White Paper
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Change Your Board Operator to a Process Manager with State Based Control

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Abstract

This paper examines the attributes of state based control and the value delivered to manufacturing from the initial design through the operating life of the facility by improving the effectiveness of operators.

Introduction

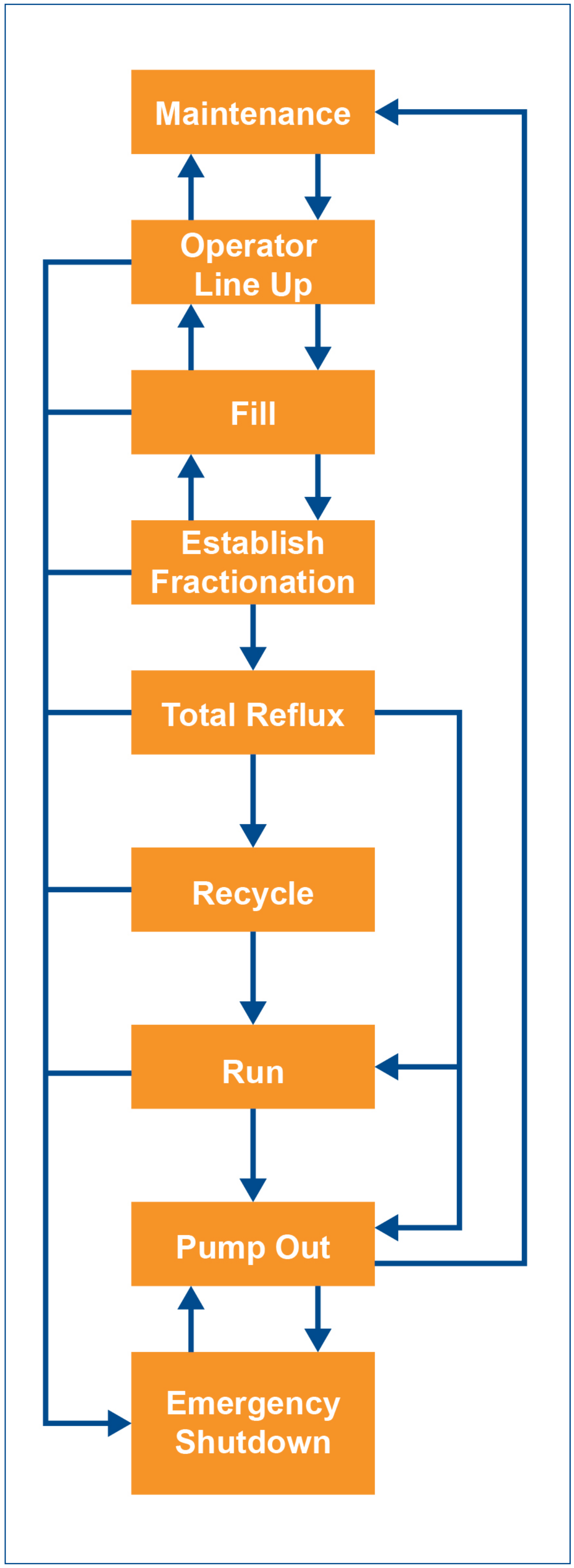
Processes operate in a number of different states which range from downtime for maintenance to running in steady state and any normal or abnormal state in between. State based control uses the state or mode that the process is in to optimize the control of the process.

The result is a plant that performs better over the entire range of states for safety and asset utilization. The use of standardized established architecture can reduce the time and effort to implement the control system with improved performance. Operational process knowledge is captured and leveraged in the design process. This keeps the knowledge of the best operator on the board at all times and reduces training demands. The knowledge, once captured, can also be leveraged through the corporation, improving the return on the initial investment. All of the operators on the board can manage the process at a higher level based on the experience and collective knowledge of everyone running the plant. This causes the plant to become smarter over time.

State based control is much more robust in the management of abnormal situations than monolithic control. State based control is designed to capitalize on knowing that what is normal in one state, is abnormal in another. State based control incorporates instrument justification and dynamic alarm rationalization into the design process.

This reduces the initial cost to build and maintain, requiring only the instruments that are essential for a specific purpose, while eliminating I/O creep and the rework associated with it. It reduces start up time and alarm loading on operations during the critical commissioning of a new plant. This allows the plant to start up at the ISA 18.2 standards for alarm loading.

