An Application on an Alarm Root Cause Tracking System (ACTS)

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Introduction

Conventional alarm systems in nuclear power plants

- based on 'one sensor - one indicator' design
  - no processing of alarm signals and hardwired display
- cause Alarm Avalanche during plant upset
- increase Operator's Cognitive Workload
  - leading human error at transients

Utility Need for urgent improvement (EPRI NP-6839) – most cost effective areas

- Alarm Screening and Management System
- On-line Root-Cause Analyzer
- On-line Thermal Performance Advisor
- On-line Tech Spec. Monitor/Advisor
Introduction

KAERI’s ADIOS development

- ADIOS (Alarm and Diagnosis-Integrated Operator Support System)
  - Dynamic Alarm Processing System
    - Alarm Prioritization
    - Alarm Classification
    - Alarm Suppression and Filtering
- 2001 ~ 2005: KNICS project (supp. by MOST and MOCIE)
  - Improved ADIOS – process status diagnosis technology
  - ACTS (Alarm Cause Tracking System)
  - Plant Performance Analysis System
  - Signal Fault Detection Technology
ADIOS (Alarm and Diagnosis-Integrated Operator Support System)

- Identify Monitoring Parameter

PMM (Process Parameter Monitoring Module)
- Track process parameter and decide on entry condition
- Invoke diagnostic module related with degradation
- Basic Signal Validation, Range check

PDM (Process Diagnostic Module)
- Diagnose the disturbed processes as a result of sensor failures or hardware failures
- Detect failure mode on input/output of controller, signal

PEM (Performance Evaluation Module)
- Evaluate thermal performance and diagnose degradation of passive components
- the decreasing rate of thermal performance is as a measurement of degradation
- Detect failure mode on passive components

SDM (Signal Fault Diagnostic Module)
- Evaluate signal fault based on estimation of a noise signal from sensors
- Detect sensor failure and drift

DAS (Dynamic Alarm Suppression&Filter Module)
- Suppress and filter a nuisance alarm and temporary alarm due to mode change
- employ Alarm Classification and dynamic Prioritization
- Dynamic Alarm Suppression & Filter

ACT (Alarm Cause Tracking Module)
- Tracking causes of alarm generated by a process disturbance
- Tracking cause of alarm through computerizing CLD and ARP

Operator or Maintenance Personnel

Goal Tree Success Tree

CONDITION MONITORING ON PROCESS DISTURBANCE

PMM (Process Parameter Monitoring Module)

PDM (Process Diagnostic Module)

PEM (Performance Evaluation Module)

SDM (Signal Fault Detection Module)

DAS (Dynamic Alarm Suppression Module)

ACT (Alarm Cause Tracking Module)
ACTS (Alarm Cause Tracking System)

Display of Precedent Alarms

ARP with the cause

Logic diagram- alarm cause tracking
ACTS (Alarm Cause Tracking System)

✿ A Prototype for KORI-3&4
  ◆ Westinghouse-type 950MW
  ◆ Installed to the Simulator for obtaining user response

✿ ACTS for YGN 3&4
  ◆ Pre-KSNP, CE-type 1000MW
  ◆ Full scope version developed

✿ ACTS Application to Wolsong 3&4
  ◆ PHWR 700MW
  ◆ Request from the Plant I&C dep’t
Issues of Alarm System in Wolsong Plant

- Too many numbers (>50) of alarm tiles in a matrix
- No grouping by channels – difficulty in readability
- Many combined alarms in a tile
- Inconsistency in the use of abbreviation and terminology – both in alarm tiles and in CRT alarm lists
- Too small letters, use of inconsistent not well readable fonts
- Some legends use more than 4 lines
- Long words in alarm legends
Issues of Alarm System in Wolsong Plant

- Max. 40 lines with 2 CRTs
- Difficulty in reading alarms bursting in more than one page during transients
- Not good readability – all capital letters, no grouping, use of old-fashioned CRT fonts
Project Summary

