AN ITERATIVE LMI APPROACH TO RFDF FOR LINEAR SYSTEM WITH TIME-VARYING DELAYS

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ABSTRACT

This paper deals with robust fault detection filter (RFDF) problem for a class of linear uncertain systems with time-varying delays and model uncertainties. The RFDF design problem is formulated as an optimization problem by using $L_2$-induced norm to represent the robustness of residual to unknown inputs and modelling errors, and the sensitivity to faults. A sufficient condition to the solvability of formulated problem is established in terms of certain matrix inequalities, which can be solved with the aid of an iterative linear matrix inequality (ILMI) algorithm. Finally, a numerical example is given to illustrate the effectiveness of the proposed method.

KeyWords: Fault detection, filter, robustness, sensitivity, time delay.

1. INTRODUCTION

Research on fault detection and isolation (FDI) in dynamic systems with modelling errors has received considerable attention during the past time [1-4]. However, most of the obtained results are about delay-free systems. On the other hand, dynamic processes with time delays are often met in industry. To our best knowledge, however, only few researches have been developed to this topic, see for instance the work in [5-9]. Note that Jean-Yves and Woihida [6] studied only the fault isolation problem for a kind of discrete-time system; Jiang et al. [7] dealt with the nominal case fault identification (without considering the influence of modelling errors and unknown inputs); Liu and Frank [10] formulated the fault detection filter (FDF) design problem as a two-objective nonlinear programming problem where no analytic solution can be constructed in general; Jiang et al. [8] extended the results in [10] to the discrete-time case.

In this paper, our main attention will be focused on the design of observer-based robust FDF (RFDF) for a class of linear system with modelling errors and time-varying delays, where the RFDF is sought that ensures the asymptotic stability of residual generator dynamics and a proposed objective function is made small. By applying $H_\infty$ optimization techniques, a sufficient condition to solve the above problem is established in terms of certain matrix inequalities (MIs), which can be solved via an iterative linear matrix inequality (ILMI) algorithm.

II. PROBLEM FORMULATION

The system model under consideration is given by

$$\dot{x}(t) = (A + \Delta A) x(t) + \sum_{i=1}^{N} (A_i + \Delta A_i) x(t-d_i(t)) + (B + \Delta B) u(t) + \sum_{i=1}^{L} (B_i + \Delta B_i) u(t-d_i(t)) + (B_f + \Delta B_f) f(t) + (B_d + \Delta B_d) d(t)$$

(1)

$$y(t) = C \cdot x(t) + D u(t) + D_f f(t) + D_d d(t)$$

(2)

$$x(t) = 0, \quad u(t) = 0 \quad \text{for } t \leq 0$$

(3)
where \( x(t) \in \mathbb{R}^n, \ u(t) \in \mathbb{R}^p, \ y(t) \in \mathbb{R}^q, \ d(t) \in \mathbb{R}^m, \) and \( f(t) \in \mathbb{R}^r \) denote the state, control input, measurement output, L2-norm bounded unknown input, and fault, respectively. \( A, B, C, D, B_a, B_b, D_a, D_b, A_i (i = 1, 2, \ldots, N), B_l (l = 1, 2, \ldots, L) \) are known matrices with appropriate dimensions. The time-varying delays satisfy

\[
d_{a_l}(t) \leq \overline{d}_{a_l} < \infty, \quad d_{a_l}(t) \leq \overline{m}_{a_l} < 1
\]

\[
d_{d_l}(t) \leq \overline{d}_{d_l} < \infty, \quad d_{d_l}(t) \leq \overline{m}_{d_l} < 1
\]

It is assumed that

\[
[\Delta A \Delta B \Delta A_i \Delta B_j \Delta B_d] = E \Sigma(t) [F_{a_l} \ F_{b_l} \ F_{d_l} \ F_{f_l} \ F_{h_l}]
\]

where \( E, F_{a_l}, F_{b_l}, F_{d_l}, F_{f_l}, F_{h_l} \) are known matrices and \( \Sigma(t) \Sigma(t) \leq I \). System (1)-(3) is supposed to be asymptotically stable when \( \Sigma^T(t) \Sigma(t) \leq I \), \( u(t) = 0, \ d(t) = 0 \) and \( f(t) = 0 \).