As far as safety is concerned, state based control goes beyond the typical safety instrumented systems design. It coordinates driving each operating unit to a predefined, appropriate, safe state that is beyond just a safety function. This safe state can be used for any number of different safety functions. Operators can quickly monitor that the systems have gone to the safe state and are performing correctly.



Background

Before distributed control systems (DCS), board operators could walk the board and see a panel of controllers and recorders with a few strategic alarms. Plants were not operated in monolithic control. The operator had a smaller number of loops in view and reach and operated the plant based on the state that the plant was in, which had its advantages. We do not want to go back to that, but we have lost some things as we have moved forward. We take advantage of the fact that the DCS brings in a tremendous amount of information and alarms on many more loops per operator than in years past. For the most part, we do not take advantage of what the DCS can do with this information in the form of suppressing invalid alarms for the current process state. We also don't drive the outputs differently based on what the current state requires. The DCS has moved to a monolithic control, creating an unmanageable demand for the operator to now handle the state based aspects for startups, shutdowns, upsets and disturbances. The operator needs to do this with many more loops that are not neatly visible and accessible to him on the board and that are probably in an alarm flood.

Control systems in a manufacturing facility are many times configured for optimal performance during the running state of the plant. This is a problem for the effective operations of other operating states. Since normal and abnormal changes are based on the state of the process, not all possible alarms are relevant to operations in every state. State based control maximizes the digital control system's ability to detect and convey unique operational situations through dynamic alarming and state based managements of the outputs. In terms of time spent in a state, it seems reasonable to optimize the running state. Hopefully, plants spend most of the time in the running state. In terms of risk, it is not able to deliver. According to the Process Improvement Institute, 70% of incidents occur on startup or shutdown of the plant (Process Improvement Institute, 2011). In large continuous plants, these are the states that everyone has the least amount of experience with and where the control system provides the least amount of support. Without some type of state based control or dynamic alarm management, the control system easily becomes more of a hindrance than a help. In terms of reducing risk, it is much wiser to look beyond the running state. State based control allows operations to manage the plant through states of a startup, shutdown, upset or a disturbance such as Circulating, Heating Up, Conditioning Catalyst, etc. Safety systems that are based on hazard analysis perform well when managing strategic loops within an acceptable probability of failure on demand.

However, the operator is left with how to deal with the rest of the plant when the safety system has just taken the reactor down. For instance, they have to deal with the issue at hand with the reactor and the implications on the up and down stream equipment. They must now operate the plant with many valves in manual, dealing with an alarm flood, while making decisions in a very stressful situation. At shift change the required communication regarding what is in manual may be overlooked. There is no reason to take these risks. The "reactor tripped state" is a state that can be identified and controlled automatically by the DCS. The knowledge for how to control the process is captured in the DCS and leveraged to everyone who runs the board. The reactor system also communicates that it has tripped to the upstream and downstream equipment, so that they can take the appropriate actions.

Through state based control, the operator is transformed to a process manger. This is achieved by moving from making many manual adjustments by hand in an upset, such as an alarm flood, to allowing the state based control to take care of it. In normal running conditions, operators can monitor the plant for optimal performance. In upsets, they can manage the safety of the process and respond to meaningful alarms.

Cost of Not Automating

State based control can dramatically reduce operator errors. There can be some significant cost in terms of operator errors as is documented in “The Cost of Operator Errors and What You Can Do to Minimize” (Henry, Ferrer, Persac & Beebe).

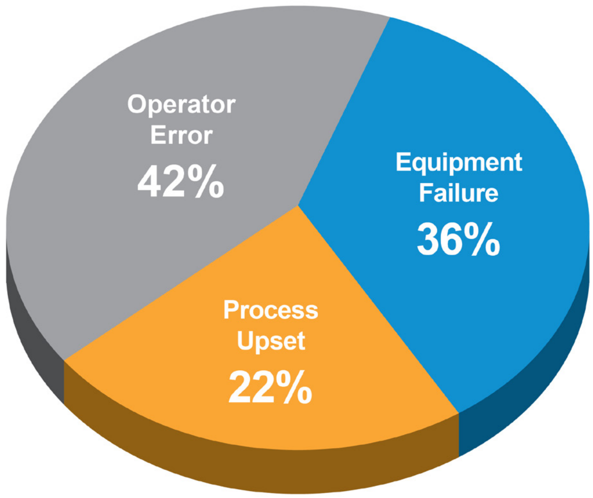


Figure 1: Causes of unscheduled shutdowns/ slowdowns
Source: ARC Whitepaper, January 201

Operator errors result in the highest average dollar loss per major incident at over $80 million (J. H. Marsh & McLennan, 2010). According to the ACR Advisory Group, operator error accounts for 42% of the unscheduled plant shutdowns with equipment failures and process upsets rounding out the list (O’Brien, 2010). State based control reduces all of these.

