The Power Derived from Automating Root Cause Analysis

Executive Summary

Plants and factories today are growing increasingly larger and more complicated. Because of these complexities, operators are easily overloaded from analyzing and searching large amounts of information to determine the root cause of problems. During the time taken to search for an answer, the problem may escalate and result in a negative impact for production and a reduction in operating profits.

All companies experience problems that interrupt operations. According to studies, the cost of plant downtime can be anywhere between $2,500 per hour[1] to $12,500 per hour,[2] and even up to $250,000 per day for some oil wells.[3] Not to mention, the costs incurred from lost time of production due to wasted man-hours and idle energy consumption.

Experienced human troubleshooters know that in a complex environment with multiple variables, multiple faults may have led to the symptoms which indicated a problem. Therefore, complex process environments are demanding an automated root case analysis approach which will empower operators with an immediate corrective action. To be effective, an automated root cause analysis approach requires an intelligent framework.

Emerson has created a modern intelligent framework through its Plantweb Optics Analytics decision support application and modules which enable **automated root cause analysis** and real time diagnosis with embedded predictive features. The deployment of Plantweb Optics Analytics and its tools manage abnormal conditions from detection all the way through resolution for optimal performance. This methodology allows the problem-to-resolution cycle time to be reduced and consequently leads to increased savings and a higher return on investment (ROI).

[1] Harvard Corporation: Oil/Gas/Power/Industrial Plants; 2011
[2] Totally Integrated Automation VAULT: Automation Services Reduce Downtime for Manufacturers; October 2009
[3] Centek Ltd: Staying centered; Oil & Gas Next Generation Magazine; May 2010

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Root Cause Analysis Diagnoses the Source of the Problem

Problems can be discovered at any level in the business hierarchy

Plants and factories today are growing increasingly larger and subsequently more complicated. Because of these complexities, operators are easily overloaded when issues arise especially if they have negative impacts on safety, quality, reliability, or a reduction in operating profits. These problems must be quickly assessed, resolved, and prevented from recurring before getting worse or spreading. As a result, many organizations have deployed manual root cause analysis' tools where each problem can be described as anything that represents an abnormal or undesirable condition.

Deploying root cause analysis manually is very beneficial when the problems are not complex or time is not critical. However, in a complex process environment, an **automated root case analysis** approach is required. Therefore, Emerson has created a modern intelligent framework with automated root cause analysis to ensure real time diagnosis with predictive features.

Let's take a look at the typical approach to the root cause analysis process.

Problem Identification and Fault Propagation Models

When the problem nodes within the fault propagation diagram have no further upstream possible causes, the "root causes" are identified

As problems are identified, either by alarms or some other method, the natural approach is to make a correction to bring operations back to normal. Tests may be performed to validate the problem and link to a fault, but these tests may not point to the actual fault causing the symptoms. Experienced human troubleshooters know that in a complex environment with multiple variables, multiple faults may have occurred that led to the symptoms that indicated the problem.

Therefore, once a problem is identified, the next step is to build a fault propagation model to identify possible causes. Each of the possible causes is itself another problem. Arrows are drawn between the problems to indicate the cause and effect. As an example, an arrow may be drawn from "Fluctuations in reactor delta temperature" to "Sudden drop in RON." This arrow indicates that "Fluctuations in reactor delta temperature" can be the cause of "Sudden drop in RON". Another example of a cause may be "stabilizer operating problems". Progression continues "upstream" for possible causes until the "root causes" are identified and corrective action can be taken.

