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A Survey on Fault Diagnosis-Its Approaches and Applications in Diverse Processes

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ABSTRACT: A wide spread appraisal and study of the works on diverse approaches to fault diagnosis is obtainable with distinct prominence on the chores of detection, isolation and identification. An amount of recognized procedures contained by each methodology are auxiliary revealed, and their corresponding benefits and shortcomings are emphasized. This paper evaluates the up-to-date methods implemented for the diagnosis of faults in different schemes. It also takes into interpretation the restrictions of the ancient techniques like limit checking. The model-based means of parameter estimation, parity space and other such approaches are also deliberated. This paper analyses the elementary conceptions early from its beginning onto the advanced aspects involved in fault diagnosis.

KEYWORDS: Detection, Isolation, Identification, Limit Checking, Parity Space, Parameter estimation.

I. INTRODUCTION

Contemporary industrialized practices necessitate intellectual and multifaceted preparation of diverse kinds of controllers, actuators and sensors. This is done essentially, to interpret the offset of parameter deviations and disturbances, happening within. While, the controllers are sound enough of matching several variations, they are ineffective, when it move towards to quashing the consequences, taken around in the system. The faults upsetting the system noticeable in one of the sub sequent practices: difficulties accompanying the actuator, deviations in process parameters and conflicts at different ends in a system and measurements recorded over the sensor.

II. RELATED WORK

A fault is defined as a kind of breakdown in the dynamic system, but fault detection aids to identify a fault which has happened; fault diagnosis enables finding the cause, nature and location of fault. Early detection and diagnosis of faults existing in the plants can lessen the downtime, equipment safety and accordingly results in fiscalaction by getting down the manufacturerate [1] [2].

This manuscript springs a bird's eye vision of diverse improvements completed so far in the ground of fault diagnosis. It deliberates the different performances hired for the diagnosis of faults happening in the system. At the onset, there is a transitory depiction of the justification behind the study of fault diagnosis. Succeeding segments deal with the diverseparts of fault diagnosis.

III. FAULT DIAGNOSIS SYSTEM

A system that combines the competences of detection, isolation and identification or classification of faults is designated as a fault diagnosis system. All real-world systems reveal a shared hostile feature - they are subjected to faults, breakdowns at certain point of spell during the operation and consequently, portray abrupt means of behavior. This reasonably validates the necessity of consistent and nonstop monitoring systems that employ effective fault-

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management of fault-diagnosis approaches. This elucidates the significant role that fault diagnosis shows in the maneuver of operational and effectual control systems [3] [4]. Fault Diagnosis System is shown in Fig.1.

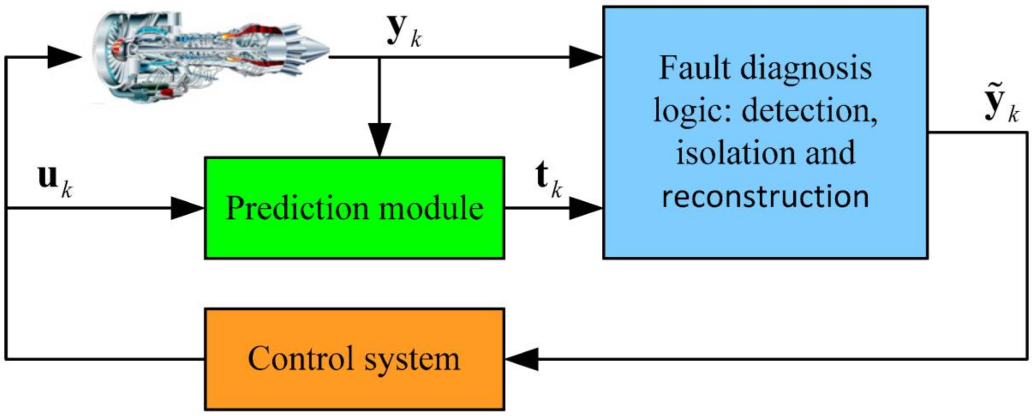

Fig.1.Faults Diagnosis System.

