Improving Measurement by Addressing the Sensor Fault Isolation Problem in Control System

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***Abstract*—In many processes, an intelligent system using a development simulation effective for the diagnosis system depends on the sensor fault isolation problem. This work presents a review of using advanced measurement technology relevant to the sensor fault detection field through the implementation of process instrumentations to improve safety and reliability in systems. The system's dynamics change in time as it is affected by multiple functions and nonlinear characteristic measurements. In such an environment, the controllers should adapt on the fly to ensure performance stability. An adaptable development method should be employed to improve measurement in control systems.**

Keywords-sensor fault types; nonlinear characteristic measurement; fault detection and isolation FDI; diagnosis; adaptable method.

I. Introduction

All real systems may encounter malfunctions or defects, which occur in sensors, actuators or the components of the system itself [1]. Abnormalities and component faults are increasingly studied as part of research meant to improve reliability and safety in industrial systems, especially in automatic control systems. Passive faults and active faults based on fault diagnosis can refer to the design and operation of measurement and control [2]. If a characteristic property or parameter of a system changes from the standard condition, the diagnosis system checks some predictable faults such as the blocking of an actuator or the loss of sensor or the disconnection of a system component. A diagnosis decision using previously acquired knowledge from a healthy system is usually made by using observation based methods or parameter estimation techniques. However, some nonlinear characteristics in the system may not be exact or observed in the estimating process. There is a need to require an effective adaptive development method for sensor fault diagnosis. Improving fault measurement via sensor isolation is the main way to achieve an intelligent environment for a diagnosis system as compared to other conventional fault diagnosis procedures that only work with fault tolerant system.

In a dynamic system, the intrinsic parameters of a system will modify the system's dynamic. For the measurement system, inaccurate values of physical variables in the sensor and the environment factors, such as poor or bad environmental conditions, affect to stable configuration structure or cause damage to the stability of the system. For example the bias, the drift or the freezing at low temperature of sensors can lead to seriously unstable configuration or can influence the system structure. These inner unstable characteristics are described by using the function of phenomenological analysis or general basis function, which are observed behaviors of the system. The change in the inputs affects the output and it can be the reason of some otherwise unobserved states in control system.

The step of detecting and measuring these nonlinear characteristics in a system, such as factors for structural damage, is critical towards measuring the quality of a system. Because the characterization of each component or each part in a system is completely different, such as for example random fault-variation of supply voltage, temperature changes or inaccurate instrument reading, the automatic recovery system needs some specific control techniques to improve safety and reliability. The methods for fault detection of these nonlinear characteristics have to operate under the constraint that there is potential inaccuracy in the model, or the model used may not precisely match the situation. The following optimization techniques in [4][7] present the identification of possible improvements of the onboard systems[6].

Improving measurements by sensor fault isolation in a control system to avoid accidents and optimization route is an efficient desired fault detection method to improve a diagnosis system. This work gives an overview of the various ways of measurements to better analyze and design for adaptable development methods. This also combines with modern control theory, provides a development simulation of nonlinear characteristic as a virtual tool for understanding the effects of input noise and time delay on the system operation and tolerance. The diagnosis system then identifies the relationship between fault detection and the allowable delay operations while ensuring a stable system performance. These analysis improvements based on the model free nonlinear control, a well defined controllability observer, provide more for the mathematical basis by multifunction faults in section II. Section III is the application adaptive method for some sensor fault groups. The conclusion will approach to the periodic diagnosis role in the complex system using this method.

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II. MAIN PROBLEM

There are two main aspects to improving detection of when a fault happened in the control system. The first is the sensor fault type which is either open loop or close loop. Understanding the process control loop in the field of instrumentation by open loop- manual mode and close loop-automatic mode determines the solution and decision for the parameter faults involved in the process. The second is the method based on modelling to reflect the control system.

A. Maintaining the sensor fault types

There are different faults in an automatic control system such as sensor faults, actuator faults, component faults or control unit faults. At the same time, there are unknown inputs acting on the system causing disturbances generating system noise in a dynamic system. This paper gives some idea of sensor faults as occurring in the electronic part of an automatic control system working with mission critical aspects and operating in a well defined and protected environment.