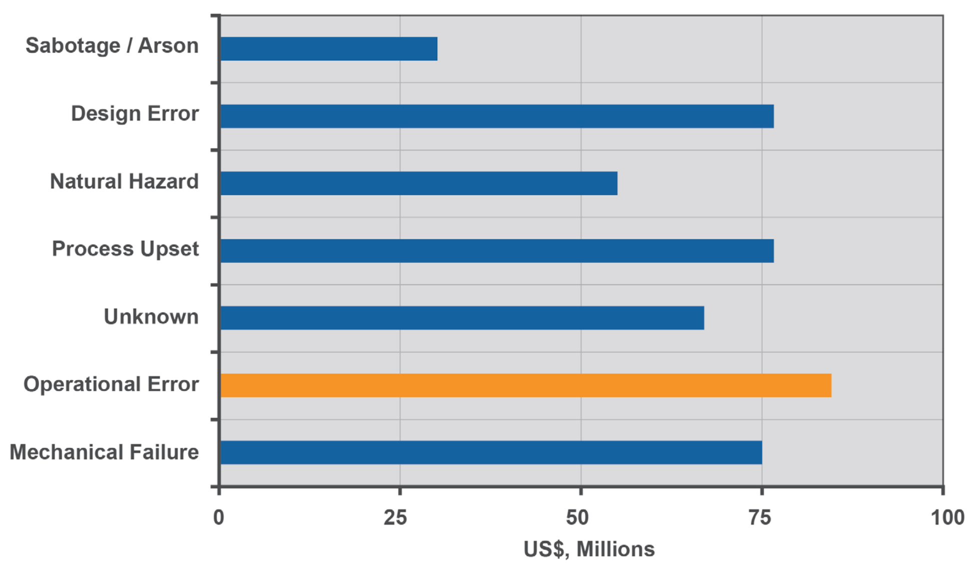


Figure 2: Average loss per major incident by cause
Source: J & H Marsh & McLennan, Inc.

The peripheral cost of incidents is also devastating in terms of injuries, loss of life and economic impact (Henry, Ferrer, Persac & Beebe).

Deepwater Horizon Oil Spill – BP – 2010

- U.S. Environmental Protection Agency (EPA) fines of $15 million
- Occupational Safety and Health Administration (OSHA) fine of $51 million for a single facility
- Escrow account of $20 billion to the U.S. Government to cover potential oil spill costs
- ~45% decrease in stock value in the months following the incident
- Temporary reduction in sales at BP stations by as much as 40%

Bhopal Disaster – Union Carbide – 1984

- ~15,000 incident related deaths
- ~550,000 incident related injuries
- ~$500 million in legal decisions and voluntary funding of support facilities (hospitals, research facilities, etc.)
- ~30% decrease in stock value in the months following the incident
- Eventual devaluing and sale of consumer products division
- Divesting of assets

Workforce

Aging Workforce and Knowledge Loss

Over the coming years, a great deal of experience and knowledge will leave the workforce with the retirements of the baby boomer generation. Within the next five years, about 20% of the workforce could retire. This will lead to skill gaps in the workforce and a large burden and expense for training. The Social Security Administration estimated 10,000 per day will retire in a 2012 report.

