CONTROL OF THREE PHASE INDUCTION MOTOR BY H_2 AND H_∞ METHOD

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ABSTRACT

In this paper discuss the control technique of three phase Industrial induction motor drives are applied in numerous applications such as conveyer, cranes and ventilation systems. A wide range of induction motors can be driven by standard drives to cover a wide range of applications. This requires that fault tolerant control system embrace the wide parameter variation of the applied motors quite recent and of great practical importance the development of powerful and efficient interior point methods to solve the LMIs that arise in system and control theory. In this paper introduces the robust performance (pole placement, H_2 or H_∞) and also presents the LMI formulation of H_2, H_∞ and pole placement. The numerical example of continuous time system has been described at the presence of fluctuations in structural parameters of three phase induction motor such as rotor and stator resistance, inertia moment and friction coefficient. The performance and robustness of proposed control algorithm has verified using MATLAB Simulation.

***Keywords:* Fault Tolerant Control, H_2 /$H\infty$ Guaranteed, Induction Motor, LMI Approach and Pole Placement.**

I. INTRODUCTION

Nowadays the evolution of electrical engineering achieved a successful expansion in the area of fault tolerant electrical machines. To achieve the fault tolerant researchers tried to design various geometries and different electrical drive. The fault tolerant control is to accommodate automatically the fault effects bearing the safeguarding of both the system stability and nominal performance; therefore, avoiding the immediate halt of the system and allowing its functioning within the degradation mode.

Industrial induction motor drives are applied in numerous applications such as conveyer, cranes and ventilation systems. A wide range of induction motors can be driven by standard drives to cover a wide range of applications. This requires that fault tolerant control system embrace the wide parameter variation of the applied motors.

Control systems are generally subjected to various faults as caused by actuators, sensors, and unexpected parameter change in the system. Under these circumstances, it is important for the system to be kept stable with an acceptable closed loop control performance when fault occur. It is a key feature; the closed loop system should be capable of maintaining its pre-specified performance in terms of quality of service, safety, and stability despite the presence of fault. Control theory can be divided into two main areas: conventional and modern control. Conventional control covers the concepts and techniques developed up to 1950. Modern control covers the techniques from 1950 to the present. Conventional control became interesting with the development of feedback theory. Feedback was used in order to stabilize the control system. Feedback systems first used in locomotives. Another example was the use of feedback for telephone signals in the 1920's. Harold Stephen Black proposed a feedback system that would use feedback to limit the distortion.

II. FAULT TOLERANT CONTROL

There has been interest in a fault tolerant control system which has the ability to detect the actuator, sensor fault automatically and to prevent fault from developing into a total system failure. Active FTC law is designed, based on an open-loop system modeled as a function of fault parameter under the assumption that they are immediately identify by an FDI module, using linear matrix inequality. Control systems are generally subjected to various faults as caused by actuators, sensor, and unexpected parameter change in the system. Under these circumstances, it is important for the system to be kept stable with an acceptable closed loop control performance when faults occur. In application where continuity of operation is a key feature, the closed loop system should be capable of maintaining its performance in term of service, safety, stability despite the presence of faults. That is called fault tolerant control (FTC).

With the increased requirement on the high reliability and safety of control systems, research to fault tolerant control has attracted a lot of attention in control engineering practice over the past decades, where a number of effective methods have been developed and successfully applied to practical system.

The Fault Tolerant Control (FTC) are divided into two main parts. Active and Passive Fault Tolerant Control. Active FTC schemes require explicit detection and estimation of the faults. Passive FTC schemes operate without such explicit detection. Our main motivation is to reach a compromise between controller performance and fault tolerance.

III. CONCEPTS AND METHODS IN – FAULT TOLERANT CONTROL

Faults in automated processes will often cause undesired directions and shut-down of a controlled plant, and the consequences could be damage to technical parts of the plant, to personnel or the environment. Fault tolerant control combines diagnosis with control methods to handle faults in an intelligent way. The aim is to prevent that simple faults develop into serious failure and hence increase plant availability and reduce the risk of safety hazards. Fault-tolerant control merges several disciplines into a common framework to achieve these goals. The desired features are obtained through on-line fault diagnosis, automatic condition assessment and calculation of appropriate remedial actions to avoid certain consequences of a fault. The envelope of the possible remedial actions is very wide. Sometimes, simple re-tuning can suffice. In other cases, accommodation of the fault could be achieved by replacing a measurement from a faulty sensor by an estimate. In yet other situations, complex reconfiguration or online controller redesign is required. This paper gives an overview of recent tools to analyze and explore structure and other fundamental properties of an automated system such that any inherent redundancy in the controlled process can be fully utilized to maintain availability, even though faults may occur.