The considered FDF is described by

\[
\dot{x}(t) = A \dot{x}(t) + \sum_{i=1}^{N} A_i \dot{x}(t-d_{a_l}(t)) + B_u(t)
\]

\[
+ \sum_{i=1}^{L} B_{d_l} u(t-d_{d_l}(t)) + H_y(t) - \dot{y}(t)
\]

\[
\dot{y}(t) = C \dot{x}(t) + D_u(t), \quad r(t) = V(y(t) - \dot{y}(t))
\] (4)

where \( \dot{x}(t) \in \mathbb{R}^n \) and \( \dot{y}(t) \in \mathbb{R}^q \) are state and output estimates, \( r(t) \in \mathbb{R}^q \) is residual, the observer gain matrix \( H \in \mathbb{R}^{q \times q} \) and projector \( V \in \mathbb{R}^{q \times q} \) are parameters to be designed. Denote \( e(t) = x(t) - \dot{x}(t) \). It follows from (1)-(5) that

\[
\dot{e}(t) = (A - HC) e(t) + \sum_{i=1}^{N} A_i e(t-d_{a_l}(t)) + \Delta A x(t)
\]

\[
+ \sum_{i=1}^{N} \Delta A_i x(t-d_{a_l}(t)) + \Delta B u(t) + \sum_{i=1}^{L} \Delta B_{d_l} u(t-d_{d_l}(t))
\]

\[
+ (B_d - HD_d + \Delta B_d) d(t) + (B_f - HD_f + \Delta B_f) f(t)
\]

\[
r(t) = V(Ce(t) + D_d d(t) + D_f f(t))
\] (6) (7) (8)

Divide \( x(t) \) into \( x(t) = x_{a_l}(t) + x_f(t) \) as follows

\[
\dot{x}_{a_l}(t) = (A + \Delta A) x_{a_l}(t) + x_f(t)
\]

\[
+ \sum_{i=1}^{N} (A_i + \Delta A_i) x_{a_l}(t-d_{a_l}(t))
\]

\[
+ \sum_{i=1}^{L} (B_{d_l} + \Delta B_{d_l}) u(t-d_{d_l}(t)) + (B_d + \Delta B_d) d(t)
\]

\[
\dot{x}_f(t) = (A + \Delta A) x_f(t) + (B_f + \Delta B_f) f(t)
\]

\[
+ \sum_{i=1}^{N} (A_i + \Delta A_i) x_f(t-d_{a_l}(t))
\]

\[
x_{a_l}(t) = 0, \quad x_f(t) = 0 \quad \text{for} \ t \leq 0
\]

Define

\[
w^T(t) = [d^T(t) \ u^T(t) \ u^T(t-d_{a_l}(t)) \ \cdots \ u^T(t-d_{a_l}(t))]
\]

We have

\[
\dot{e}(t) = (A - HC) e(t) + \sum_{i=1}^{N} A_i e(t-d_{a_l}(t))
\]

\[
+ \Delta A (x_{a_l}(t) + x_f(t)) + \sum_{i=1}^{N} \Delta A_i x_{a_l}(t-d_{a_l}(t))
\]

\[
+ \sum_{i=1}^{N} \Delta A_i x_{a_l}(t-d_{a_l}(t)) + (B_u - HD_u + \Delta B_u) w(t)
\]

\[
+ (B_f - HD_f + \Delta B_f) f(t)
\]

\[
\dot{x}_{a_l}(t) = (A + \Delta A) x_{a_l}(t) + (B + \Delta B) u(t-d_{a_l}(t))
\]

\[
+ \sum_{i=1}^{N} (A_i + \Delta A_i) x_{a_l}(t-d_{a_l}(t))
\]

\[
+ \sum_{i=1}^{L} (B_{d_l} + \Delta B_{d_l}) u(t-d_{d_l}(t)) + (B_d + \Delta B_d) d(t)
\]

\[
r(t) = V(Ce(t) + D_d d(t) + D_f f(t))
\]