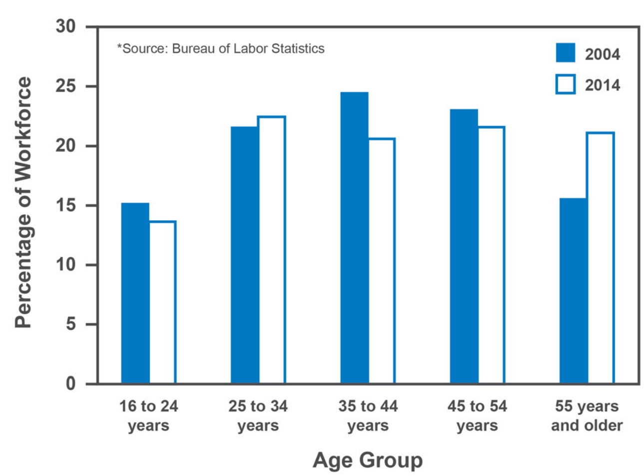


Figure 3: Percentage Workforce by Age
Source: Bureau of Labor Statistics

More Mobile, Younger Workforce

The days of people looking for a 30-year job with a gold watch and a good pension are gone. Younger people have seen their parents go through layoffs and reorganizations. They consider strategic job-hopping normal. According to the Bureau of Labor Statistics, the average worker stays at each job for 4.4 years. Most millennials expect that they will change jobs in less than every three years.

It takes years to learn to be a good board operator or the engineering subject matter expert in a process. The reality is that facilities will have a less experienced workforce.

Smaller Workforce

Today's board operator works at a console with thousands of I/O to monitor and manage. With constant pressure to reduce manufacturing costs more and more, board operators will be demanded to run the process safely and efficiently with larger spans of control.

Training Costs

With the above-mentioned workforce issues, training will be a major problem.

According to John Grubbs, author of Surviving the Talent Exodus – 2011 and Leading the Lazy – Early 2015:

- ~90 million baby boomers (1946-1963) are retiring at a rate of 12k per day since 1-1-11
- ~40 million Generation Xers (1964-1980) cannot fill the vacuum created by the exodus of boomers
- ~70 million Generation Years AKA Millennials (1981-2000) are the future workforce
- By the year 2020, close to 50% of all workers in the US will be Gen Y Millennials
- The baby boomers are very loyal and will spend 20-30 years with one company
- Gen X average tenure with one company is 5 years
- Gen Y average tenure with one company is 16-18 months – He calls them the nomadic generation

"Organizations that don't emphasize training and development will spend the majority of Gen Y's tenure in poor training and about the time they reach competence; these young workers will move on to the next company. Only those companies that can accelerate the time it takes to make a young worker competent will benefit from this investment."

Green and Brown Field Project Expectations

Projects have ever-growing expectations. There is pressure for timelines to be shorter to get to market in a competitive environment, expectations for cutting costs and being efficient with capital, and rising expectations for plant performance when they come online. Plants need to come up smoothly and safely with no environmental or safety issues while meeting ISA 18.2 alarm loading standards from OSHA as RAGAGEP.

How State Based Control Can Help

The implementation of state based control through standard reusable architecture can improve the profitability and performance of manufacturing from the initial design throughout the operating life of the facility.

Knowledge Capture Through State Based Control

Having a well-designed state based control system is a way to guarantee that the knowledge necessary to operate a facility is captured for future use after the retirement of experienced employees. Capturing the knowledge in state based control gives a complete means of capturing the operating expertise of startup, normal run conditions, shutdown and abnormal conditions. Capturing knowledge into state based control is an efficient way to retain, use and proliferate the knowledge. The time to do it is now, before the knowledge leaves the workforce.

Leverage Reusable Control Technology

State based control has been implemented and standardized for some time through ISA S88. It is often associated with batch processes but works equally well for continuous processes. S88 was written to improve efficiency. It provides a standard way to specify equipment and control modules in an architecture that can be re-used. ISA 106 Procedure Automation for Continuous Process Operations is in development.

Control modules, equipment modules and unit modules are re-usable components for the control design which are designed in a generic form to reuse in specific applications. For instance, one reactor may be charged with a number of things, and a plant may have multiple reactors leading to many charges. Some of the charges may be by weight or others by integrated flow. In the end, one equipment module can be designed using different control modules for all of the charges. The state based control and dynamic alarm rationalization can be designed into the charge equipment module and reused where needed. On a high level, unit modules are made by combining equipment modules, and equipment modules are made by combining control modules. Control modules interface with the instrumentation and many of the differences in the process can be isolated in the control module level. For instance, two reactors in the same service, in different locations, may charge the same component. In one location a weight change is used, and in the other, an integrated flow is use. A control module can be built for each and plugged into the same charge equipment module. That equipment module plugs into the same unit module that can be reused for each application.

One recent project was implemented with this architecture. It took 30% of the time to complete versus a standard architecture.