Many measurement errors are caused by defects in sensors such as shortcut, offset, bias, power breakdown, sticking, scaling error, hysteresis. Approaching the fault free functioning in the electronic part for measured outputs is discussed as a problem to perfect performance. The open loop system is decomposed into three parts: sensors, actuator and plant dynamics. External system disturbances or process noise affect the dynamic of the plant and FDI needs robust to deal with these uncertainties and remain fault sensitive for diagnosis. Figure 1 presents some type of faults happening in an open loop.

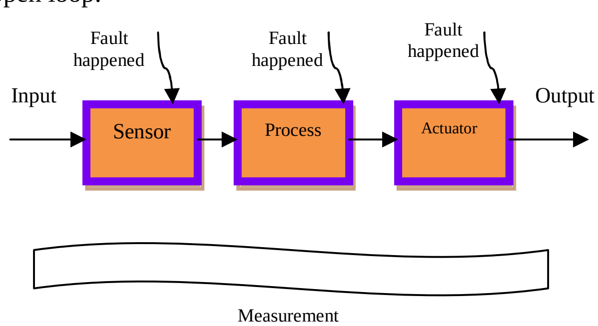

Figure 1. Fault happened in open loop system.

Starting at the input with the fault happening in sensor and then in each part of components in open loop, the diagnosis system uses dynamic switches to check the connection between them for the maintenance mode. Measurement of these faults as active faults or passive faults depends on using the system model. Based on the modeling approach as model based or model free, different FDI techniques are used for the system dynamic. Some technical details are needed in order to deal with the nonlinear characteristic while stabilizing a fault. The sensor fault types are the small and large bias, the slow and fast sensor drift, the freezing at the current sensor location or the oscillatory failure, increased sensor noise, non return to zero, the malfunction as short circuits, heating or erroneous signal conversion from analog to digital, aging, etc [8]. The basic faults detected in sensors are divided in passive faults and active faults. Passive faults are such as small and large bias, the slow and fast sensor drift, non return to zero. Active faults are two groups. The first group is based on the freezing at the current sensor location, oscillatory failure, increasing sensor noise. The second group considers the cause of sensor fault and external influences as the malfunction itself, the malfunction of the sensor heating or the aging for longtime, the erroneous signal conversion from the analog to digital or the influences as temperature or dust. Nonlinear characteristic sensor fault approach in this way is critical to the quality of measuring production processing capability. First, to determine the fault detection method in the operation system, the development adaptation measure is referred. Second, an intelligent control needs a development simulation to find complementary characteristic faults like type of faults, location fault or duration fault for diagnosis system. The reason is these characteristics in each part of the components are completely different from random faults to specific faults. A method implies nonlinear characterization fault detection for operating constraints in process system can be suggested. Based on the measurements obtained at the current and the past operating point, the position of the next operating points with respect to the previous is found by solving a nonlinear optimization problem in its application to the stabilization as a set of points. Regarding the measurement and control methods, this knowledge about the optimization solution is on the use of models for dynamic system. Extending in the system perspective, the plant model mismatch presented the uncertain or the unknown disturbances estimation becomes a solution model nonlinear compensation. This called characteristic structure is intrinsic to a corporation with the potential inaccuracy unobserved.

Another approach is an advance control method for nonlinear optimization based on the control law. It provides an overview of distinction between measure and control system as operating point and set point regulation. In this action, when the computer control is either reliable or prone to errors, the controller software handles using entirely different error and accommodation mechanisms. The stable controller, corresponding to each situation is designed off-line using model predictive control method with the fixed parameter sent to online controller redesign- design control system.

Three mains fault types in this approach are abnormal fault, the regular and the random fault or the control law as normal law, alternate law and direct law. These are called the characteristic structure control outside by law.

A structure of the definition control laws requires the entire process envelope. Since each automation operation of a dynamic system is characterized by the establishment of the operating points, the control system is interested in the dynamic behavior related to the observations. In figure 2, fault happened in a close loop related with the control law programming.

