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A QUICK FAULT DETECTION SYSTEM APPLIED TO PITCH ACTUATORS OF WIND TURBINES

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Abstract

The design of fast respond fault detection systems to wind turbines results an important subject and represents a notable challenger too. This paper presents a recent approach on a quick response fault detection system to pitch actuators in controlled wind turbines. The obtained time detection is about 10 seconds. Our scheme was possible by manipulating an adaptive parametric estimation block by varying the time scales among the actuator and the identification process dynamics. Additionally, numerical experiments are realized to support the main contribution.

Adaptive parametric on-line identification

The recursive least-squares algorithm for parametric identification uses the following performance index [2]:

$$J = \int_0^t [\theta^T(t)w(\tau) - y_p(\tau)]^2 d\tau \qquad (1)$$

where $\theta(t) \in R^p$ is the on-time estimation vector of the parametric plant, $w(t) \in R^q$ is the regression vector, and $y_p(t) \in R$ is the plant output given by:

$$y_p(t) = \theta^{*T} w(t) \qquad (2)$$

being $\theta^* \in R^p$ the nominal system vector parameter. Then, we state:

Proposition 1.- The following alternative on adaption dynamics minimizes the previous cited performance index equation:

$$\dot{P}(t) = -g_1 P(t)w(t)w^T(t)P(t) \qquad (3)$$
$$\dot{\theta}(t) = -g_2 P(t)w(t)[w^T(t)\theta(t) - y_p(t)] \qquad (4)$$

where g_1 and g_2 are two different positive constants controlling the transient respond to each dynamic equation.

Problem statement

Given the pitch actuator system of a wind turbine in Laplace-domain [1]:

$$\frac{\beta(s)}{\beta_{ref}(s)} = \frac{w_n^2}{s^2 + 2\zeta w_n s + w_n^2} \qquad (5)$$

where $\beta(t) = y_p(t)$ is the pitch angle response and $\beta_{ref}(t)$ is the reference command supplied by the control power management system. Table I gives the parameters' system scenarios [1]. Therefore, the problem statement consists to design a quick fault detection system for a pitch actuator mechanism under the cited faulty stages.

Tabela 1: Parameters for hydraulic pitch system under common faulty scenarios.

Scenario	Parameter w_n (rad/s)	Parameter ζ
No fault (H)	11.11	0.6
High air oil content (F_1)	5.73	0.45
Hydraulic leakage (F_2)	3.42	0.9
Pump wear (F_3)	7.27	0.75

Fault detection and numerical experiments

Just for the fault detection system design, the next actuator system is employed [1]:

$$\dot{\beta}(t) = -a_1\beta(t) + a_2\beta_{ref}(t) \qquad (6)$$

where a_1 and a_2 are the model parameters. The overall fault detection system is shown in Figure 1.

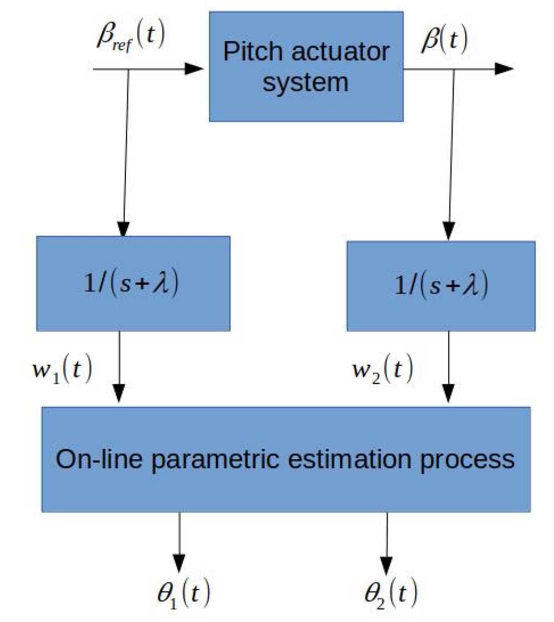

Figura 1: General fault detection system.λ is a design parameter.

Results

By using Proposition 1 and system (6), see details in the paper in the conference's proceeding, the fault detection algorithm in Figure 1 was developed, where:

$$\theta^T(s) = [\theta_1(s) \quad \theta_2(s)] \qquad (7)$$

will converge to $[a_2 \quad (\lambda - a_1)]$ under a persistent excitation of the signal command $\beta_{ref}(t)$. Figure 2 shows the obtained numerical experiment results. This corresponds to a complete simulation for each stage described in Table 1. The system starts at $t = 0$ seconds. Then, at $t = 250$ seconds, a fault is introduced. The three faults are represented and compared with respect to the healthy case. Here, the red, blue and green lines are for the faults F_1, F_2 and F_3, respectively. The yellow line is for the healthy scenario.A quick signal discrimination can be inferred. This is not the case if, for instance, $g_1 = g_2$; which is the standard adaptive scheme.

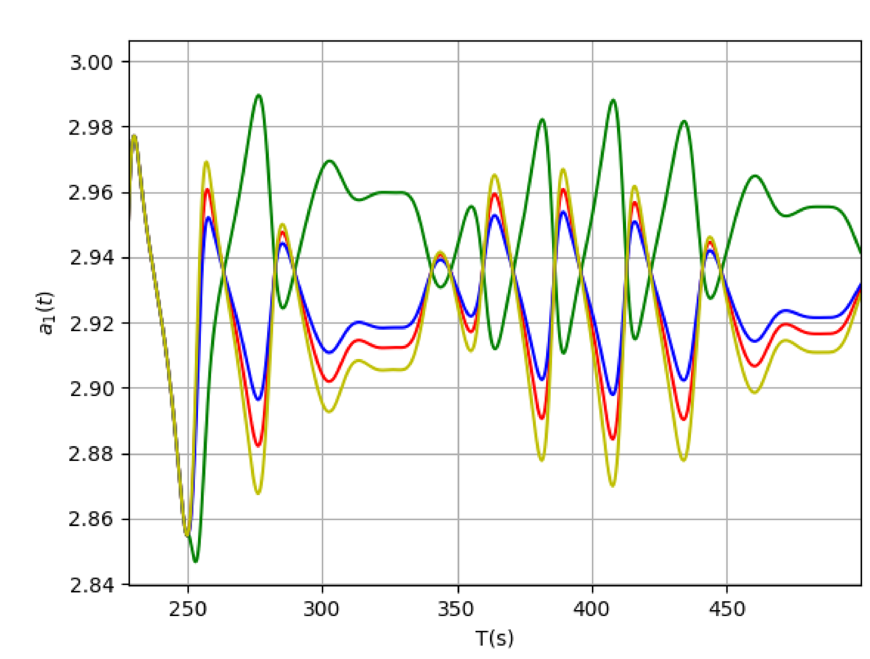

Figura 2: Simulation results for $a_1(t)$: a zoom picture version.

Conclusions

This paper has presented a recent approach on fault detection system to pitch actuators of wind turbines. This approach is based on manipulating the time scales among the actuator system of the wind turbine and the dynamic stages of the adaptive parametric estimation algorithm. Its main advantage is its quick response time.

Acknowledgement

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References

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[2] Shankar Sastry and Marc Bodson. *Adaptive control: stability, convergence and robustness*. Courier Corporation, 2011.