Instrument and Alarm Justification

Throughout the design process, control engineers, process engineers and equipment subject matter experts should be involved in justifying all instrumentation by its intended purpose. The instrument may be for the safety instrumented system, control, alarming, troubleshooting, regulatory or accounting purposes. Dynamically rationalize alarms in accordance to the corporate alarm philosophy to both determine the correct alarms to have for the process and the instruments required. More of the work may be shifted forward, but I/O creep and the associated costs are eliminated, resulting in improved capital efficiency, lower cost and higher quality.

Coordinated Safety Response

(Beyond a Safety Function, A Safe State) Beyond the safety instrumented systems ability to keep the plant safe by interfacing with the instrumentation identified in the hazard analysis, state based control takes the entire unit operation to a safe state. Other units respond by moving to their appropriate states in response. For instance, you may have a Safety Instrumented Function (SIF) that cuts the steam to a reactor on a high pressure. With state based control, you could define a safe state for the reactor that would perform the actions that the operator would have to take in this scenario. The transition to this state could come from the high pressure or other causes. The safe state, once created, can be used for any number of scenarios the user thinks are appropriate. In this state, the control system would take actions that the operator might need to take, such as cut the steam, cut off the feed, put on full cooling and open the vent to the flare heater automatically and immediately. In addition to the safety function, alarms are dynamically managed so that only alarms that are applicable are enabled.

Therefore, there is no alarm flood to confuse the situation. The reactor trip is an identified degradation scenario. A degradation scenario is a case where something has happened in the plant which the other units need to respond to in order to keep the facility in the maximum possible readiness to return to normal operation. Beyond handling the issues to safely manage the reactor, the reactor unit will communicate to the other up and down stream units that it has tripped. The other units can respond by going to the appropriate state to minimize the time required to come back online. For instance, the back end of the plant can put itself on recycle. When the reactor is restarted and seen to be in a normal run state, the back end of the plant can leave the recycle state and continue with normal operation, minimizing any impact to production. A crude unit, for instance, can have a similar response for a crude tower heater trip and automatically recycle the back end.