IV. FAULT TOLERANT CONTROL DESIGN FOR INDUCTION MOTOR

Fault tolerant controller for high performance induction motor drive. The proposed approach aims to make the motor tolerant to both internal and external factors such as loading, temperature and sensor failure. To achieve this goal, a controller that switches itself between a control strategy designed for nominal operation and a robust control strategy designed for faulty conditions is developed. The switching function serves as the fault indicator as well. To compensate for sensor faults, a practical speed estimator and an open loop flux observer with online tuning of rotor resistance are proposed A fault tolerant control system with automatic controller reconfiguration has been developed. The proposed approach aims to making the motor tolerant to both internal and external factors such as loading, temperature and sensor failure. Two control strategies are considered, the FOC for the healthy controller and a robust control for the faulty conditions. Depending on the system performance the appropriate control strategy will be used.

V. LMI FORMULATION

Given a state space realizations of the plan *P* in the form (1), the closed loop system is set In state space form by:

$$X = (A + BK)\, x + B1w$$

$$Z = (C1 + D12\, K)\, x + D11\, w$$

$$Z_2 = (C2 + D22\, K)\, u$$

The specifications and objectives in this work are H_2 and H_∞ performance with pole placement. Taken separately, our three design objectives have the following *LMI.*

H_∞ Performance

The closed loop *RMS* gain from *w* to Z_∞ does not exceed γ if and only if there exists a symmetric matrix X_∞ such as

$$\begin{pmatrix} (A + B2\,K)\,X_\infty + X_\infty\,(A + B2\,K)^T & B1 & X_\infty\,(C1 + D12\,K)^T \\ B1^T & -1 & D11^T \\ (C1 + D12\,K)\,X_\infty & D11 & -\gamma^2 I \end{pmatrix} > 0$$

H_2 *Performance*

The closed loop H_2 norm of T_2 does not exceed *v* if there exist two symmetric matrices X_2 *and Q* such that

$$\begin{pmatrix} (A + B2\,K)\,X2 + X2\,(A + B2\,K)^T & B1 \\ B1^T & -1 \end{pmatrix} < 0$$

$$\begin{pmatrix} Q & (C2 + D22\ K)\ X2 & \\ X2\ (C2 + D22\ K)^T & X2 & > 0 \end{pmatrix}$$

Mixed H_2 /H_∞ **performance**

The norm H_2 of the transfer matrix between a perturbation w and a controlled output Z. Where (σi) denotes the *ithe* singular value and (λi) is the *ithe* proper value. In its abstract "standard" formulation, the H_∞ control problem is one of disturbance rejection. Specifically, it consists of minimizing the closed loop gain from w to Z_∞ This can be interpreted as minimizing the effect of the worst case disturbance w on the output Z_2 . The encountered concern is to determine the state feedback $K(s)$ such that $\gamma > 0$ and $F\ (P(s), K(s))\ \gamma\ \infty <$, in order to settle on γ as small as possible.

VI. PROGRAM DETAIL

For the development of a robust tolerant robust control of induction motor performance we need a LMI toolbox which is easy to understand and is easy to simulate. **MATLAB/SIMULINK** is a platform for multi-domain simulation and Model-Based Design of Multi Input Multi Output (MIMO) uncertain systems. It provides an interactive graphical environment and a customizable set of block libraries that let you accurately design, simulate, implement, and test control, signal processing, communications, and other time-varying systems and hence providing immediate access to an extensive range of tools for algorithm development, data visualization, data analysis and access, and numerical computation.

The main simulation modal starts with assigning the parameters to the variables used in the model.