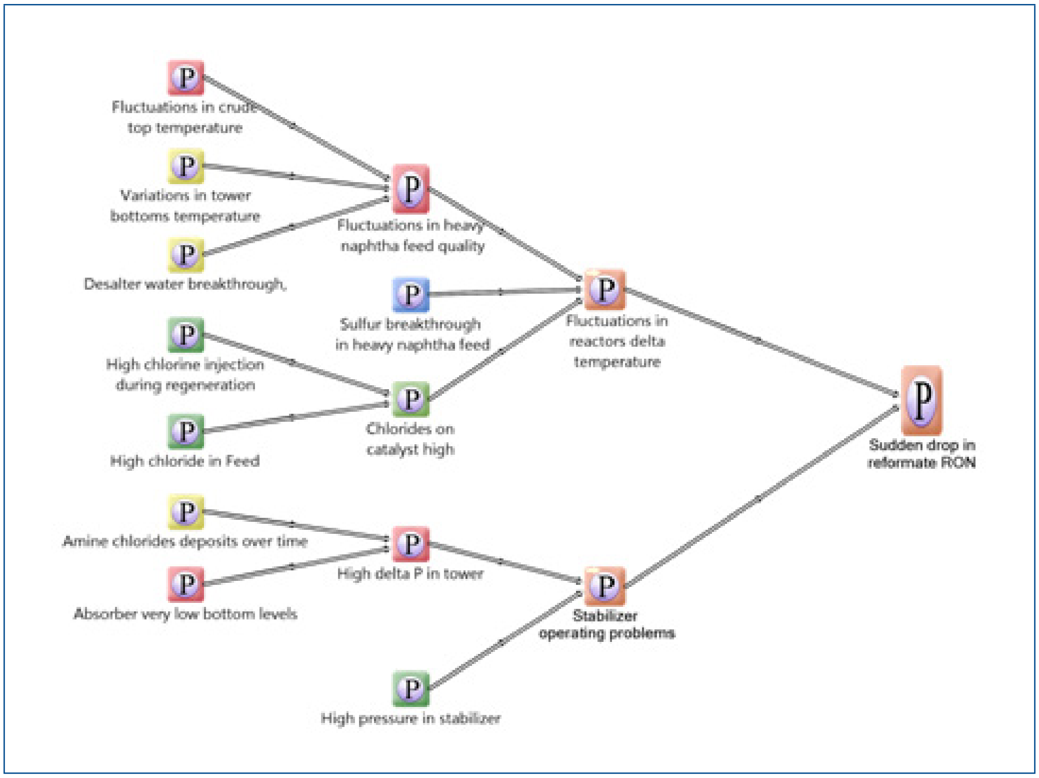

Figure 1: RCA example for drop in reformate RON

Similarly, a view downstream predicts the impacts of a problem. “Fluctuations in crude top temperature” may lead to another problem such as “Fluctuations in heavy naphta feed quality.” Again, arrows are drawn to indicate the cause and effect link. The result of the process to look upstream for possible causes and downstream for effects is a **fault propagation model**. When the problem nodes within the diagram have no further upstream possible causes, the “root causes” are identified. Note that one root cause problem may result in multiple downstream problems. Similarly, any problem may have many possible root causes.

With the complexity of multi-variables, sophisticated fault propagation models, and the possibility of many root causes associated with any one problem, is it possible to automate the process? If yes, will this automation serve to proactively manage abnormal conditions? The answer is yes to both questions.

Let’s take a look at how the Plantweb Optics Analytics solution enables these activities and the power that is provided to the operations environment.

Plantweb Optics Analytics’ Integrated Modules Automate Root Cause Analysis

The benefits of automated diagnosis extends throughout the business hierarchy

The tools offered in the Plantweb Optics Analytics solution provide the sophistication required to address problems from detailed process control elements through planning and the business-level hierarchy. Business analysts, managers, and engineers, as well as operations personnel, can initiate the diagnosis to detect problems associated with KPIs at the business or process level of data. This enables the benefits of automated diagnosis to extend throughout the business hierarchy. Linkages between problems at each level are captured and represented through the cause and effect models in Plantweb Optics Analytics’ Root Cause Analysis (RCA) module.

RCA's fault propagation models become valuable representations of how problems propagate from cause to effect enabling better operations decision making. With the automation of root cause analysis, these models are usually built during development of the system and can be modified at any time. At run time, once an initial symptom is detected, a reasoning engine drives diagnosis, which is then driven by the embedded fault propagation models combined with observed events.