IV. FAULT CLASSIFICATION

Faults are categorized on the origin of location and on the basis of individual behavior.

A. BASED ON LOCATION

These faults denote the partial or total loss of the system function. Alternatively, these are perceived as any fault in the system that actuates the system e.g. a breakdown of the pneumatic system in a plant. In a plant, actuator symbolizes the final control element that gets activated, due to a breakdown and can drive the entire system into a state of fault. These faults are said to happen when certain changes brought about in the system force it to an invalid dynamic relation amongst its diverse physical variables. These can be pictured as certainsevere variations in the measurements made in the system and appear in the practice of divergences between the actual and measured values of process variables [1].

B. BASED ON BEHAVIOR

(i)Abrupt fault: This fault happens owing to quick variation in the values of variables. Normally, a variable value remains constant throughout the operation of the plant. But on the existence of fault, this value quickly assumes a new magnitude. Accordingly, the system state is altered.

(ii)Incipient fault: This fault varies steadily and gradually progresses to an extremely large value. If a component is degrading in operation, this is witnessed as an incipient fault.

(iii)Intermittent fault: A fault is intermittent if it occurs and then suddenly vanishes and this process continues to happen in a repeated manner, over a period of time.

For retaining healthy system operation, it becomes essential to isolate the fault as early as possible [3].

V. FAULT DETECTION METHODS

Over fault detection significant data is derived in the form of signal values from fault, process and signal models, based on the diverse techniques that can be perpetually be applied on a plant experiencing varied processes.

A. ***PARITY SPACE METHOD***

This model-based approach depends ona test that is conducted to authenticate the reliability of the parity equations which are system equations altered using the measured signals of the specified process. This is done in order to enable the decoupling of the residuals from the system as well as faults so that they could be easily distinguished from each

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other. The discrepancy rising in the parity equations gives rise to residuals that further helps to sense the faults to which the residuals observed are in closer proximity [5].

B. ***GENERATION OF RESIDUALS***

The value of these residuals is usually zero under no-fault conditions. They accomplish non-zero values only under the effect of noise and model errors. In case, the faults are originated in the system, the residuals attain high values. This needs the making of thresholds and involves that residuals be tested against them [6].

C. ***STATE OBSERVERS***

This approach attempts to restructure the system using input and output signals of the system with the help of observers. The difference between parameters measured from the system and those estimated serve as residual vector. This technique of residual generation relies on restructuring the system outputs using observers or Kalman filters. A diagnostic observer in the form of output observer is intended in the frequency domain, which does not necessitate the application of state-space concept. The objective behind the proposal of such observers for residual generation is modified residuals or directed vectors in a manner that each fault assumes a different direction. This aids in decoupling of each fault. Each observer is made robust to the effect of unknown inputs (read fault) and is capable of handling proficiently a certain type of fault [5].

D. ***LIMIT CHECKING***

This is a traditional technique concerning the measurement of output variable. This technique attempts to put a ceiling on the values of output variables to ensure that these lie within preset limits, known as thresholds. There are two maximum and minimum values, between the ranges of which, the output is anticipated to remain for the healthy flow of process. For monitoring the process development, the derivatives of the change in output with reverence to a suitable variable, normally chosen as time are checked for limits. For early fault detection, signal prediction is done using polynomial regression and least square methods. This aids in early detection of threshold crossing and averts the generation of false alarms. This classical limit-value technique is useful in the detection process only when the variation in the process variable is significantly large. This commonly happens either in anevent of large sudden fault or continuous gradual-increasing fault. A severe problem enforced by this method is the concurrent triggering of alarms, causing atotal confusion associated with the basis of the fault [3].

E. ***STATE ESTIMATION***

The method of state estimation involves either giving class labels or drawing real-valued description in terms of parameters for time or space-varying processes. The states estimated from the system are then calculated against those attained from the model to finally generate the residuals [7].

