. 15. Result for yaw angle of TRMS with redundant system (simulation)

C. Graphs for TRMS under actuator failure condition(Real Time)

Real time graphs of TRMS with actuators failure condition (using DPDT switch) is shown in Fig. 16 and Fig. 17. Similar to the simulation results the output of

TRMS takes a dip during actuator failure because there are no redundant actuators to take up the control signal.

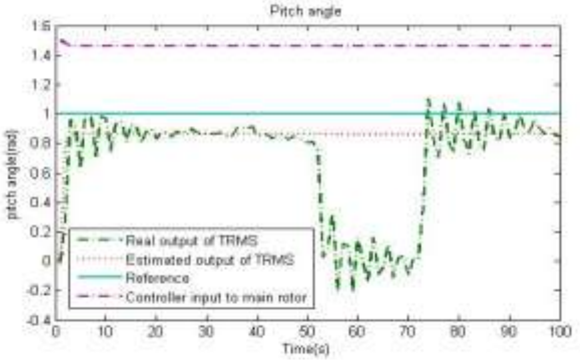

Fig. 16. Result for pitch angle under actuator failure condition (Real time)

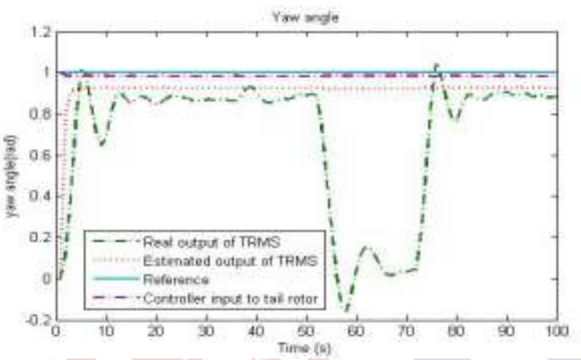

Fig. 17. Result for yaw angle under actuator failure condition (Real time)

D. Graphs for with redundant system (Real Time)

The real time implementation graphs for TRMS with redundant system is shown in Fig. 18 and Fig. 19. Between 30s to 50s the partial failure will occur in tail actuator. So it will switch to redundant tail actuator. Between 50s to 70s complete failure of main as well as tail actuator will occur. So both the rotors run through redundant main and tail actuators. At 90s both the actual actuators will restart. During partial and complete actuator failure the failure is not reflected in the TRMS output because the redundant actuators take up the control signal and maintain the TRMS output at the same position as that of no failure condition without losing its stability. But due to the lower rating of the redundant actuator, there is a performance degradation which is reflected in slight decrease in TRMS Pitch and Yaw positions.

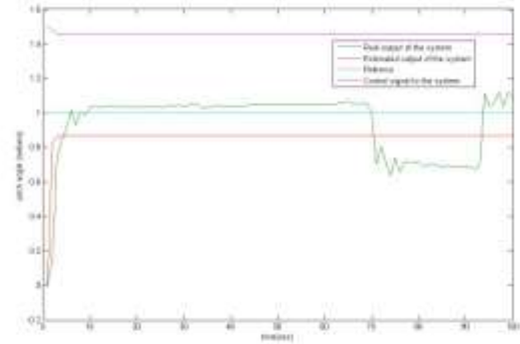

Fig.18. Result for pitch angle of TRMS with redundant system(Real Time)

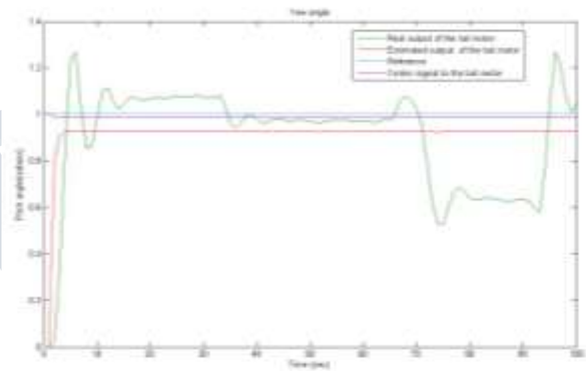

Fig. 19. Result for yaw angle of TRMS with redundant system (Real Time)

V. CONCLUSIONS & FUTURE WORK

The redundant system designed for the TRMS is tested for partial failure as well complete failure of the actuators. Already designed H infinity observer controller produces the control signal even though the actuator fails. This signal is used to run the redundant actuators to maintain the system stability. Referring to the output graphs there is slight degradation in the performance because of the difference in the ratings of the motor used for redundant actuators. Otherwise, it would have given similar performance as that of the actual actuators. Automated switching system can be applied instead of manual switching as described in this paper. This can be extended to the helicopter system whenever there is failure of control system components.

REFERENCES

[1] "Twin Rotor MIMO System Advanced Teaching manual-1"pp.33-007-4M5, 2002, Feedback Instruments Ltd.

[2] Vidya S.Rao,Milind Mukerji, V.I.George, Surekha Kamath, Shreesha C, "System Identification and Observer Design For TRMS", IJCEE, Vol. 5, No. 6, pp.563-567, 2013.
[3] Vidya S.Rao, V.I.George, Surekha Kamath, Shreesha C., "Reliable H infinity Observer-Controller Design for Sensor and Actuator Failure in TRMS", proceeding ICAEE-2014, VIT Vellore, Jan 9-13, DOI. 10.1109/ICAEE.2014.6838536,IEEE, 2014
[4] Vidya S.Rao, George V.I, Surekha Kamath, Shreesha C, "Implementation of Reliable H infinity Observer-Controller for TRMS with sensor and actuator failure", Proceedings Asian Control Conference, Malaysia, DOI:10.1109/ASCC.2015.7244381, pp.1588-1593, 2015.
[5] Datasheet of PCI-1711 Multipurpose Card
[6] .Datasheet of Maxon A-max D.C motor.
[7] DPDT, http://www.learningaboutelectronics.com/Articles/Double-pole-double- throw-switch-DPDT.
[8] M. Belkheiri, "Model Parameter Identification and Nonlinear Control of a Twin Rotor MIMO System TRMS".