Diagrams can be easily built with a drag, drop, and connect graphical editor. The application developer may be a business analyst when diagnosing business or supply chain problems. If diagnosing process equipment, the application developer is typically an engineer or someone else familiar with the process being analyzed. However, the real advantage of these simple cause-and-effect diagrams is that they are viewable by operations (where basic cause-and-effect is well known). In addition, libraries of these diagrams can be provided for common types of process equipment, thus speeding applications development.

The RCA module manages abnormal conditions from detection all the way through resolution for optimal performance. This methodology allows the problem-to-resolution cycle to increase in speed, consequently leading to increased savings and higher return on investment (ROI).

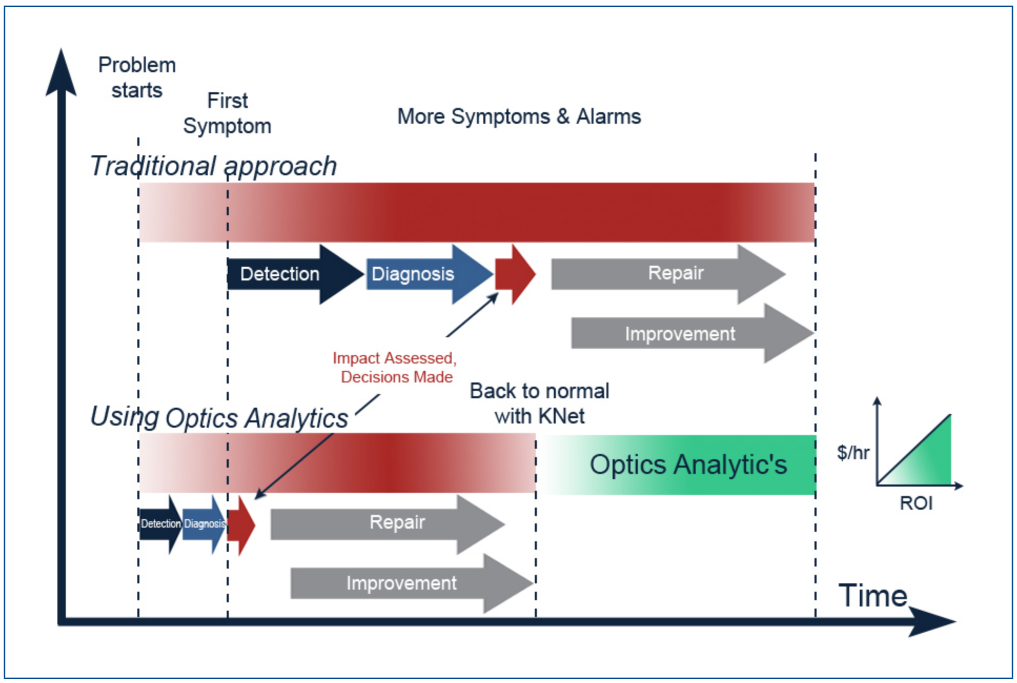

Figure 2: Benefits of the Plantweb Optics Analytics root cause analysis approach vs. traditional approach

Fault propagation models will seem natural and documentation already exists

The knowledge captured in the fault propagation models is in a familiar form. Printed or electronic documentation of troubleshooting procedures are typically organized in a way that can be readily translated to RCA fault propagation diagrams. Each page usually corresponds to a problem. On that page, there will often be an indication of how to detect the problem, possible causes, and ways to distinguish them. This identifies the upstream problems and tests needed to recognize them. There will also often be a statement of the impact of the problem which identifies downstream effects, indicating the downstream problem nodes and the causal links to them.

There are several major differences between RCA and other variations of fault propagation models. The first is that RCA is used online, responding in real time. The other techniques are typically manual efforts and focused on past problems. However, RCA provides a mechanism to take the past studies and incorporate the modeled knowledge for real-time use.