VII. STATE SPACE DISCRIPTION

The state space description of this this system is:

$$\dot{i}ds = -\frac{1}{\sigma Ts} ids + (ws + \frac{1-\sigma}{\sigma} wr) iqs + \frac{M}{\sigma LsTr} idr + \frac{Mwr}{\sigma Ls} iqr + \frac{1}{\sigma Ts} vds \qquad 1.1$$

$$\dot{i}qs = (-ws - \frac{1-\sigma}{\sigma} wr) ids - \frac{1}{\sigma Ls} iqs - \frac{Mwr}{\sigma Ls} idr + \frac{Mwr}{\sigma LsTr} iqr + \frac{1}{\sigma Ts} vqs \qquad 1.2$$

$$\dot{i}dr = \frac{M}{\sigma LrTs} ids - \frac{Mwr}{\sigma Lr} iqs - \frac{1}{\sigma Lr} idr + (ws + \frac{wr}{\sigma}) iqr - \frac{M}{\sigma LsTr} vds \qquad 1.3$$

$$\dot{i}qr = \frac{Mwr}{\sigma Lr} ids + \frac{M}{\sigma LrTs} iqs + (-ws + \frac{wr}{\sigma}) idr - \frac{1}{\sigma Tr} iqr - \frac{M}{\sigma LsTr} vqs \qquad 1.4$$

$$\dot{w}r = -(np\ )^2 \frac{M}{J} iqr.ids + (np)^2 \frac{M}{J} idriqs - \frac{F}{J} wr - \frac{1}{J}(-npT_1) \qquad 1.5$$

TABLE

Parameter	Symbol	Quantity
Rated power	**Pn**	**15 Kw**
Rated current	**In**	**72A**
Rated voltage	**Vn**	**220V**
Rated frequency	**Fs**	**50 Hz**
Stator resistance	**Rs**	**0.2761Ω**
Rotor resistance	**Rr**	**0.645Ω**
Rotor leakage inductance	**Lr**	**2.191Mh**
Stator leakage inductance	**Ls**	**2.191Mh**
Magnetizing inductance	**Lm**	**76.14Mh**
Moment of inertia	**J**	**0.010 Kg/m^2**
Pole	**P**	**2**

In this study, we highlight the three phase induction motor drive and describe its model in synchronous frame. The control has previously been realized through its disturbances. In fact, the system is unsteady in an opened loop. Many poles have some real parts which are positive.

VIII. SYSTEM PARAMETER

$$A = 1.0_e{+}003^* \begin{pmatrix} -0.1008 & 4.0148 & 0.0815 & 3.8386 & 0 \\ -4.0148 & -0.1008 & -3.8689 & 0.0815 & 0 \\ 0.0964 & -3.8340 & -0.0839 & 4.3218 & 0 \\ 3.8340 & 0.0964 & 3.6938 & -0.0839 & 0 \\ 0.3922 & 0 & 0 & 0 & 0.0002 \end{pmatrix}$$

$$B1 = \begin{pmatrix} 1 & 1 & 1 & 1 & 0 \end{pmatrix}^T$$

$$B2 = \begin{pmatrix} 84 & 0 & 0 \\ 0 & 84 & 0 \\ -80 & 0 & 0 \\ 0 & -80 & 0 \\ 0 & 0 & 90 \end{pmatrix}$$

$$C1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$C2 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$$D11 = 0$$

$$D12 = \begin{bmatrix} 0 & 0 & 0 \end{bmatrix}$$

$$D21 = \begin{bmatrix} 0 & 0 & 0 & 0 \end{bmatrix} T$$

$$D22 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

$$K = \begin{pmatrix} -0.4666 & -47.9144 & -1.9935 & -594.2312 & -0.0000 \\ 47.9243 & 1.2057 & 46.1725 & -1.3407 & 0.0000 \\ 4.3581 & 0.0000 & 0.0000 & -0.0000 & -0.1120 \end{pmatrix}$$

Pole of the system on the opened loop are:

P1 = -0.2

P2 = 5330.1

P3 = 17

P4 = -202.4

P5 = -5514.2

Next, we specify the LMI region for pole placement which is the disk with a center having an abscise = -10 and a radius = 1. Using state feedback control u = kx, we obtained the following results :

Pole of the system on the closed loop are:

P1 = -10.0481 + 0.9311i

P2 = - 10.0481 – 0.9311i

P3 = -10.5171

P4 = -9.9861

P5 = -10.2313

The Lyapunov matrix is:

$$X = 1.0e + 008* \begin{pmatrix} 1.0694 & -0.0000 & -1.2028 & -0.0008 & -0.0000 \\ -0.0000 & 0.0000 & -0.0000 & 0.0000 & 0.0000 \\ -1.2028 & -0.0000 & 1.3528 & 0.0009 & 0.0000 \\ -0.0008 & 0.0000 & 0.0009 & 0.0000 & 0.0000 \\ -0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \end{pmatrix}$$

Where the eigen values are:

$$1.0e + 008* \begin{pmatrix} 0.0001 \\ 0.0002 \\ 0.0001 \\ 0.0001 \\ 2.4211 \end{pmatrix}$$

The existence of Lyapunov matrix X, symmetric definite positive has; thus we can say has been proved. For this system or this type of formulation we study the stabilization of the point given by the certain value rotor and stator resistance and inertia moment and friction coefficient.

IX. SIMULATION MODAL OF INDUCTION MOTAR:

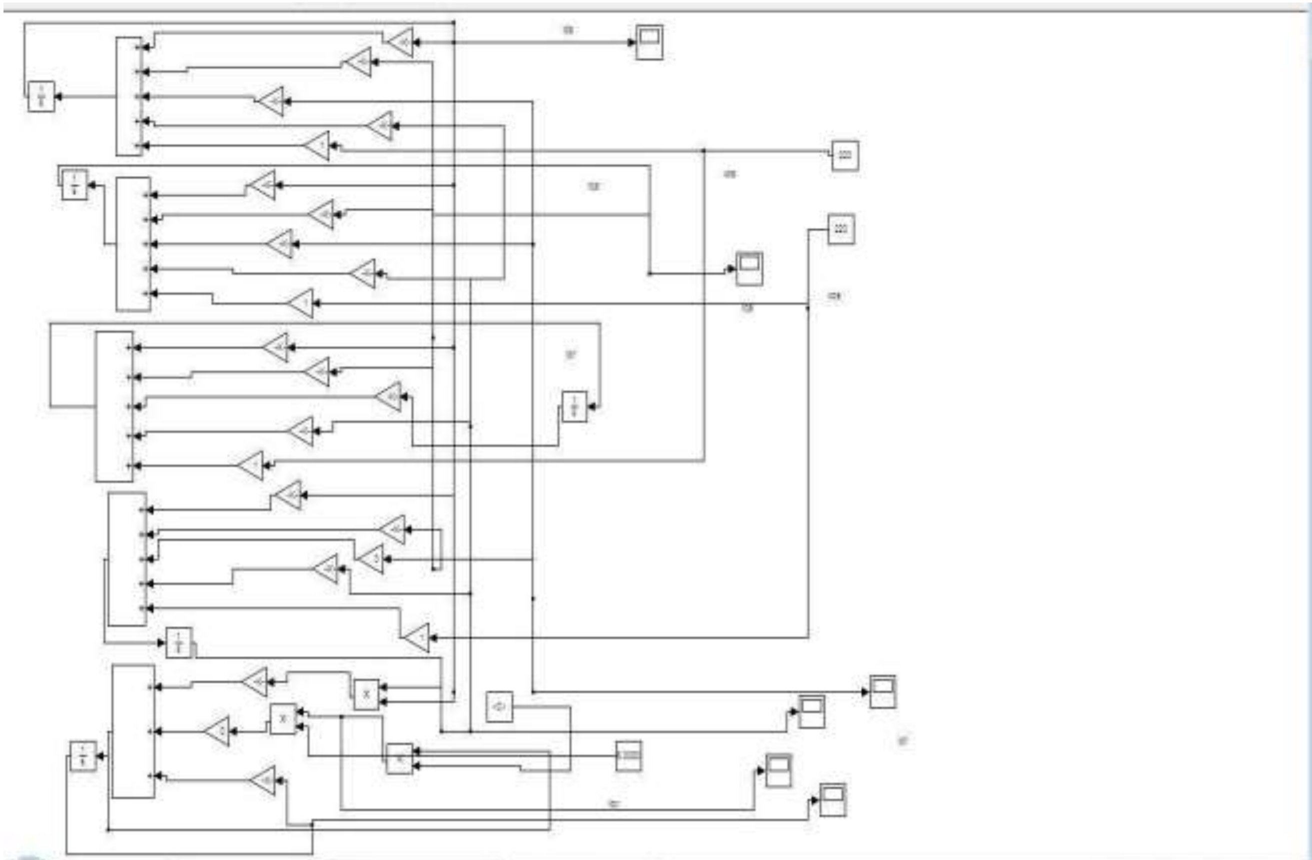

Figure 1 Simulation modal of induction motor

X. SIMULATION RESULT

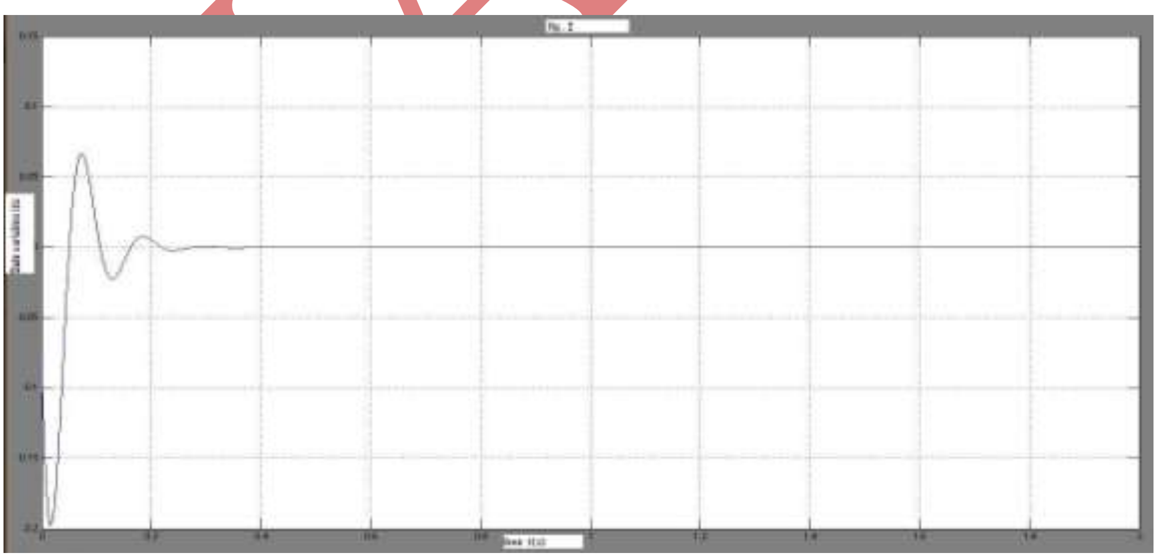

Figure 2 State Variable (ids) with time t(s)

