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·OWLEDGE-BASED SYSTEM FOR FAULT DETECTION
Ↄ DIAGNOSIS IN INDUSTRIAL CONTROL SYSTEMS

BY

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TO MY PARENTS & WIFE

بسم الله الرحمن الرحيم

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering.

The work included in this thesis was carried out by the author in the Department of Computer and Systems Engineering, Ain Shams University, from December 1990 to April 1993.

No part of this thesis has been submitted for a degree or qualification at any other university or institution.

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ABSTRACT

During a process control system operation, some fault may occur in some component in the overall system which may lead to dangerous results (e.g. a nuclear reactor) or loss of the operating conditions that may take a large time to be recovered. So, a fault detection and diagnosis system, which early detects, identifies, and evaluates the fault and may give advisory action to the process operator to isolate such fault before its effect increases before recovery, is needed.

A survey on the existing techniques for fault detection and diagnosis is made. A new methodology for fault detection and diagnosis (FDD) in industrial control systems is suggested and applied through the thesis where, a Knowledge_Based System for FDD is made which consists of three stages. The first stage is fault free control system modelling using a new proposed modelling methodology that is Modelling with Uncertain parameters and Incomplete Knowledge (MUPIK). The second stage is fault detection through comparing the actual control system status with its status predicted by MUPIK. The third stage is Adaptive Knowledge-Based Diagnostic System . The diagnostic system gives the operator list of the different possible faults each with a corresponding Confidence factor using inference through a rule-base for the control system. The diagnostic system presents to the operator the following facilities: explanation of the diagnosis, advisory actions, ability to add or modify the

rule base and some parameters of the system used during MUPIK, and others.

The proposed technique is formulated within the (KADS) Approach to modelling a Knowledge-Based System where a conceptual and design models are made. The suggested FDD technique was tested by being applied to computer models of a simple hypothetical control system and a complex control system of the Binary Distillation Column where the occurrence of some faults have been simulated. The suggested FDD technique was able to detect and diagnose the faults simulated to occur in both control systems.

SYMBOLS AND ABBREVIATIONS

Symbols:

A : Continuous state space form coefficient matrix of the state vector.

B : Bottom product flow rate in the distillation column in lb-mole/hr.

C : Continuous state space form coefficient matrix of the state vector in the output equation.

C_p : Heat capacity.

C_v : Valve constant.

D : Distillate flow rate in the distillation column in lb-mole/hr.

E : Continuous state space form coefficient matrix of the input vector.

e : Error signal in a control system.

$\underline{e}$: Measurements error vector.

F : Feed flow to the distillation column in lb-mole/hr.

h_l : Liquid enthalpy in BTU/lb-mole.

δh_l : Liquid enthalpy change.

$\underline{h}_l$: Vector of liquid enthalpia on every tray in the distillation column

H : Holdup in the condenser drum in lb-mole.

H_v : Vapor enthalpy in BTU/lb-mole.

δH_v : Vapor enthalpy change.

$\underline{H}_v$: Vector of vapor enthalpia on every tray in the distillation column

I : Current in mA.

K : Static gain.

K1 : Minimum value of the static gain range.

K2 : Maximum value of the static gain range.

$\bar{K}$: The nominal value of the static gain.

k : Number of the sampling period.

L_i : The liquid flow rate effluent from the tray(i) in the distillation column in lb-mole/hr.

$\underline{L}$: Vector of the liquid flow rates effluent from the trays.

N : The number of trays in the distillation column.

n : The number of delay samples.

P : Pressure in N/m

P_k : Percentage of the static gain uncertainty.

q : The leakage heat flow rate from the distillation column base in BTU/hr.

Q_i : Heat flow rate input to the column base. (Reboiler heat duty).

R : Reflux ratio.

R_r : Required reflux ratio.

Rrfx : Required reflux value.

r : A set point to a controller in percentage.

rfx : Reflux flow rate in lb-mole/hr.

T : Sampling period.

T_f : Feed flow temperature in C.

Tm : A temperature in C.

$\underline{Tm}$: Vector of temperature at each tray in the distillation column.

u	: A module's input.
$\bar{u}$	: The nominal value of (u).
$\hat{u}$	: Incremental value of (u).
$\underline{u}$	: Vector of a system inputs.
V_i	: The vapor flow rate rising up from the tray(i) in the distillation column in lb-mole/hr.
$\underline{V}$	: Vector of the vapor flow rates rising up from the trays.
X	: Input/output matrix that is used in process parameters estimation.
Xd	: Distillate concentration.
X_i	: The concentration of the more volatile component in liquid effluent from tray (i) in the distillation column
X_f	: The concentration of the feed flow to the distillation column.
X_v	: The vector of concentration of the more volatile component in liquid effluent from each tray
$\hat{X}$	: The estimated state vector.
y	: A module's output.
$\hat{y}$	: Incremental value of (y).
$\bar{y}$	: nominal value of (y).
y_i	: The concentration of the more volatile component in vapor rising up from tray (i) in the distillation column
$\underline{Y}_v$	: The vector of concentration of the more volatile component in vapor rising up from each try.
$\tilde{y}$	: Residual output vector.

τ_2 : Time constant.

τ_d : Dead time.

α : Firing angle.

ϕ : Discrete state space form coefficient matrix of the state vector.

Γ : Discrete state space form coefficient matrix of the input vector.

β : Measurements vector used in the process parameters estimation.

$\underline{\theta}$: The process parameters vector.

$\hat{\underline{\theta}}$: Estimated parameters vector.

ξ : Feedback gain matrix of the state variables.

ψ : Total number of modules.

ω : Total number of rules in a module.

Σ : Total number of components in a module.

Abbreviations:

CC : Concentration controller.

C.ct. : Conditioning circuit.

Cf : Confidence factor.

CT : Concentration transmitter.

DEC : Decrement.

DIFF : Differentiation.

DPT : Differential pressure transmitter.

FC : Flow controller.

FDD	: Fault detection and diagnosis.
Finval	: Final value a module's output aims to reach.
FT	: Flow transmitter.
GLSE	: Generalized least squares estimation method.
IQ	: Incremental quantity.
INC	: Increment.
INTEG	: Integration.
I/P	: Current to pressure converter.
JC	: Power controller.
KBS	: Knowledge-Based system.
LSE	: Least squares estimation method.
Maxval	: Maximum value a module's output aims to reach.
Minval	: Minimum value a module's output aims to reach.
MSLS	: Multi-stage least squares estimation method.
MUPIK	: Modelling with uncertain parameters and incomplete knowledge.
Op	: A module's output.
Op_{prev}	: A module's output in the previous sampling period.
QS	: Qualitative state.
qval	: Qualitative value.
TC	: Temperature controller.
TT	: Temperature transducers.

LIST OF FIGURES