There is an important efficiency difference between RCA and other approaches of fault trees, RCA analysis, fishbone diagrams, or simple documentation, even if there was an attempt to use them in real time. Other diagrams focus on one problem at a time. RCA diagrams incorporate multiple root causes and multiple problems.

Events detection and tests provide run-time information with a value of True or False

In addition to defining causes and effects for problems, part of the model configuration also identifies events detection and tests associated with the problem. Events detection is associated with incoming events that have a True or False value, providing evidence of a problem, or ruling it out. Events detection is typically detected in the Rules module. For instance, the rule below was designed to detect the variations in crude top temperature by real time monitoring of crude tower overhead temperature and top pump around temperature.

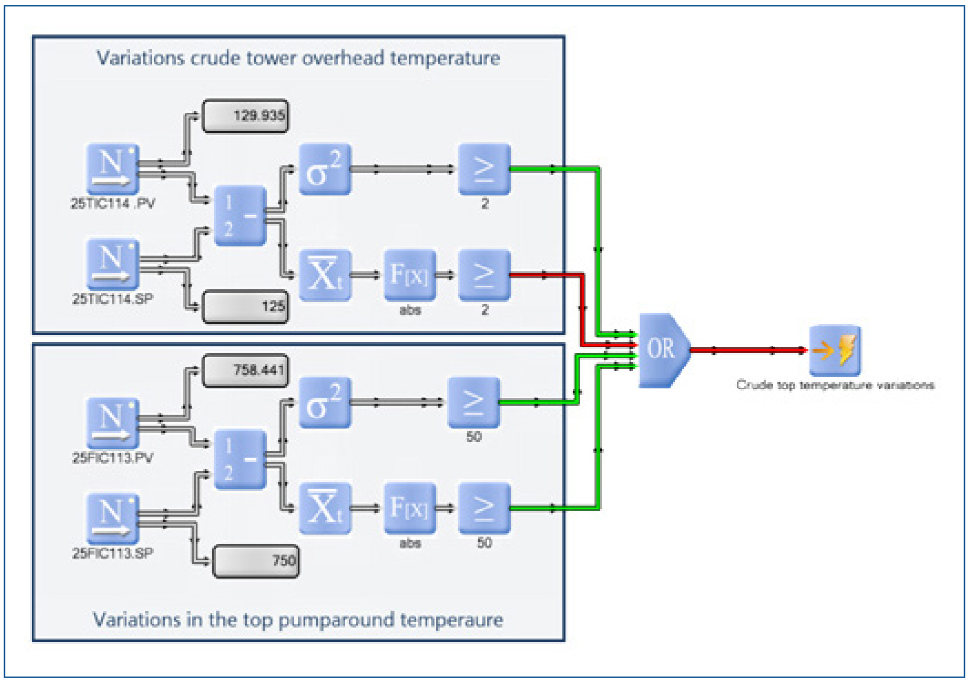

Figure 3: Rules example for event detection of crude top temperature variations

Tests also provide evidence of a problem or rule it out completely by presenting a value of True or False in the same way as events detection. The difference is that the tests are requested on demand by RCA.

Sometimes a manual input is requested from the user (e.g., a manual test may ask if there is a layer of water visible in a level sight gauge). The sequence of events would follow detection and confirm the presence of a problem, RCA would determine possible root causes, and a useful test would be identified. The test is requested from the console operator who communicates with a field operator via radio. When the field operator does the check, he notifies the console operator, and the console operator answers “confirmed” or “not confirmed” via the graphical user interface (GUI) of the application.

Another type of test could involve a complex series of operations, requiring both manual and automated steps. These tests would typically be implemented as workflows using Workflow. A request would be generated for the operator to do a “step test” on a flow control loop. The operator would temporarily put the control loop in manual mode, make small changes up and down on the valve output, determine if a corresponding flow meter changed value, and then return to automatic control mode. This test covers several root causes such as a stuck valve or a frozen sensor.