Let \( r_f = r_{d<0,a<0}, r_w = r_f \mid_{t=0} \). Under the zero initial condition, we use \( \|r_f\|_2 \) and \( \|f\|_2 \) to measure the robustness of residual to unknown input and modelling errors, and the sensitivity to fault, respectively. The main problem of this paper is to find \( H, V \) such that system (8)-(11) is asymptotically stable when \( u(t) = 0, \ d(t) = 0 \) and \( f(t) = 0 \) and, for all possible \( u(t), d(t) \) and \( f(t) \), the objective function \( J = \|r_f\|_2 \) is made as large as possible in the feasibility of

\[
\|r_f\|_2 > \beta \|f\|_2, \quad \|r_w\|_2 < \gamma \|w\|_2, \quad \beta > 0, \quad \gamma > 0
\]
III. DESIGN OF RFDF

**Lemma 1.** If there exist matrices \( P > 0 \) and \( R_i > 0 \) \((i = 1, 2, \ldots, N)\) such that the following LMI

\[
\begin{bmatrix}
\Gamma_{11} & PB + C^T D & \Gamma_{13} \\
B^T P + D^T C & -\gamma^2 I + D^T D & 0 \\
\Gamma_{13}^T & 0 & \Gamma_{33}
\end{bmatrix} < 0
\]

\(\Gamma_{11} = A^T P + PA + C^T C + \sum_{i=1}^{N} R_i\)

\(\Gamma_{13} = [PA_i \cdots P A_N]\)

\(\Gamma_{33} = \text{diag}\{-(1-m_1) R_1, \ldots, -(1-m_N) R_N\}\)

holds, then the system

\[
\begin{aligned}
\dot{x}(t) &= A x(t) + \sum_{i=1}^{N} A_i x(t-d_i(t)) + B w(t) \\
z(t) &= C x(t) + D w(t), \quad x(t) = 0 \quad (t \leq 0) \\
d_i(t) &\leq \bar{d}_i < \infty, \quad \dot{d}_i(t) \leq \bar{m}_i < 1
\end{aligned}
\]

is asymptotically stable and, for given \( \gamma > 0 \), satisfies \( \|z\|_2 < \gamma \|w\|_2 \).

Similar to Lemma 1, the following proposition can be obtained (with proof omitted).

**Proposition 2.** For given \( \beta > 0 \) and asymptotically stable system (13)-(15), if there exist matrices \( Q > 0 \) and \( S_i > 0 \) \((i = 1, 2, \ldots, N)\) satisfy LMI

\[
\begin{bmatrix}
\Xi_{11} & -QB + C^T D & \Xi_{13} \\
-C^T Q + D^T C & -\beta^2 I + D^T D & 0 \\
\Xi_{13}^T & 0 & \Xi_{33}
\end{bmatrix} < 0
\]

with

\[
\Xi_{11} = -A^T Q - QA + C^T C - \sum_{i=1}^{N} S_i
\]

\(\Xi_{13} = [QA_i \cdots QA_N]\)

\(\Xi_{33} = \text{diag}\{-(1-m_1) S_1, \ldots, -(1-m_N) S_N\}\)

then \( \|z\|_2 > \beta \|w\|_2 \).

By applying Schur Complement, Lemma 1, and Proposition 2, we are now in the position to present our main result.

**Theorem 3.** For given \( \gamma > 0 \) and \( \beta > 0 \), system (8)-(11) with \( H \) and \( V \) that \( \nu^T V = G \) is asymptotically stable and satisfies (12), if there exist \( \varepsilon_1 > 0, \varepsilon_2 > 0, P_1 > 0, P_2 > 0, Q_1 > 0, Q_2 > 0, G > 0, P_{10} > 0, P_{12} > 0, R_{ij} > 0, S_{ij} > 0 \) \((i = 1, 2, \ldots, N; j = 1, 2)\), \( H \) and \( H_0 \) satisfy MIs

\[
[N_{ij}]_{658} < 0, \quad [M_{ij}]_{658} > 0
\]

with

\[
N_{ij} = A_i^T P_i + P_i A_i + C_i^T G C_i + \sum_{i=1}^{N} R_{ij}
\]

\[
+ 2(P_{10} P_{10} - P_1 P_1 - P_2 P_2)
\]

\[
+ C_i^T (H_0^T H_0 - H_i^T H_i - H^T H_0) C_i
\]

\(N_{13} = P_i B_i + C_i G D_i, \quad N_{14} = P_i A_i\)

\(N_{16} = P_i E, \quad N_{15} = (P_i - HC)^T\)

\(N_{22} = A_i^T P_i + P_i A_i + \sum_{i=1}^{N} R_{i2}, \quad \varepsilon_1 F_i^T F_i
\]