✿ Project Title : Development of Alarm Cause Tracking System
✿ Project Period : May 2007 ~ Dec. 2008 (19 months)
✿ Scope
  ◆ Tracking and Display of Alarm Causes and the Causes of Setback, Stepback and Rx Trips
  ◆ Alarm Suppression and Filtering during Setback, Stepback and Rx Trip
  ◆ Alarm Information Presentation
  ◆ Alarm Presentation in Mimic displays
  ◆ Display of SOE lists
  ◆ Display of Entry Conditions for AOPs and EOPs
✿ Cooperative development with the Plant I&C Dep’t
Tracking an Alarm Cause

* Computerize the control logic diagram for tracking alarm cause during abnormal operation
  - Computerize the control logic diagrams (CLDs)
  - Link signals of alarms, status or condition of components to input points of logic diagrams
  - Tracking an alarm cause through tracking the logic diagrams when a new alarm occurs

Tracking an alarm cause through logic diagram
Tracking Causes for Setback, Stepback and Rx Trip

* Tracking of operation status of components as alarm cause in Alarm Response Procedure
  - Tracking first out alarm when alarm avalanche occurs during plant transients, Setback, Stepback and Rx Trip
  - Tracking a root cause through tracking of status of components in Alarm Response Procedure of the First Out Alarm
  - Display Alarm Response Procedure of the First Out Alarm
  - Highlight their root cause and operator actions in Alarm Response Procedure

* Display of a detailed information of the alarms

* Display of a schematic MIMIC Board to confirm the operator actions based on Web-based Display

* Display of information on the entry conditions of EOP and AOP
Moderator Temp
Abnormal PL5-1

PZR Level Hi
PZR Press Lo
PZR Level Lo

1.0 원인

1) 계기장치 상실
2) 기기대수 상실
3) 냉각기결합 상실
4) 운도조절기 고장
5) 기기 제어용 공기 상실
6) 감속제온도제어(MTC) 상실

2.0 영향

1) 감속제 운도 상대스 높아짐
2) 감속제 온도 79°C에서 연속출력임계 발감
3) 감속제 온도 87°C에서 제1정치계통 작동

3.0 조치

1) 계기를 정비한다.
2) 기기대수를 확보한다.
3) 원료를 복구한다.
4) 필요시 원료로 홀리주를 갚한다.
5) 감속제 운도가 자동 제어 되는지 확인한다.
6) 감속제온도제어(MTC)가 정상적으로 동작하지 확인한다.
7) 감속제 수위를 점검한다.

4.0 총요

1) 계통-301 : 주감속제계통
2) 86-32110/62111-DM-000
3) 32000-1.1-OF

Display of a root cause of Setback through tracking of status of components in operation procedure:
CCW Cooling Control Valve xxx-CVxx Close
Display of a root cause of Setback
Alarm Processing Techniques

* Alarm Prioritization
  - Default priority according to its importance
  - To adopt a criteria of Alarm Priority of Wolsong NPPs
    * Red - Safety Alarm
    * Yellow - Major Alarm
    * Cyan - Minor Alarm
    * Green - Return to normal

* To filter or suppress unimportant or nuisance alarms
  - Plant Mode Dependency Processing: plant operation mode
    * Suppressing a temporary, usual and nuisance alarms activated as a consequence of the plant mode change
  - Multi-setpoint Relationship Processing: unserious alarm prior to currently activated alarm from the same process variable
    * Suppressing a unserious alarm prior to the currently activated alarm
  - Cause-Consequence Relationships Processing
    * Suppressing a consequential alarm activated as a consequence of a causal alarm
**Alarm Processing: Plant Mode Dependency Processing**

- **Suppressing the temporary alarms during Plant Transient, Rx trip:**
  - Ex: Tavg/Tref HI, LO, RCP LTDN HX OUTLET Press HI/LO

- **Suppressing the temporary, usual and nuisance alarms due to changing line-up of flow according to a change of plant modes:**
  - Change of flow due to TBN Trip: HTR DRN, HP FW HTR 7A, 6A, 7B, 6B, 5A, 5B, 4A, 4B, MSR 1ST, 2ND STG REHTR DRN TK B LVL HI/LO ...