F. ***ADAPTIVE FILTERING TECHNIQUE***

This technique is appropriate to discrete-time linear stochastic systems and takes into account the abrupt jumps in the values of state variables that are used to model the system behaviour. The projected system comprises of a Kalman-Bucy filter, capable of sensing a jump in the state variables and based on generalized likelihood ratio (GLR) hypothesis testing. This filter adjust itself to jump detections in the following three ways: (i) the value of state estimates areamplified using parameter estimates, (ii) covariance of the estimation error can also be increased using GLR testing data and modify the Kalman filter to the new position of jump and (iii) both error covariance and estimates could be used for adjusting the value of the Kalman-Bucy filter. This method is found to be beneficial in the failure detection applications [8].

G. ***PARAMETER ESTIMATION***

This method assumes that the faults manifest themselves in the form of physical parameters such as resistance, capacitance, inductance, friction, mass, damping force etc. These parameters are simultaneously being monitored, estimated on-line by retaining diverse estimation techniques and consequently the results are matched with parameters of the fault-free reference model. Any discrepancy inrevealing the process change and henceforth a fault is said to be occurred. The procedure for process estimation comprises estimating the mathematical parameters and their succeeding

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transformation into the physical parameters [8]. A verge over its counterparts, it produces the amount of deviation from the normal or fault-free conditions. Its constraint lies in constant updates of parameters for calculation of estimates. It is supposed to be one of the most dominant means of instigating the FDI approach.

H. *AUXILIARY SIGNAL FAULT DETECTION*

In recent times, a new description of 'active' systems has developed, which is different from the conventionally used term 'active' that infers those taking action for accommodating the faults in a system. Such systems are in close interaction with the system by making use of a test signal, which benefits to undo the abnormal performance of the system. For excitation, a tests signal called auxiliary signal is introduced into the system, either at repetitive intervals or when safety of the system appears to be critical [1].

VI. FAULT ISOLATION

Fault isolation comes into effect once the fault is detected in the system with the cause of finding the type and location of the fault. In case, where there are diverse fault modes, fault isolation indicates the decision making process, related with indicating under which fault mode the process is being determined. Fault isolation is recognized by cautious assessment of non-zero residuals with pre-computed fault vectors. For fault to be isolated from the system residuals generated in system should be fault-sensitive and they ought to react contrarily dependent on the type of fault. In other words, they should be capable of distinguishing among diverse kinds of faults. Following two approaches are used for fault isolation:

1) Directional Residual Method: Here residual vectors are generated along a specific direction in the residual space conferring to a certain fault kind. Here the problem of fault isolation is re-shaped into a problem of launching the direction of residual vector.

2) Structured Residual Method: Here the vectored residuals are categorized such that they are sensitive to a single fault or to a class of similar faults for which the residuals perceived are in closer proximity and insensitive to others. Any two faults devising nearly same fault behavior may not be isolated from each other. Every fault isolation approach should take into account and appropriately weigh all the permutations and combinations of the different errors before arriving at a decisive conclusion [9]. Fault with Model is shown in Fig.2.

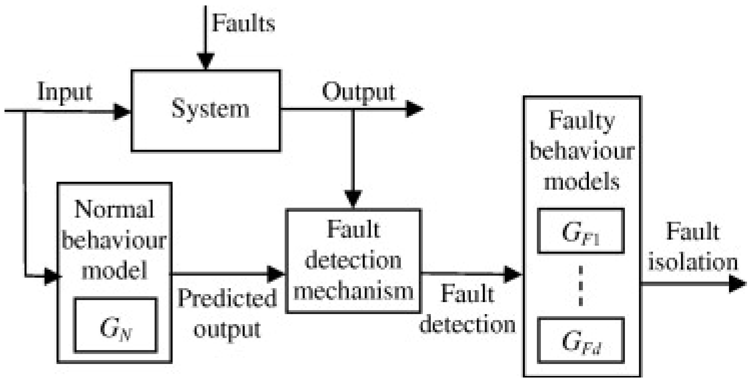

Fig. 2. Fault with Model.

VII. FAULT DIAGNOSIS FOR VARIOUS PROCESSES

In a paper [11] of neural network based methodology for fault detection in pneumatic actuator is presented. The data essential for the progress of neural network model have been attained through the DABLIB of the system considered. Totally 19 faults in pneumatic actuator were considered in the established model. A main issue in neural network based approach is pinpointing a descriptive set of features from which to develop the network for a particular

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assignment. Based on the outcomes acquired, the performance of the neural network model is considerably upgraded by decreasing the input facets.