\(N_{18} = P_i, \quad N_{23} = P_i B_i + \varepsilon_1 F_i^T F_i
\]

\(N_{25} = P_i A_i + \varepsilon_1 F_i^T F_i, \quad N_{26} = P_i E
\]

\(N_{33} = -\gamma^2 I + D^T G D_i + \varepsilon_1 F_i^T F_i
\]

\(\quad + D_i^T (H_i^T H_i - H_i^T H_i - H^T H_0) D_i
\]

\(N_{55} = \varepsilon_1 F_i^T F_i, \quad N_{58} = -D_i^T H_i^T
\]

\(N_{44} = -R_{i,i}, \quad N_{55} = R_{i,i} + \varepsilon_1 F_i^T F_i
\]

\(N_{66} = \varepsilon_2 I, \quad N_{77} = -I, \quad N_{88} = -I
\]

\(M_{11} = -A_i^T Q_i - Q_i A_i + C_i^T G C_i - \sum_{i=1}^{N} S_{i}, i
\]

\(\quad - 2(Q_i Q_{i0} - Q_{i0} Q_i - Q_i Q_{i0})
\]

\(\quad - C_i^T (H_0^T H_0 - H_i^T H_i - H^T H_0) C_i
\]

\(M_{13} = -Q_i B_i + C_i^T G D_i, \quad M_{14} = Q_i A_i\)

\(M_{16} = Q_i E, \quad M_{17} = (Q_i - HC)^T, \quad M_{18} = Q_i\)

\(M_{22} = -A_i^T Q_i - Q_i A_i + \sum_{i=1}^{N} S_{i}, i
\]

\(\quad - \varepsilon_2 F_i^T F_i
\]

\(M_{23} = -Q_i B_i - \varepsilon_2 F_i^T F_i, \quad M_{25} = Q_i A_i + \varepsilon_2 F_i^T F_i
\]

\(M_{33} = D_i^T G D_i - \beta^2 I - \varepsilon_2 F_i^T F_i
\]

\(\quad - D_i^T (H_i^T H_i - H_i^T H_i - H^T H_0) D_i
\]

\(M_{26} = Q_i E, \quad M_{35} = \varepsilon_2 F_i^T F_i, \quad M_{18} = -D_i^T H_i^T
\]

\(M_{44} = S_{i,i}, \quad M_{55} = S_{i,i} - \varepsilon_2 F_i^T F_i
\]

\(M_{66} = \varepsilon_2 I, \quad M_{77} = I, \quad M_{88} = I
\]

Others, \( N_{ij} = 0 \quad M_{ij} = 0 \)

\(R_{i,j} = \text{diag}\{(1-m_i) R_{i,j}, \ldots, (1-m_N) R_{i,j}\}
\]

\(S_{i,j} = \text{diag}\{(1-m_i) S_{i,j}, \ldots, (1-m_N) S_{i,j}\}
\]

\[A_i = [A_i \cdots A_N]\]
\[ F_{ax} = [F_{a1} \cdots F_{aN}] \]

\[ F_{bx} = [F_{b1} \cdots F_{bN}] \]

**Proof.**

\[ \dot{A} = diag \{ A - HC, A \}, \quad \dot{A} = diag \{ A, A \} \]

\[ \Delta A = \tilde{E} \Sigma(t) \tilde{F}_a, \quad \Delta \tilde{A} = \tilde{E} \Sigma(t) \tilde{F}_{au} \]

\[ \dot{B}_u = \begin{bmatrix} B_u - HD_u \end{bmatrix}, \quad \tilde{B}_u = \begin{bmatrix} B_f - HD_f \end{bmatrix} \]

\[ \Delta \tilde{B}_u = \tilde{E} \Sigma(t) \tilde{F}_{bu}, \quad \Delta B_f = \tilde{E} \Sigma(t) F_{bf} \]

\[ \tilde{C} = [C 0], \quad \tilde{E} = [E^T \ E^T] \]

\[ \tilde{F}_a = [0 \ F_a], \quad \tilde{F}_{au} = [0 \ F_{au}] \]