- **Suppressing the nuisance alarms out of service systems or components due to ESFAS Signal**
  - Ex: Isolation of Feedwater System due to AFIS signal

- **Suppressing the temporary alarms due to changing Equipment-State, such as on/off of Pump or Valve On/Off:**
  - Ex: Letdown Flow Low due to L/D Isolation
Mode Definition for Plant Mode Dependency Alarm Processing

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Refuel/Cool Shutdown</td>
<td>100 %</td>
<td>93.3 °C</td>
<td>93.3 °C</td>
<td>27 kg/cm²</td>
<td>100 %</td>
<td>1 kg/cm²</td>
</tr>
<tr>
<td>Heatup/Cooldown</td>
<td>100 %</td>
<td>216 °C</td>
<td>176 °C</td>
<td>76.6 kg/cm²</td>
<td>50 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Startup</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal, Rx Trip, ESFAS</td>
<td>330 °C</td>
<td>292 °C</td>
<td>22 %</td>
<td>157 kg/cm²</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Reactivity**

- Critical
- 1.77 %/k
- 10 kg/cm²
- 1 kg/cm²
- -1.77 %/k
- Refuel/Cool Shutdown
- RCP startup
- RHR pump stop
- SI Mode transfer
- SI Unblock
- P-6 Confirm
- Critical Confirm
- MFW Pump Start

**References**

- Heatup/Cooldown
- Startup
- Normal, Rx Trip, ESFAS

**Notes**

- Tavg: Temperature average
- RCS Press: Reactor Coolant System Pressure
- S/G level: Secondary/Generator level
- S/G press: Secondary/Generator pressure
Logic for Alarm Suppression: Cause-Consequence Relationship

Suppressed by Multi-setpoint relationship

FWBP 04P Lube Oil Press lolo(P2) (Level Precursor)

FWBP 04P Lube Oil Press lolo(P2) (Caused Alarm)

Suppressed by Cause-Consequence relationship

FWBP 04P Trip(P2)

Rx PWR>75%

RPCS ACTu(P1)

MFWP 01P Trip(P2)

Suppressed by Cause-Consequence relationship

FWBP 04P Trip(P2)

Level Precursor Multi-setpoint

Raw Alarm Prioritization

Cause-Consequence Alarm Presentation
Alarm Processing Sequence

Phase 1

**Alarm Activation and Tracking**
(Setpoint checking by rule)

If activated, check alarm priority,
  track input signal in CLD,
  track an alarm cause and check status of components,
  then go to phase 2
If deactivated, reset from alarm processing condition.

Phase 2

**Alarm Suppression**
(Procedure calls on each condition)

Suppressing AL(currently activated alarm)
  on conditions of : mode dependency relationship
  : cause-consequence relationship
Suppressing BL(level precursor of AL )
  on the condition of level-precursor relationship
And then put AL and BL into lists of alarm processing
Go to Phase 3
Phase 3

**Alarm Presentation**

(Rule and Procedures for Display)

Alarm Icon displayed on the mimic
  Color coding changes on its priority
New alarm Blinks
Alarm on the overview mimic Board

Display of tracking a root cause of alarms
Logic Diagram of the tracked alarm
Alarm Response Procedure

Textual Display in Time Sequence
Detailed alarm information
Same color coding to the associated alarm icon
Selective displays for all alarms list,
suppressed alarm list and
categorized list in priority
Display for tracking alarm cause and Operation Procedure

Logic tracking operating state of component for alarm cause

Link operating state to presented alarm

Alarm Cause Tracking by linking the operating state to presented alarm or alarm procedures

Display for alarm logic
Configuration of Hardware

✧ ACTS has been configured separately from the existing control computer DCC and Annunciator Windows.

✧ Signals for processing and tracking an alarm enter ACTS from the Remote Monitoring Computer through the TCP/IP Protocol.

✧ ACTS consists of one processing server and two CRTs.

✧ ACTS will be implemented in a Web-based System for the use in MCR and Site Offices.
Configuration of Hardware

Field Input Signal

Remote Monitoring Computer

Main Processing Unit

DCC

TCP/IP

Socket

ACTS Server

Annunciator & Alarm CRTs

ACTS

* Web-Based Service

ACTS Serv
Conclusion

- Alarm Root Cause Tracking System (ACTs) integrated with the Alarm Suppression and Filtering Techniques
  - To be applied to the Wolsong 3&4 CANDU Nuclear Power Plant
  - To solve alarm avalanche during plant transients
  - To reduce operator's cognitive workload.
  - Can improve the conventional alarm systems in nuclear power plants
Thank you!