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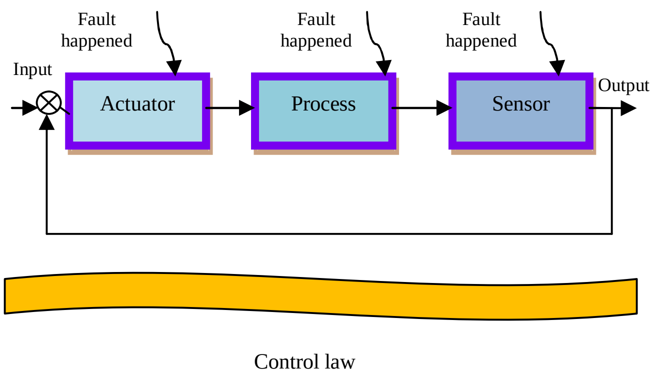

Figure 2. Fault happened in close loop system.

The requirement to reduce isolation faults based on the control method is still the subject of ongoing research. From the point of view of the control system, feedback is used to deal with active faults and adjustments are made to bring the system back in order. In fault detection, the first step is the stabilization assurance. The second step is the operating of threshold and false. The threshold includes the sensitivity to load, speed or noise, repeatability. Isolation fault consist of threshold, false, discrimination and severity. To achieve the best performance in a system, a predicted condition and remaining life need a suitable threshold. Modern control method approaches are to have the output which has characteristic input for detection as the prediction, and dynamic function as dysfunction. Control law provides set points, which are based on the best performance for the robust control system.

Depending on the fault characterization on sensors and control rules, the diagnosis system decides which is the suitable method based on the model based method and model free method. There are many research articles such as signal based fault detection and integration with the model based method fault detection to achieve full control system functionalities [1][4][8]. These can be considered as the combination between the method model based and model free. Each opinion makes some choices and generated somewhat different results. There are a few articles comparing the differences between them and also the application for each particular fault.

B. *Model based and model free method*

Considering the traditional model approaches to system engineering, we have traditionally relied on mathematic models. There are two main approaches: model based approaches and model free approaches. In the system dynamic, methods are model based which is done according to the structure of the model and the existing input-output relationships. Model based fault diagnosis is a fundamental role of fault detection for small faults with determining time, size and cause of fault in a dynamic system operation. Model free is used in real time measurements and process history when model based are unavailable or not useful [3]. The majority of FDI techniques have been designed assuming linearity while the majority of physical processes are strongly nonlinear, so the accurate models of dynamic system are nonlinear. In the model based method, analytical redundancy means to exploit mathematical relations between measured or estimated variables to detect possible dys-functions and should be understood as knowledge based dynamic model [3]. Residual generation uses the model of the system, in which the control inputs sent to the actuators and the system outputs, as measured by the injected sensors predicting the behavior of the system or part of it, comparing between the prediction actions and the actual action. Fault detection computes quantitative indexes of fault presence and the residual. The associated algorithms associate functional and non-functional properties of models to performance benchmarking and optimization. Modern control theory approaches are not only model based but also model free in which the output has a characteristic prediction of the input for fault detection. Model free is used when there is no explicit dynamical model of the control system, and it actually uses the redundancy and correlations of the data in a hidden manner. It exploits measurements acquired in real time, or available in a previously constructed database, such as using the behavioral signal model. The idea of this work is the residual generation which indices the fault presences, fault isolation problem changes into an appearance sensor fault. It integrates a characteristic prediction function in the passive fault situation via hidden data related with time delay and noise operation in the system. These sensors work as a real time measurement and process history data independent of the control system. The meaning is that a control based mechanism replaces measurements from a sensor in passive fault to ensure stable performance as per an adaptive model.

III. APPLICATION ADAPTABLE METHOD

Some methods approach to diagnosing fault system are divided into four groups. Group 1 and group 2 are following an obtained model method. Group 3 is the connection from the choice of group 1 and 2 to achieve suitable characterization threshold for structure state. Group 4 shows the combination for adaptable method as automatic tool for the supervision.