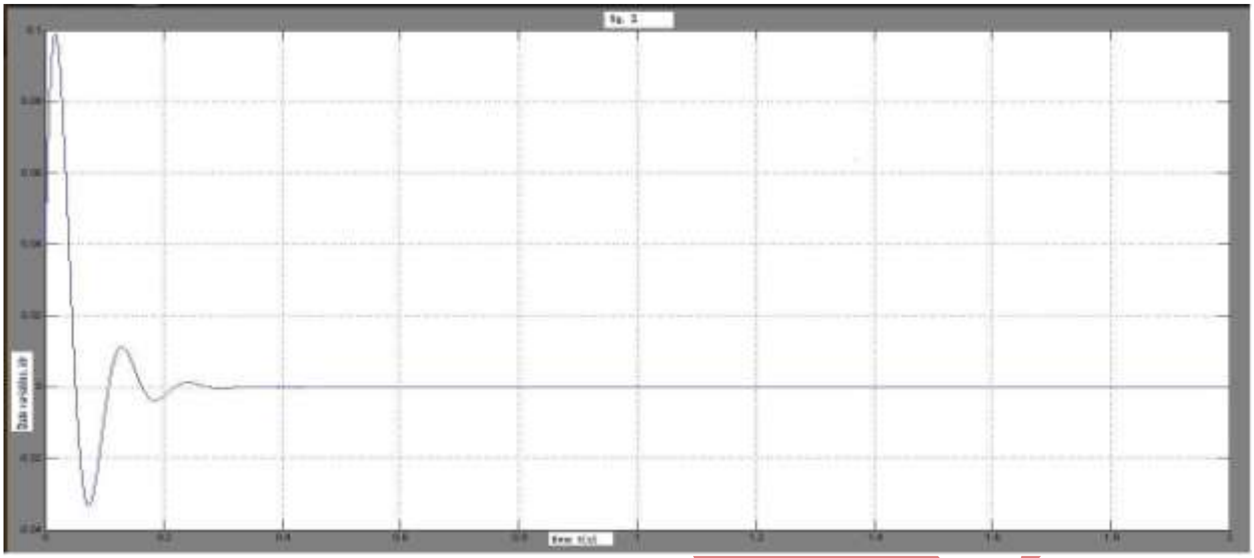

Figure 3 State Variable (idr) with time t(s)

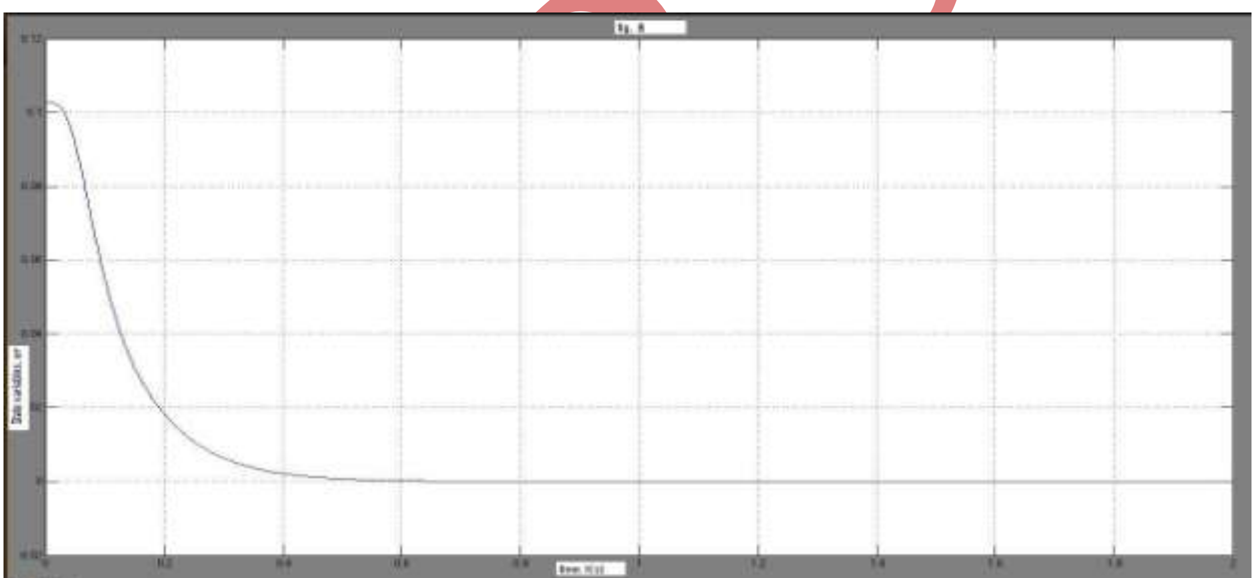

Figure 4 State Variables (wr) with time t(s)

XI. CONCLUSION

In this paper, we emphasize the fault tolerant robust control of induction motor right through the pole assignment with a combination H_2 / H_∞ constraints for the uncertain system. Moreover, we present in the state feedback case, a systematic *LMI* approach to mix H_2 / H_∞ synthesis with pole clustering in sector *LMI* region. Eventually, the numerical example for continuous time system has been exhibited showing the efficiency and the performance of the proposed method, Furthermore, a performance test of this control has been carried out with the presence of structural parameter fluctuations of the induction motor such that rotor and stator resistances, inertia moment and friction coefficient. The efficiency and robustness of this control algorithm are also verified through the simulation results which have been found in the MATLAB.

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