For given \( \gamma > 0 \) and \( \beta > 0 \) from Lemma 1 and Proposition 2, we know that system (8)-(11) is asymptotically stable and satisfies (12), if there exist \( \Phi_i, \Psi_i \) (\( i = 1, 2, \ldots, N \)), \( G = V^T V \), and \( H \) satisfy

\[ [\Phi_i]_{3 \times 3} < 0, \quad [\Psi_i]_{3 \times 3} > 0 \]  \hspace{1cm} (17)

with

\[ \Phi_{i1} = \tilde{A}^T P + P \tilde{A} + \tilde{C}^T \tilde{G} \tilde{C} + \sum_{i=1}^{N} R_i + P \Delta \tilde{A}^T P + P \Delta \tilde{A} \]

\[ \Phi_{i2} = P(\tilde{B}_u + \Delta \tilde{B}_u) + \tilde{C}^T GD_u \]

\[ \Phi_{i3} = \{ P(\tilde{A} + \Delta \tilde{A}) \cdots P(\tilde{A}_N + \Delta \tilde{A}_N) \} \]

\[ \Phi_{22} = -\gamma^T I + D_u^T GD_u, \quad \Phi_{23} = 0 \]

\[ \Phi_{33} = diag \{ -1 - (1-\tilde{m}_1)R_1 \cdots -1 - (1-\tilde{m}_N)R_N \} \]

\[ \Psi_{i1} = -\tilde{A}^T Q - Q \tilde{A} + \tilde{C}^T \tilde{G} \tilde{C} + \sum_{i=1}^{N} S_i - \Delta \tilde{A}^T Q - Q \Delta \tilde{A} \]

\[ \Psi_{i2} = -Q(\tilde{B}_f + \Delta \tilde{B}_f) + \tilde{C}^T GD_f \]

\[ \Psi_{i3} = \{ Q(\tilde{A}_1 + \Delta \tilde{A}_1) \cdots Q(\tilde{A}_N + \Delta \tilde{A}_N) \} \]

\[ \Psi_{22} = -\beta^T I + D_f^T GD_f, \quad \Psi_{23} = 0 \]

\[ \Psi_{33} = diag \{ (1 - \tilde{m}_1)S_1 \cdots (1 - \tilde{m}_N)S_N \} \]

Let

\[ \Upsilon_p = [\tilde{E}^T \ P \ 0 \ \cdots \ 0] \]

\[ \Upsilon_q = [\tilde{E}^T \ Q \ 0 \ \cdots \ 0] \]

\[ \Theta_p = [F_a \ F_{bu} \ F_{a1} \ \cdots \ F_{au}] \]

\[ \Theta_q = [-F_{bf} \ -F_{au} \ -F_{a1} \ \cdots \ -F_{au}] \]

By using Schur complement, MIs in (16) are equivalent to

\[ [\Phi_i]_{4 \times 4} < 0, \quad [\Psi_i]_{4 \times 4} > 0 \]  \hspace{1cm} (18)

with

\[ \Phi_{i1} = (A - HC)^T P_i + P_i (A - HC) + C^T GC + \sum_{i=1}^{N} R_{i,3} \]

\[ + 2(P_1 - P_1)(P_1 - P_1) + C^T (H_0 - H)^T (H_0 - H) \]

\[ \Phi_{i2} = 0, \quad \Phi_{i3} = P_i (B_u - HD_u) + C^T GD_u, \]

\[ \Phi_{i4} = [P_i A_i \ 0 \ P_i E], \quad \Phi_{23} = P_i B_u + e_i F_a^T F_{bu}, \]

\[ \Phi_{22} = N_{22}, \quad \Phi_{24} = [0 \ P_i A_i + e_i F_a^T F_{ax} \ P_i E] \]

\[ \Phi_{33} = -\gamma^T I + D_u^T GD_u + e_i F_a^T F_{bu}, \]

\[ + D_u^T (H_0 - H)^T (H_0 - H) D_u \]

\[ \Phi_{34} = [0 \ e_i F_{bu}, \Phi_{24}] \]

\[ \Phi_{44} = diag \{ - R_{i,3} - R_{i,2} + e_i F_{bu}, -e_i I \} \]

\[ \Psi_{i1} = -(A - HC)^T Q_i - Q_i (A - HC) + C^T GC \]

\[ + \sum_{i=1}^{N} S_{i,3} - 2(Q_i - Q_0) (Q_i - Q_0) \]