Rules allows custom rules to be designed graphically

Rules allows users to automatically collect data, filter out noise, validate the data, detect and validate events based on key events, symptoms, process behavior, and other variables, perform logical inferences, and initiate workflows or diagnosis. Rules is often used to detect symptoms of abnormal conditions which are then transmitted to RCA for root cause diagnosis. This generally includes data validation with extensive capabilities to work with current and historical data. The ability to ignore spikes in data, check against limits, filter out noise, and look for frozen values or excessively noisy values are all included as part of learning “normal” behavior. Changes over time, statistical process control tests, and comparing information from key events, symptoms, process behavior, and other variables are also provided.

Rules is also used for performance monitoring, as in Key Performance Indicators (KPI) calculations, and detecting deviations from the KPIs. KPIs and other calculations can be based on current or historical data. It can be used to synchronize data between different systems, and recognizing business rule violations.

Users configure these rules with a drag, drop, and connect graphical editor. Rules building blocks include filters, arithmetic, time series calculations, statistical process control, logic gates, timers, counters, observations to draw logical conclusions from numeric data, and others. Local variables can be defined for any diagram. Most applications can be accomplished with the wide variety of graphical building blocks provided, although custom scripts in C# can also be embedded in custom blocks.

Mitigation and corrective actions can be simple messages or entire workflows

Mitigation and corrective actions are also configured for problems. A corrective action is a fix for the root cause of a problem. For instance, it may be a request for maintenance to fix a stuck valve. Mitigation actions are those actions taken while waiting for the fix, and in the case of our example, the mitigation action may be as simple as putting a control loop in manual mode. In a second example of feed loss to a distillation tower, it could involve putting the tower on recycle so that conditions are maintained. Mitigation actions do not fix a problem; instead, actions are taken to contain the effects of the problem. Like tests, mitigation and corrective actions can be simple messages or entire workflows. If they are workflows, they would be implemented through Workflow or an external workflow engine.

Real-time diagnosis is performed to determine root causes

At run time, Rules or other sources determine the status of events detection and tests (True, False, or Unknown) and transmits it to RCA for diagnosis. The propagation across the fault model starts processing in one or both directions: diagnosis and prediction. RCA checks additional events detection and runs tests to determine root causes. It notifies the operator if mitigation or corrective actions are required and/or starts workflows. Unlike systems that just do alarm filtering, a relevant root cause analysis is performed.

A "test planner" component of RCA automatically plans tests. The test planner looks at the "test cost" of each symptom or test, and first requests the cheapest ones. For instance, the lowest "cost" problems are ones that can be calculated automatically from DCS variables. They would be requested first. If that doesn't pinpoint one or more root causes, the next cheapest tests are run. Those would be "easy" entries, based on quick readings from manual sensors or non-integrated computer systems. More "expensive" tests would include those with significant time delays or effort.

The diagnosis methodology step approach with RCA

Once data integration has been accomplished, the ongoing approach to diagnosing with RCA, as noted in *Figure 4*, could be put in place:

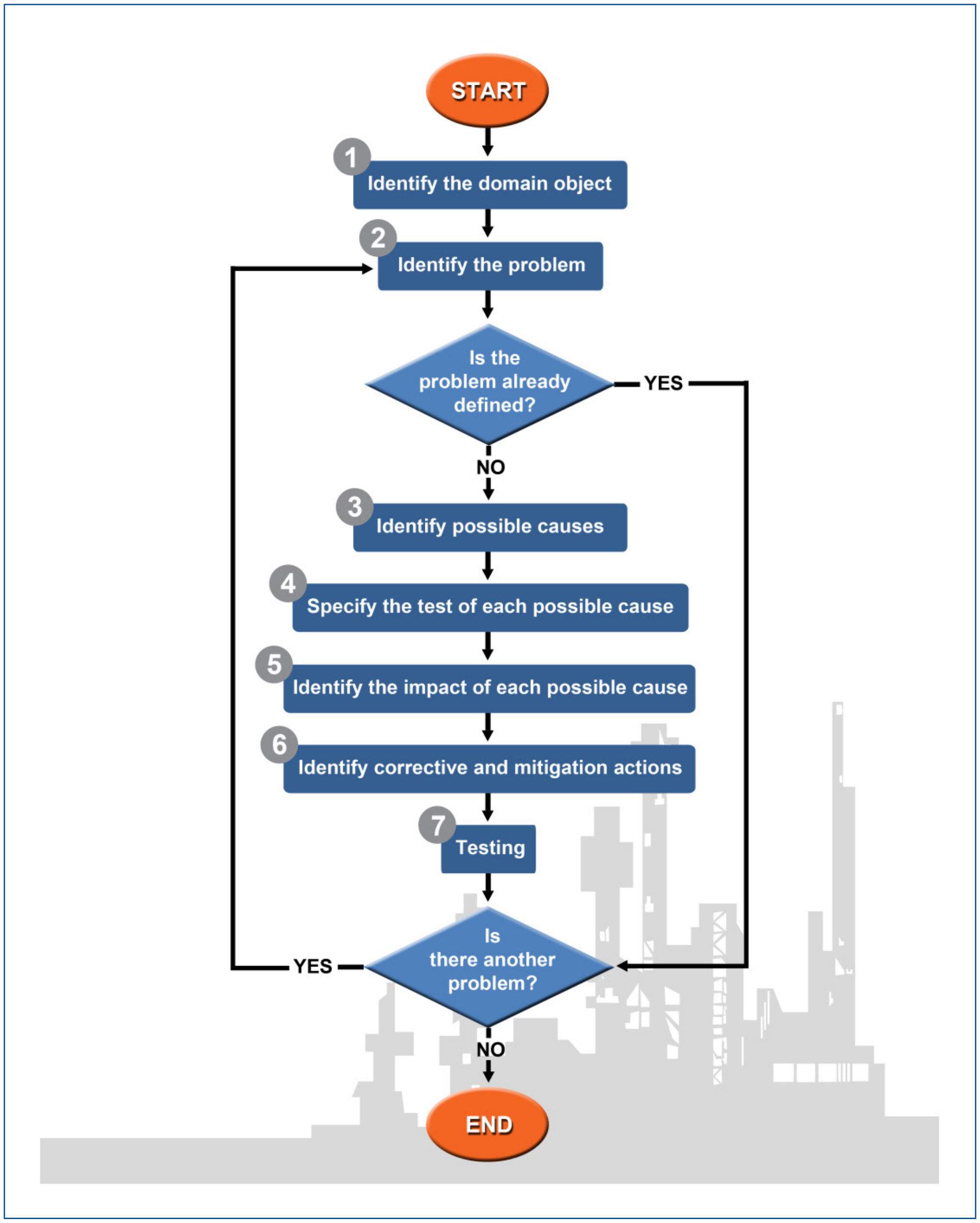

Figure 4: The RCA problem detection and diagnosis process

Workflow allows graphical construction and execution of workflows

Workflow allows users to graphically define sequential and parallel processes for execution by a workflow engine. These workflows can involve both automated actions and manual actions or decisions. Users can invoke workflows on demand or they can be started automatically with conditions indicated by Rules or RCA. Users can display lists of outstanding workflows, pause, resume, stop, or restart outstanding workflows. Workflow steps can be logged to a file or sent to a message display, for auditing, or other analysis. Examples of workflows include the following:

- Troubleshooting procedures
- Problem mitigation or resolution
- Detection and resolution of repeated problems or KPI deviations
- Coordination of efforts among multiple departments
- Management and escalation of responses to incidents

Continuous process improvement by diagnosing KPI deviations

Since Plantweb Optics Analytics integrates with plant and business systems, it has access to the information needed to calculate many KPIs. Therefore, Plantweb Optics Analytics can be configured to automatically calculate KPIs from technical plant performance through business targets. In addition, upon detecting deviations from KPI targets, Plantweb Optics Analytics can initiate root cause diagnosis to determine the cause of the deviations. The diagnosis can include manual steps and workflows as well as automatic retrieval of data from disparate systems.