Effectiveness of the projected system has been verified through different fault detection in the pneumatic actuator. With the proposed feature extraction system, a precise ANN models is developed in a short period of time for any type of actuator systems. The same models can be extended to any technical systems by considering suitable parameters and the faults. Industrial applications of the proposed scheme will afford path for wide execution.

In this article [12] a neural network set up with hybrid adaptive controller for robot manipulators are projected. The controller uses an ANFIS and back propagation based artificial neural network. Each network has two stages which are learning stages and detection stages. The proposed scheme produces a feed forward signal which adapts to changes in the payload and other operating parameters. In accordance to the simulation results the proposed system is at ease to manipulate and have a better performance after failure on one of its joints, also notable characteristics for the application of fault tolerance. To show the viability and performance of the proposed control system, it has been tested on the model of a PUMA-560 robot, with a gear ratio of 30.

Three dedicated observers [13] are designed using multiple adaptive neuro-fuzzy inference system by fixing the optimal shape and parameters of the membership functions and effective rule base by neural networks to estimate the normal velocity, pitch rate and pitch attitude of a satellite launcher. From the study implemented it has been observed that the system has detected failures within 0.03 seconds in any sensor if it happens. The sensor that failed is correctly recognized through the reporting of fault alarms. The control law is revisedconsequently and the pitch attitude is retained at the desired value even in the failure conditions. No missed alarm and false alarm are reported. Since the effect of change in system parameters and noises on estimation are not considered in this work, advance work is recommended to progress the performance of the estimators so that no false alarms are reported in such environments as well.

In the study [15] of MMALKF (Multi Model Adaptive Linear Kalman Filter) approach that includes adaptive gain scheduling algorithm along with the multiple linear kalman filters to detect and isolate multiple sensor and actuator faults which occurs successively and concurrently. The efficiency of the proposed approach was tested through extensive simulation on spherical process. The MMALKF used to develop a nonlinear model based FDI scheme for faults and fault tolerant control schemes. The proposed MMALKF performs better even in the presence of considerable amount of plant-model mismatch.

The paper [16] presents the different facets of fault diagnosis through the study of a three-tank CSTR, which depicts the alkaline hydrolysis of ethyl acetate in the presence of sodium hydroxide. The development of the reaction has been monitored using real-time data, under the effect of different operating conditions. The projected work recognizes the faults at the same instant. Hence it is capable of handling the detection of faults instantly. The future work shall emphasis on shrinking these faults by adopting controllers or probably through artificial intelligence techniques.

In this paper, [17] a model-free approach to the fault diagnosis problem was givenbuilt on a mixture of diverse learning stratagems like ANN, adaptive neuro-fuzzy and ANFIS. This model-free approach identifies a presence of a possible fault from the profiles of the sensor outputs. Changes in the fault signatures such as settling time and the steady-state value, give a quick indication that a fault may be in the making. An abrupt change in the sensor output profile indicates a probablestart of a fault. As such, this model-free approach can be made an effective part of an overall integrated approach that tackles both fault detection and isolation where the isolation part would be moved to an additional section using a model-based approach.

A fuzzy based expert system [14] is proposed for fault diagnosis for two tank system tosensors with the aid of dedicated Kalman filter. The FD is designed based on model with coolant flow and feed water flow as inputs. Concentration, temperature are the outputs. The deviation in the output is very low as the estimators are very accurate. The estimator state and the actual state variable are compared to form the residuals which are evaluated for the fault

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detection and Identification. The proposed expert scheme isolate the fault at the very same instant of its occurrence showing its capability of instantaneous handling of sensors fault in addictive and multiplicative nature.

VIII. CONCLUSION

From the perception of fault diagnosis, diverse methodologies have been deliberated. The different approachesoffered in this paper reflect the type and deepness of research done so far in this field. In this paper, the problem of Fault Detection, Isolation and Identification (FDII) in different systems was demarcated and formulated.

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