Optegrity for Abnormal Condition Management

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Abstract

This paper discusses the problem of abnormal condition management, defines the requirements for addressing this problem, and presents Optegrity, Gensym Corporation's software platform for building Abnormal Condition Management applications for manufacturing industries. The goal of these applications is to sustain operational performance and maintain continuous availability of production assets. Optegrity applications detect and resolve abnormal process conditions early -- *before* they impact operations.

Abnormal Condition Management

The more time it takes to discover and correct abnormal process conditions, the greater the loss and disruption to business operations. Abnormal conditions range from those that cause lower quality or reduced production rates to those that cause catastrophic shutdowns. These conditions can result from equipment failure or degradation, variability in raw materials, process drift, and operator error.

Managing abnormal conditions is harder than ever. In the chemicals, oil, and gas industry, for example, the number of control loops that operators must manage has increased from two hundred to eight hundred per operator over the last twenty years. Increasingly complex processes and sophisticated control strategies contribute to the problem. It is not possible for operators to pay sufficiently close attention to every aspect of the operation.

Control systems are unable to provide early problem detection. They notify the operator of process excursions outside of predetermined limits, e.g., "*x is too high*" or "*x is too low*." But these limits are set wide to avoid false alarms. As a consequence, many problems are not discovered until a production disruption is imminent or is already taking place. The industry needs techniques to reliably warn of impending problems before they cause off-normal operation.

Control systems are also limited in their ability to diagnose and correct process problems. They give the operator little help in determining why "*x is too high*". Limit excursions are symptoms, not root cause problems. Alarms indicate that a problem exists, but they do not point out the source of the problem, nor do they explain the best course of action.

Part of the problem is the number of standing alarms that operators must manage and the alarm floods that result when problems occur. Too much time is spent trying to figure out what went wrong. Even after the root cause is identified, operators do not necessarily execute the ideal corrective response. Delays and inappropriate responses are costly; minor problems can quickly escalate.

The consequences of abnormal process conditions are significant; in the petrochemical industry they are estimated to cost at least $20 billion annually. Consequences include:

- off-specification production
- waste
- expensive unplanned shutdowns
- schedule delays
- equipment damage
- environmental risks
- broken product schedules
- safety problems

Many operations managers can gain more from minimizing unplanned shutdowns and off-specification production than they can from applying advanced forms of process optimization. A single shutdown can wipe out all those hard-won gains. Consider, too, the cost of loosing even a single batch of life-sustaining pharmaceuticals or the safety and environmental impact of a major accident. Preventable industrial accidents occur too often.

Proven Technology

Since 1988, many expert operator advisory systems have been built with Gensym's G2 software. Some of those applications save millions of dollars per unit per year on waste reduction alone. All have contributed to our understanding of what is required for successful abnormal condition management. Abnormal condition management applications must:

- monitor operations to assure that the process plant is operating properly;
- detect off-normal operation as early as possible and before a major failure results;
- determine the cause of off-normal operation;
- advise operators and monitor responses guiding operators through recovery.

Off-normal operation in this case includes product quality problems, plant efficiency problems, improper operation of equipment, process upsets, and unintentional emissions of materials to the environment.

Optegrity Capabilities

Optegrity provides all the necessary capabilities for building robust and re-usable abnormal condition management applications. It incorporates all of G2's capabilities for *real-time process monitoring and analysis, early problem detection*, and more. In addition, Optegrity includes capabilities for:

- Real-time root cause analysis, automated testing, and fault isolation.
- Advising operators on the best corrective procedures and automating those actions.
- Advising operators on best practices during normal operations.
- Alarm filtering and correlation for handling alarm floods and the high volume of standing alarms.
- Impact analysis for discovering the consequences of each production problem.

Causal Modeling and Fault Management

At the heart of Optegrity are its *generic fault models*, which define:

- the faults associated with each type of asset;
- how those faults propagate within the asset and to related assets;
- observable symptoms associated with those faults;
- tests for isolating the root cause faults;
- Actions for correcting the fault and restoring the process to normal operation.

Example

For example, the following figure shows part of a generic fault propagation model for reactors.