A. *Application model based for sensor in group 1*

Fault detection relies on the analytical redundancy principle using an accurate model of the system to mimic the real process behavior. If a fault occurs, the residual signal can be used to diagnose and isolate the malfunction such as a set point. In the case of noisy measurement, the identification technique gives the variances of the input-output noise signals. Fault detection by multi set points is based on the history data for the ability of time delay and noise operation as full control functionalities system. To analyze the

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diagnosis effectiveness of the FDI system in the presence of abrupt changes or drift in measurements, fault modeled by step or ramp functions have been generated, indicate that the minimal detectable faults on the various process is a parameter of interest for industrial diagnosis applications. Comparisons between values of working parameters obtained in the simulation and measurement can make it possible to predict and design. Small and large bias, the slow and fast sensor drift, non return to zero are caused by the freezing at the current sensor location, and is considered as the malfunction of the sensor heating or the aging for longtime. Multi set points as multi malfunction sensor propose the technical layers are applied model based method [2][3][5].

B. Application model free for sensor in group 2

The dynamic nonlinear model has been developed by dividing the dynamic operation of the machine into elementary model by means thermodynamic and mechanic links. Reconfigure system from the different methods by the predicted suitable method. When uncertainties are caused by modeling errors, linearization errors, parameter variations, etc, such a disturbance decoupling approach cannot be directly applied, an approach suggests an exploiting estimated distribution matrices. From the group 1, group 2 continues with the adaptive method to observe the behavior in the system as model free in the operating system [1][2][5].

C. Equation relationship between them in structure state equation

Characterization applies to suitable threshold prediction as nonlinear characteristic to improve the safety and reliability in system from the structure state equations. The full nonlinear control applied to the positioning and orientation problem is assessed and adapted to the expected performances. Following the free model based, structure state equation change to the positioning and orientation relationship equations [1][2][8]. This promising method to solve the FDI problem consists of using an accurate model of the system to mimic the real process behavior by covering the difference between real system and model behaviors rather than the corporation with the potential inaccuracy of the model or model mismatch in parameter identifications.

D. Adaptive method for improving measurement

The way to ensure stability performance in the system becomes a step in the control based mechanism [5][9], related to the time delay and noise operations, the dysfunction for the stabilization and observation is applied to sensor fault isolation problem. Time delay and noise operation become the condition environment as a standard to adaptive method for improving measurement. The application includes automatic supervision of close loop operation as early as possible.

IV. CONCLUSION

An adaptable development method following this way can improve the measurement in control system. It shows that sensor fault isolation in control systems achieves the robust system by controlling passive faults and active faults. The material in sensor problem relates to the design of control structure allowing established autonomous position and orientation characterization. Coating material combines specific requirements towards the best available solution. Selecting the variety and technical guidance applied to the sensor fault isolation problem achieves the required standard structure. Future works will study the detail of the relationship between switch dynamics with the role sensor in the tolerance fault for the actuators. Finally, this justifies the periodic diagnosis point in complex dynamic system by securing the self-control problem.

REFERENCES

[1] S.Simani, C. Fantuzzi and R. J. Patton ‘’Model based fault diagnosis in dynamic systems using identification techniques’’, Springer, 2003, pp. 2-28.

[2] R. Isermann, ‘’Fault diagnosis systems- An introduction from fault detection to fault tolerance’’, Springer, 2006, pp. 15-25.

[3] L. Fernandez and J. Luis, ‘’Fault detection for nonlinear systems: a new approche’’, thesis unpublished, pp. 8-20.

[4] P. Goupil, ‘’Fault diagnosis and fault tolerant control and guidance for aerospace vehicles’’, Springer, 2014, pp. 2-18.

[5] T.N. Thai, ‘’ Characteristic matrix faults for flight control system’’, ICMMS, 2014, pp. 1-4.

[6] S. Chatty, S. Convesy, H. Gaspard and J.L. Vinot, ‘’The accident of flight 447 Rio-Paris: a case study for HCI research’’, Hal, 2009, pp1-4.

[7] O. T. Pleter, C.E. Constantinescu and B.I.Jakab, ‘’Reconstructing the Malaysian 370 Flight trajectory by optimal search’’, Journal of navigation, 2016, pp. 4-8.

[8] D. Ossmann, H.D. Joos and P.Goupil ‘’Enhanced sensor monitoring to maintain optimal aircraft handling in case of faults’’, Journal of guidance control and dynamics, 2017, pp. 1-5.

[9] T.D. Nguyen, ‘’ A conceptual approach to the problem of action angle variables’’, ARMA, August 2018, Volume 229, Issue 2, pp. 789-794.

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