Villez, K, Garcia, H, Rieger, C, Venkatasubramanian, V (2011). Kalman-based fault-tolerant control (FTC) for a pilot-scale cooling loop. Proceedings of the 2011 AIChE Annual meeting, Minneapolis, MN, USA, October 16-21, 2011, 283

Kalman-Based Fault-Tolerant Control (FTC) for a Pilot-Scale Cooling Loop

Wednesday, October 19, 2011: 8:50 AM

101 I (Minneapolis Convention Center)

Kris Villez[1], Humberto Garcia[2], Craig Rieger[2] and Venkat Venkatasubramanian[1], (1)School of Chemical Engineering, Purdue University, West Lafayette, IN, (2)Idaho National Laboratory, Idaho Falls, ID

TITLE:

Kalman-based Fault-Tolerant Control (FTC) for a pilot-scale cooling loop

AUTHORS:

Kris Villez, Humberto Garcia, Craig Rieger and Venkat Venkatasubramanian,

List addresses : Purdue and INL details

ABSTRACT:

We report on the real-life evaluation of a fault-tolerant control strategy for a pilot-scale version of a cooling loop of a nuclear plant [1]. This cooling loop is equipped with two valves, a butterfly valve (BFV) and a glove valve (GLV) which both exhibit substantial hysteresis. This is the result of a coupling of the motor and vane axles design which allows for leeway between the valve motors and valve vanes, thereby leading to a safer valve subsystem. The whole system is used as a study object in the context of resilient system design and control [2].

In order to design a supervisory control system allowing for fault-tolerance, the Fault Detection and Identification (FDI) method from [3] was used as a first component. This method is based on the deployment of the Kalman filter for FDI purposes as proposed earlier in literature [4,5]. The FDI component essentially consists of two steps, namely fault detection and fault identification. The original method allows for a single type of fault only, namely the bias type, though in any actuator or sensor in the studied system. In [3], it was specifically extended to allow for a wider range of faults, such as drift, stuck and sticky faults in both actuators and sensors. With this new method, several types of faults can be identified correctly.

A second component consists of the supervisory controller which enables corrective actions based on the diagnostic result. Whenever a fault is detected, the supervisory controller order the valves to open, leading to maximum cooling capacity, thus enabling the safest of possible operations. Following a fixed waiting time, collected data is used to identify the correct fault (second step of FDI). When that is done, a final action is taken. For a bias or drift fault, the regulatory control system can be corrected by means of a parametric adjustment (e.g. in the corresponding measurement or actuator signal). For other faults, like a stuck fault, one reconfigures the control system so that the remaining working valve is used (only) for flow control. We call this a structural adjustment. In our earlier work [1], we have applied this method successfully in simulation showing that the hybrid behavior (discrete and continuous dynamic behavior) can be handled well in a simulation based study. Indeed, it was shown that several faults could be detected and diagnosed correctly. Figure 1 shows one simulated run in which the first valve gets stuck at 50 seconds in the simulation. Detection follows at 60 seconds and at 80 seconds the fault is identified correctly. Following that, the supervisory controller decides to use the second valve instead of the first one.

With this work, we will report on the real-life implementation of the described supervisory controller. In particular, we expect to answer whether:

- The Kalman filter works well for the valves with hysteresis.
- The FDI strategy allows for successful detection and identification of faults in the real system
- To which extend the supervisory control system allows to mitigate the effect of introduced faults in the valve subsystems such as faults of the bias, drift and stuck type.

REFERENCES

1. Villez, K., Venkatasubramanian, V., Garcia, H., Rieger, C.,"Supervisory control of a pilot-scale cooling loop", submitted to the 4th International Symposium on Resilient Control Systems (ISRCS2011), 2011.

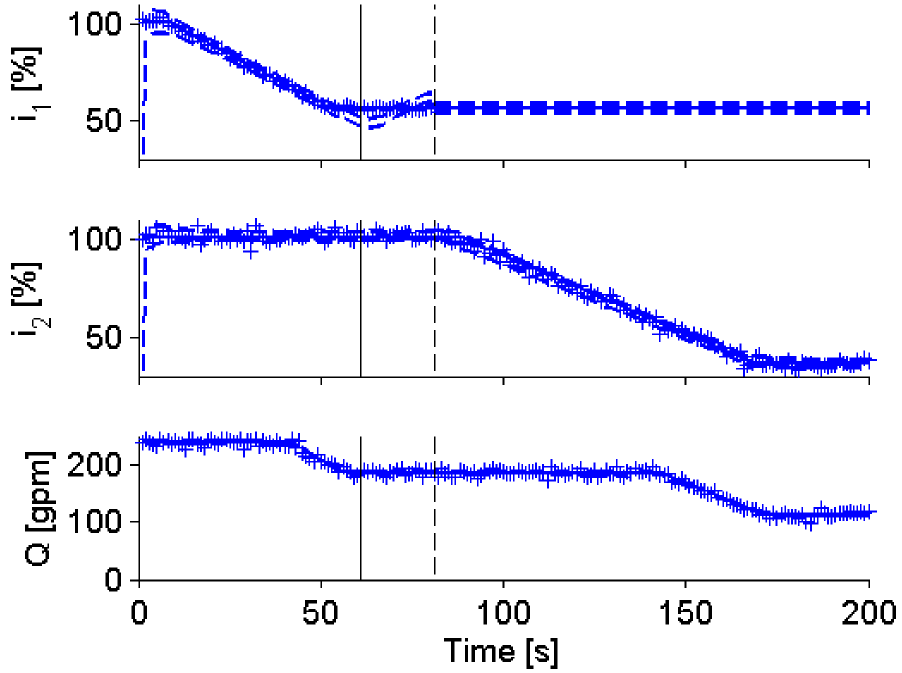
2. Rieger, C. G., Gertman, D. I., and McQueen, M. A., “Resilient control systems: Next generation design research.” In 2nd IEEE Conf. on Human System Interaction, Catania, Italy, May 2009.

3. Villez, K., Srinivasan, B., Rengaswamy, R. and Narasimhan, S., “Kalman-based strategies for Fault Detection and Diagnosis: Extensions and critical evaluation for a simple benchmark system.” Comput. Chem. Eng., 2011, In press.

4. Prakash, J., Narasimhan, S., and Patwardhan, S. C., “Integrating model based fault diagnosis with model predictive control.” Ind. Eng. Chem. Res., 2005, 44 , 4344-4360.

5. Prakash, J., Patwardhan, S. C., and Narasimhan, S., “A supervisory approach to fault-tolerant control of linear multivariable systems.” Ind. Eng. Chem. Res., 2002, 41 , 2270-2281.

Figure 1: Valve 1 stuck scenario. Top: Valve 1 position; Middle: Valve 2 position; Bottom: Flow rate. Valve 1 gets stuck at 50 seconds. This is detected at 60 seconds and identified at 80 seconds. Following that, the second valve is now used instead of the first.



Extended Abstract: File Not Uploaded

See more of this Session: Process Monitoring, Fault Detection, and Diagnosis II
See more of this Group/Topical: Computing and Systems Technology Division