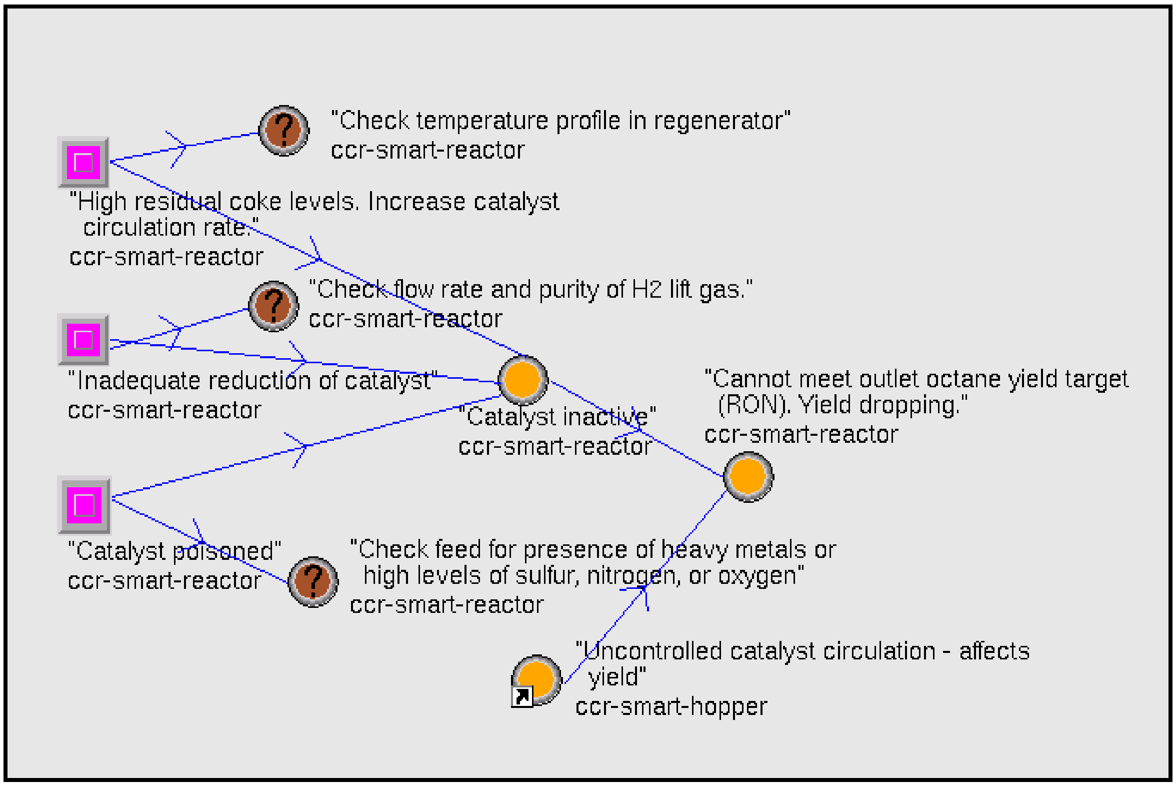

Figure 1: Generic Fault Propagation Model

This is one of several alternative views of the fault model. The pink blocks on the left are faults. The brown circles are tests. And the orange circles are symptoms. The links represent the causal relationships.

Observable symptoms are caused by faults. Tests determine whether or not a fault is present; they can include simple queries or complex analysis and can be executed automatically or presented to the operators.

Related Fault Models

The symptom node at the bottom of the reactor model in Figure 1 reads "uncontrolled catalyst circulation". This reactor symptom can result from a problem in a hopper. The symptom node is actually a link to a separate generic fault model for hoppers. Nodes like these model the propagation of events across related assets.

Verification Tools

Optegrity has a complete set of knowledge verification tools for these generic fault models. For example, Optegrity provides tools for checking the fault models for configuration errors (duplicate tests or symptoms, for example). In addition, Optegrity provides model analysis tools to verify that each fault can be uniquely identified and that each fault is detectable. For example, to enable detection, a fault must have at least one test or symptom. To be isolated, a fault must have a unique pattern of symptoms and test results.

There are also convenient features for simulating faults, symptoms, operator interaction, and test results. Thus the developer can run through each possible problem scenario to verify that the fault diagnostic and recovery procedures perform as designed.

Managed Asset Model

An Optegrity application also includes a graphical model of all managed assets and their relationships. Optegrity uses this asset model during fault diagnosis to trace symptoms back to their root cause faults within a group of related assets.

Optegrity provides a developer's interface for building these models. In addition, it is possible to automatically generate the asset and process models from descriptions that may exist in other applications, external databases or other files.

How Fault Management Works

At runtime, Optegrity performs ongoing process monitoring and analysis. When Optegrity detects a symptom, it uses the generic fault models in combination with the managed asset model to identify:

- all faults that could have produced the observed symptom;
- all the symptoms and candidate tests whose results will either rule-out or confirm each of those faults.

Optegrity then:

- performs the tests that are indicated by the model or advises operators on the best tests to run;
- diagnoses the root cause failure;
- executes the appropriate corrective response or guides the operators through recovery.

Operator's View

Optegrity provides configurable message servers and browsers for viewing event messages, diagnostic conclusions and more.

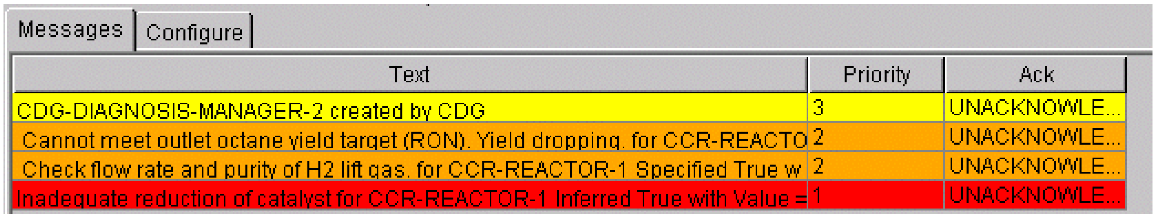

Figure 2: Message Browser

Optegrity also includes a Runtime Operator Advisor that informs, monitors, and guides the operator during event correlation, testing, fault isolation, diagnosis, and recovery. This browser provides a convenient view of:

- Known Symptoms
- Suspected Faults
- Candidate Tests
- Known Test Results
- Known Faults

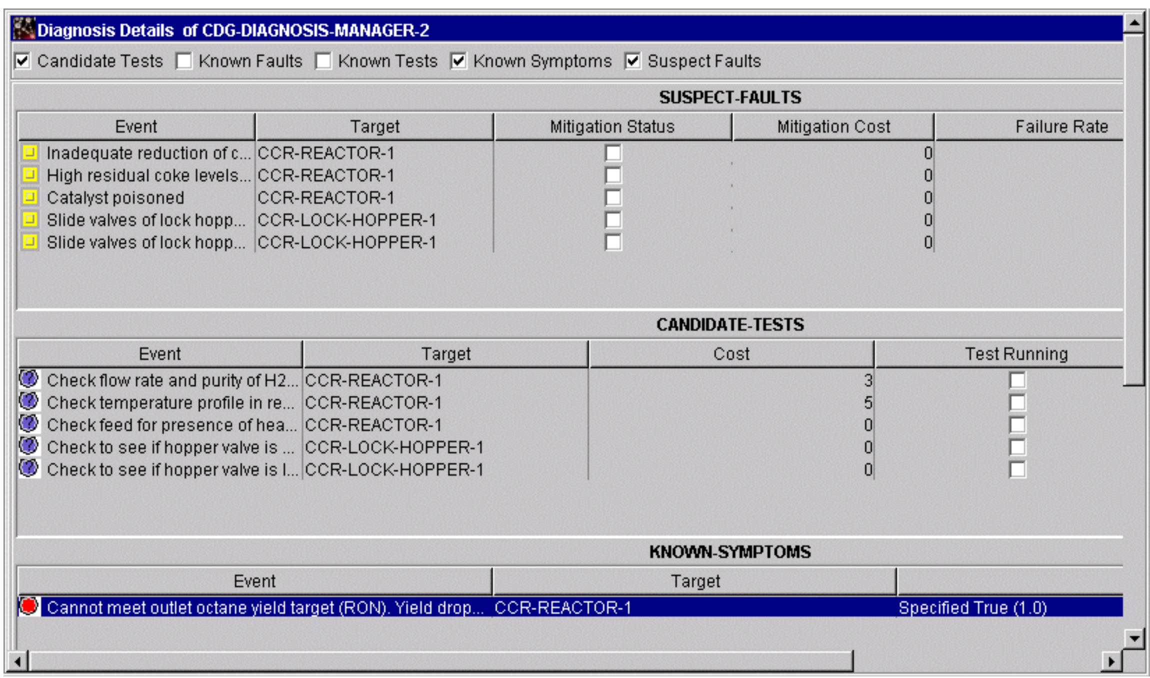

Figure 3: Run-time Operator Advisor

Within this browser operators can run tests and recovery procedures, ask for explanations, view message details and more. Through this interface operators can detect, diagnose, and resolve each problem quickly, and consistently apply the best known practices to each abnormal event. It is also possible to replace this run-time interface with a Web-browser-based interface or an interface to the operator's existing display.

Adaptive, Extensible, and Scalable Fault Management

Optegrity's generic fault models are adaptive, extensible, and scalable.

Adaptive: Optegrity's generic fault models are independent of the specific configuration of managed assets. At run-time, the diagnostic analysis automatically adapts to equipment configurations, topology, and operating modes. This minimizes the need for application customization and the need for expensive application maintenance and reconfiguration. This adaptive diagnostic capability also enables the development of robust point solutions that can be rolled out from plant to plant.

Extensible: New symptoms, faults, tests, or recovery procedures can be added to fault models for any class of assets. Also, new asset fault models can be developed and *plugged in* without needing to update any part of the existing application; Optegrity will automatically employ the new fault models in all related fault diagnosis.

Scalable: Optegrity automatically builds specific fault models at run-time only when those models are required to identify suspect faults, run candidate tests, and resolve process problems. This minimizes the size and computational requirement for each application. Additionally, Optegrity acquires test data only when the data is needed. This eliminates the requirement for massive amounts of routine polling of every possible variable.

Conclusions

In summary, applications built on the Optegrity platform provide early problem detection, diagnosis, and recovery, resulting in the following operational benefits:

- Improved asset availability
- Fewer unplanned shutdowns
- Increased on-specification production
- Less waste
- Greater productivity
- Improved start-up, shutdown, and product transitions
- Safer operation

The benefits of the development platform include:

- Proven methodology
- Robust real-time operation
- Minimal maintenance
- Smooth roll-out to similar units and processes

Summary

Control systems are unable to provide early problem detection. Many problems are not discovered until they reach the alarm stage. Then alarms simply indicate that there is a problem, but they do not point out the source of the problem nor do they explain the best course of action. Unassisted, it takes too much time for operators to discover the root cause. When the cause is discovered, operators do not always execute the best response. The consequences are costly. Optegrity addresses each of these areas by providing all the necessary capabilities for robust and reliable abnormal condition management.