Plantweb Optics Analytics addresses re-use by providing the RCA facility to specify fault propagation models, visible in a graphical form. These diagrams show the cause-and-effect links between root causes and subsequent downstream problems. So, during safety discussions, these diagrams can be used as a starting point showing cause-and-effect links already known. During the discussions, new causes and effects will be determined. These can be documented directly by constructing the fault model diagram on a projection screen for all to see. When the reviews are done and approved, the revised fault models can be used directly as the basis for the actual online monitoring and diagnosis. Thus, the Plantweb Optics Analytics system accumulates knowledge over time in a continuous improvement process.

Complex process environments are demanding an automated root case analysis approach. Emerson has created a modern intelligent framework through its Plantweb Optics Analytics solution and modules which enables automated root cause analysis and real time diagnosis with embedded predictive features. The deployment of Plantweb Optics Analytics and its tools manages abnormal conditions from detection all the way through resolution for optimal performance. This methodology allows the **problem-to-resolution cycle** to be reduced. The ultimate outcome is the maximization of plant operations in normal mode and consequently leads to increased savings and higher return on investment (ROI).

Keywords

A

abnormal conditions – situations occurring within a process that deviates from planned courses of production that could have significant impact on the enterprise's safety, cost, and efficiency

alarm filtering – applied to reduce the number of alarms and to prioritize them, where the goal is to produce fewer alarms and to help identify the most critical ones

applications services – represents the services offered to communicate with the business layer

automated root case analysis – the ability of an application to directly investigate the original sources of plant and process interruptions before they can have potentially critical consequences on the enterprise without requiring operator interference

C

client layer – represents the presentation layer. This layer stands for the top-most level of the application and is used to translate tasks and results to something the user can understand

corrective action – the resolution to be taken in order to correct an abnormal condition such that the process once again aligns with planned actions

D

data service – represents the services offered for data collection from data sources

data sources – represents several systems from which real-time, historical, or transactional data can be gathered

data sources layer – represents the data access layer, it includes several systems from which real-time, historical, or transactional data can be gathered. The data is passed to the logic tier for processing, and eventually to the user

decision support – information and knowledge provided by intelligent solutions to aid the resolution-making process

decision support systems – intelligent solutions that gather information and knowledge from throughout the enterprise in order to aid the resolution-making process in the case of an abnormal condition

E

effective operations management – Operations management typically represents the supervision of the bulk of a business' assets. Effective operations management helps companies reach their business and performance targets as well as develop capabilities that will keep them ahead of their competitors into the future, often by (but not limited to) reducing costs, increasing the safety of operations, reducing the risk of operational failure, and providing the basis for future innovation

F

false alarms – inaccurate or mistaken notifications of threats or problems

fault propagation model – a technique used to analyze an undesired event and all associated causes in order to identify the root causes of the event

K

knowledge capture – the act by which intelligent solutions preserve and archive valuable user experiences for future use

knowledge out-of-the-box – a ready-made technology that meets a need that would otherwise require a special development effort

O

operational intelligence – the goal of reaching optimized business efficiency by using real time monitoring of processes to detect and respond to situations involving interruptions, opportunities, and bottlenecks

P

Plantweb Optics Analytics – Emerson's intelligent application that seeks to proactively detect and diagnose operation issues before they impact production and safety, reduce the problem-to-resolution cycle time, and aggregate and transform data into valuable knowledge and information

problem-to-resolution cycle time – the entire period during which a process problem starts, manifests, and is conclusively repaired

R

root cause – the original sources of plant and process interruptions

root cause analysis – investigation of the original sources of plant and process interruptions before they can potentially have critical consequences on the enterprise

S

server layer – represents the business logic layer. It coordinates the application, processes commands, makes logical decisions and evaluations, and performs calculations. It also moves and processes data between the two surrounding layers (data sources and client layers)

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