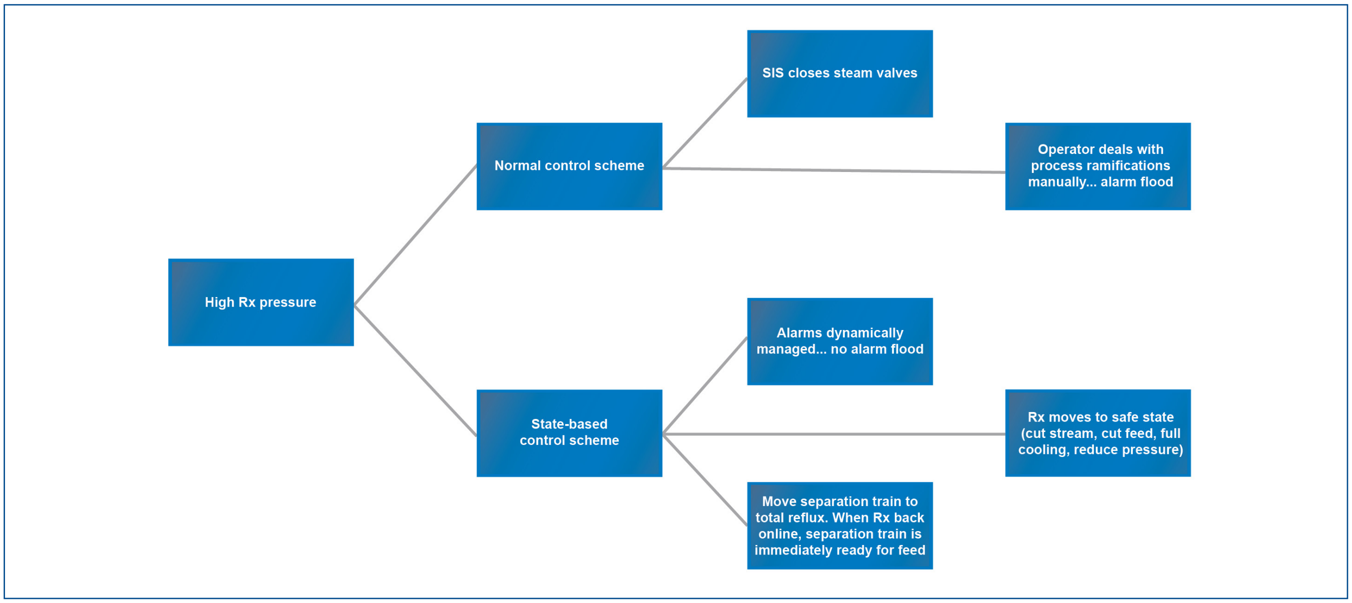


Figure 4: State Based Control Process Coordination

Avoiding a Safety Response at All

Better than handling a safety response well is not having one. Some analysis has been done linking unplanned events to alarm rates and the level of automation of a facility, with the facilities divided into four quadrants. There was a strong relationship between unplanned events and the quadrant a plant was in. Illustrated in figure 5 below, Quadrant 1 was the best case with low alarm loading and a high level of automation, and Quadrant 4 was at the other end of the spectrum with high alarm loading and a low level of automation. Not surprisingly, Quadrant 1 plants had the lowest level of unplanned events, and Quadrant 4 plants had the highest level of unplanned events over the period studied.

Quadrant 2	Quadrant 4
High Alarms High Automation	High Alarms Low Automation
Quadrant 1	**Quadrant 3**
Low Alarm High Automation	Low Alarms Low Automation

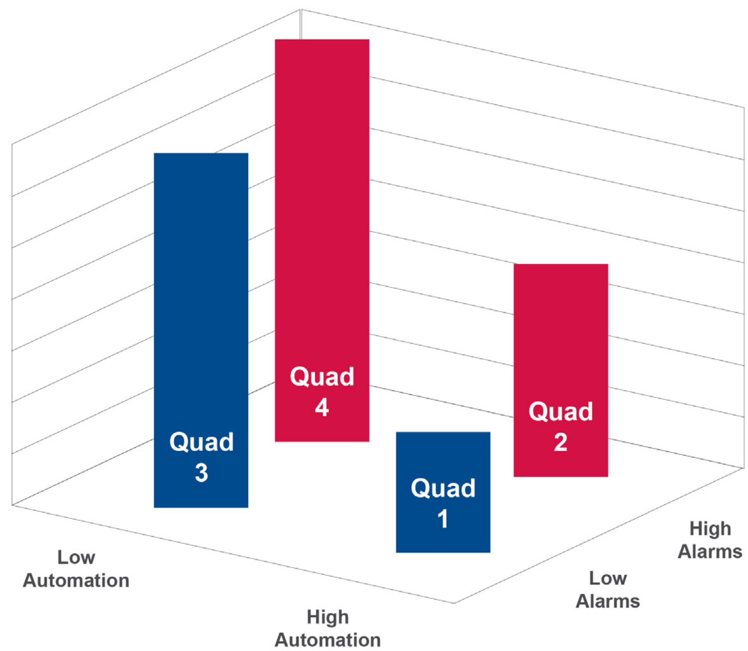


Figure 3: Relative Unplanned Events by Quadrant

Interestingly, Quadrant 2 plants that had high alarm loading but also a high level of automation had less unplanned events than Quadrant 3 plants with low alarm rates and a low level of automation.

Moving from a quadrant number to one lower reduced the unplanned events by about 2 – 3 times per thousand I/O over the period studied. So, lowering the alarm rate and moving a plant from Quadrant 4 to Quadrant 3 would reduce the unplanned events by 2 to 3 times over a similar time period, but raising the level of automation and moving from Quadrant 4 to Quadrant 2 would have twice the effect on unplanned events. As we know, unplanned events are costly and dangerous.

To put it in perspective, the takeaway here is that lowering alarm rates is a powerful tool to reduce unplanned events. Raising the level of automation can have twice the impact. The surface has twice the slope on the automation axis as the alarm loading axis. Doing both is of course the best and moving from Quadrant 4 to Quadrant 1.

Asset Utilization

State based control has also been seen to increase asset utilization. Some key areas of lost asset utilization such as equipment failures, operating discipline issues, and reprocessing can be significantly reduced through automation.

Conclusion

State based control is a viable option to improve the design process through the use of standard reusable architecture and instrument and alarm justification. It reduces time and costs and improves quality. State based control maximizes the investment in the DCS by capturing knowledge in the form of operating discipline that can be leveraged with greatly reduced training costs in a dynamic workforce. Safety and operability are enhanced through the uses of safe states in units and the communication between units to optimize the response to degradation scenarios. Operators are in a position to manage the process through state changes while having their heads up to see the big picture - avoiding problems and optimizing performance.

State based control allows project teams to meet and exceed the rising expectations they are challenged with.

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