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Alternative soft fault model of the cross-coupling effect correlated at hydroelectric power energy system

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ABSTRACT

The next article describes the application of an alternative soft fault model strategy considering the cross-coupling effect analyse at the structural architecture for hydroelectric power system generator.

The scheme is based on the Fuzzy Recursive Decision Feedback Extension (RDFE) tested and verify on a non-linear hydroelectric power system model obtained by a real system.

The Timing, Sequencing and Priority Strategy are improved inserting Fuzzy Time Series (FTS) to model a Fuzzy soft fault model for the Scheme proposed.

A case of Successful application is explained considering the development of an experiment in the laboratory of the Group of Power traction, quality and generation of power systems in the Puebla Autonomous University.

1. Introduction

New industrial processes are evolution in terms of novel requirements trying to be accomplished. Interoperability, Open and Dynamic structures and Fault tolerance characteristics are some of them [1].

In the environment of fault tolerance concept, it is desirable to reduce the effects of bad decision in the scheduling of activities/resources and to make good decision (adaptability) when one or more resources in the process fail [15].

In many application areas in which a malfunction of the system can cause significant losses or even endanger the structural environment or human management, a fault analysis scheme is preliminary to evaluate the performance and it can have the ability to anticipate possible faults in the process [2].

Examples of such areas are in transport, process control and instrumentation with devices or in this particular proposition, in the power generation systems. These type of industrial systems, which are used in such or similar application areas are expected to exhibit always an acceptable behaviour. However the peculiar dynamic of these systems are often referred to as dependability (i.e. redundance and/or multivariable coupling). This is the reason because any departure from the acceptable behaviour is considered a system *failure*. Failures are caused by faults, which can arise in different phases of the production system lifecycle [3].

Most of the techniques which have been formulated for fault analysis are targeted concerning to hardwired systems and those are not similar that the characteristics of software. A crucial difference between hardware and software system is that a program can neither break nor wear-out. Software faults can always be traced back to mistakes, which have been made during software specification, design or implementation [4].

To detect and recover the faults, the software can be verified and validated against the requirements specification (model). The weakest point of this procedure is the requirements specification. Any fault or ambiguity in the specification can result in a fault in the process implementation. Fault anticipation is another approach to increase process reliability [14].

Most of the measures applied throughout the development process attempt to make the development more strict and formal. Nevertheless It can originated in a uncertainty deviation for the process because of adding rigor and stiffness starting from the very

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beginning, i.e. from developing a formal requirements specification which defines the space of all behaviours, which can be exhibited by the software delays decision, hard recognition and lost of agility.

In the next step the unacceptable, e.g. hazardous, performances can be recognised and defined in terms of the same formalism but requiring non-rigorous model. Finally, one can check whether an unacceptable behaviour can be deduced from the residual specification, which can be modified, and the analysis repeated with lax behaviour.

A special case arises, when the formal model, which underlies a software specification, is discrete considering the possibility to apply soft computing model, in such a case the space of all behaviours is discrete, and a definition of an unacceptable behaviour can be reduced to a definition of unacceptable states. The evaluation of the software behaviour can be conducted as verification whether or not such states belong to the state space of the specification.

Therefore, this article addresses the application of an alternative form to evaluate the non-deterministic state space model converted into a soft fault model scheme describe this lax performance with the Recursive Feedback Decision Extension (RDFE) by FTS method. In the next section, Theory analysis is described to support the interconnection between the intelligent fault diagnosis and the soft fault modelling remarking the particular contribution for several authors. Section 3 lets to observe the alternative method proposed. The case of application is performed in Section 4 with the discussion of the graphical results obtained in the use of Matlab and Simulink Platform as a Simulator tool. The last Section 5 is devoted for the Section 5.

2. Background of concepts

2.1. Intelligent fault diagnosis

Actual industrial processes must accomplish the new requirement by high performance characteristics. Interoperability, Open and Dynamic structures and Fault tolerance characteristics are examples of these requirements, described by Shen and Norrie in [1].