\[ - C^T (H_0 - H)^T (H_0 - H) C \]

\[ \Psi_{i2} = 0, \quad \Psi_{i3} = -Q_i (B_u - HD_u) + C^T GD_f \]

\[ \Psi_{i4} = [Q_i A_i \ 0 \ Q_i E], \quad \Psi_{23} = M_{22} \]

\[ \Psi_{24} = [0 \ Q_i A_i + e_i F_a^T F_{ax} \ Q_i E] \]

\[ \Psi_{33} = -\beta^T I + D_f^T GD_f - e_i F_{bu} F_{bf}, \quad \Psi_{23} = M_{22} \]

\[ \Psi_{34} = [0 \ e_i F_{bu}, \Phi_{24}] \]

\[ \Psi_{44} = diag \{ S_{i,3}, S_{i,2} - e_i F_{bu} F_{ax}, e_i I \} \]

For any \( e_i > 1 \) and \( e_2 > 0 \), we know

\[ \Upsilon_p^T \Sigma(t) \Theta_p + \Theta_p^T \Sigma^T(t) \Upsilon_p \leq e_i^{-1} \Upsilon_q^T \Upsilon_q + e_i \Theta_q^T \Theta_q \]

\[ \Upsilon_q^T \Sigma(t) \Theta_q + \Theta_q^T \Sigma^T(t) \Upsilon_q \geq -(e_i^{-1} \Upsilon_q^T \Upsilon_q + e_i \Theta_q^T \Theta_q) \]
It is verified that the feasibility of MIs in (18) implies that of MIs in (17). The proof is therefore completed.

Remark 1. (i) MIs in (16) can be solved by an ILMI algorithm in [11]; (ii) The choice of $V$ is non-unique for an obtained $G > 0$. If $V$ is such that $V^TV = G$, then $UV$ is also a solution for any orthogonal matrix $U$ with appropriate dimension.

IV. NUMERICAL EXAMPLE

Consider a linear time-delay system described by (1)-(3) with parameters:

$$A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}, \quad A_t = \begin{bmatrix} 0 & 0 \\ 0.1 & 0.2 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$B_1 = \begin{bmatrix} 0 \\ 0.1 \end{bmatrix}, \quad B_f = \begin{bmatrix} 0 \\ 0.1 \end{bmatrix}, \quad B_g = \begin{bmatrix} 0.2 & 0 \\ 0 & 0.1 \end{bmatrix}$$

$$E = \begin{bmatrix} 0 & 0.5 \\ 0 & 1 \end{bmatrix}, \quad C = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad D_p = \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix}$$

$$F_a = [0.1 \ 0.1], \quad F_b = 0.1, \quad F_{hd} = 0, \quad F_{hf} = 0$$

$$D = 0, \quad D_f = \begin{bmatrix} 0.5 \\ 0 \end{bmatrix}, \quad d_{st}(t) = 1 + 0.1 \sin(t)$$

By using the proposed ILMI method in Theorem 1, we have $\gamma = 1.5$, $\beta = 1.3$ and

$$H = \begin{bmatrix} 0.1342 & -0.0018 \\ 0.0048 & 0.4488 \end{bmatrix}, \quad V = \begin{bmatrix} 1.8059 & 0.5848 \\ 0.5848 & 2.2294 \end{bmatrix}$$

On the other hand, when $H$ and $V$ obtained in [10] is directly used as the RFDF parameters, that is

$$H = \begin{bmatrix} 2.5136 & 0.1518 \\ -1.9998 & 4.2392 \end{bmatrix}, \quad V = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$

the infimum of $\gamma$ is $\gamma_{inf} = 0.85$, while the supremum of $\beta$ is $\beta_{sup} = 0.4$. Obviously, the RFDF designed by using ILMI algorithm have better performance.

V. CONCLUSION

This paper deals with the RFDF design problem for a class of linear systems with time-varying delays. The main contributions of this paper are the formulation of an optimization problem, in which the main objective is that the residual is as robust as possible to unknown input and control input, while at the same time it is as sensitive as possible with respect to fault; the derivation of a sufficient condition to the solvability of the RFDF problem; and further a solution in terms of MIs, which can be solved by an ILMI algorithm. An illustrated example is presented to demonstrate the effectiveness of the proposed method.

REFERENCES