The fault tolerance concept, consider as desirable to reduce the effects of bad decision in the scheduling of activities/resources and to make good decision (adaptability) when one or more resources in the process fails.

In many applications, in the particular case of hydro-plant industry, a malfunction of the system can cause significant losses or even cause danger to the structural and functional environment or human interaction. Reason because of the fault analysis model is required to evaluate the performance and can anticipate possible faults in the process [2]. Examples of such areas are in transport of material, process control and instrumentation with devices apply in the control energy production process [13].

The energy systems are expected to exhibit always an acceptable behaviour considering a parametrical production functional goal. This property of a system is often referred to as a novel concept denoted as dependability. Any departure from the acceptable behaviour is considered a system failure. Failures are caused by faults, which can arise in different phases of the conversion energy system lifecycle [3].

By definition, a fault represents an unexpected change of system function, although it may not represent a physical failure. The term failure indicates a serious breakdown of a system component or function that leads to a significantly deviated behaviour of the whole system. The term fault rather indicates a malfunction that does not affect significantly the normal behaviour of the system [4].

An incipient (soft) fault represents a small and often slowly developing continuous fault. Its effects on the system are in the beginning almost unnoticeable. A fault is called hard or abrupt if its effects on the system are larger and bring the system very close to the limit of acceptable behaviour. A fault is called intermittent if its effects on the system are hidden for discontinuous periods of time. Although a fault is tolerable at the moment it occurs, it must be diagnosed as early as possible as it may lead to serious consequences in time [5].

A fault diagnosis system is a monitoring system that is used to detect faults and diagnose their location and significance in a system. The system performs the following tasks:

(1) Fault detection – to indicate if a fault occurred or not in the system.
(2) Fault isolation – to determine the location of the fault.
(3) Fault identification – to estimate the size and nature of the fault.

The first two tasks of the system – fault detection and isolation – are considered the most important. Fault diagnosis is then very often considered as Fault Detection and Isolation (FDI). A fault-tolerant control system is a controlled system that continues to operate acceptably following faults in the system or in the controller. An important feature of such a system is automatic reconfiguration, once a malfunction is detected and isolated. Fault diagnosis contribution to such a fault-tolerant control system is detection and isolation of faults in order to decide how to perform reconfiguration [6,12].

2.2. Diagnosis based on analytical models

The model based fault diagnosis can be defined as the determination of the faults in a system by comparing available system measurements with a priori information represented by the system's analytical/mathematical model, through generation of residuals quantities and their analyses [6,8]. Lakhmi and Cassandras can be reviewed to determine several methods to describe the structural and functional dynamic of different type of process and in this particular case, the logical dynamic for each part of a hydro-plant (see Table 1).

When an analytical model is used to represent any system under diagnosis is that it cannot perfectly model uncertainties due to disturbances and noise. The differences provoked by the non-complete description of the model, cause the residual values, which are instruments to indicate faults. By Vasile [5] and Lakhmi [6], a robust FDI scheme represents a FDI scheme that provides satisfactory sensitivity to faults, while being robust (insensitive or even invariant) to modelling uncertainties.

The principal challenge in designing a robust FDI scheme is to make it able to diagnose incipient faults. The effects of an incipient fault on a system are almost unnoticeable in the beginning, thus effects of uncertainties on the system could hide these small effects.

Table 1
Improved RDFE algorithm.

```
PORT>>Get [P1(t), P2(t), P3(t), P4(t)] for each machine (i)
Z [P1(t), P2(t) P3(t), P4(t)] = [P1(k), P2(k), P3(k), P4(k)]
Fuzzyfing [P1(k), P2(k), P3(k), P4(k)]
For i, j = 1 to k (data number)
    A(uij) = B(1) (f1j(u), f2j(u), f3j(u), f4j(u));
    Intell_Sch = Max [Min [B(f1j)(f1j(u1)) ,B(f2j)(f2j(u1)),
    B(f3j)(f3j(u1)), B(f4j)(f4j(ui))]];
    PORT <<FF (Mesch);
End
```