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Improvements in Transmission Control Center Alarm Management Practices

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SUMMARY

The subject of alarm management in transmission control centers (TCCs) has risen in significance in recent years because the volume and complexity of the alarms received in control centers have been increasing. The operators have expressed interest in better alarm management philosophies, processes and tools.

During 2014-16, EPRI conducted 2 workshops, 2 surveys and 3 site visits to learn about alarm management practices followed by TCC operators. From these workshops, survey responses and site visits, a set of observations regarding the current alarm management practices was derived. Based on these observations, opportunities to improve the current alarm management practices were identified. These improvement efforts are currently underway and the results to date are summarized in this paper.

KEYWORDS
Alarm Management
Human-Machine Interface (HMI)
Transmission Control Centers
Energy Management System (EMS)
Distributed Control System (DCS)
Power System Event Analysis

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1. Introduction

The subject of alarm management in TCCs has risen in significance in recent years because the volume and complexity of the alarms received in control centers have been increasing. The operators have expressed interest in better alarm management philosophies, processes and tools.

During 2014-16, EPRI conducted 2 workshops, 2 surveys and 3 site visits to learn about alarm management practices followed by TCC operators [1, 2, 3]. Figure 1 shows the results of a survey conducted in 2015 of TCC staff to identify critical alarm management issues [1]. The observations from the workshops, survey responses and site visits were then weighed against the ideal alarm management practices [4,6,7,8,9]. As a result, several opportunities were identified to improve the TCC alarm management practices, processes and tools. These observations and improvement opportunities are described in this paper [4, 5]. Industry efforts underway to address the suggested improvements are also presented in this paper.

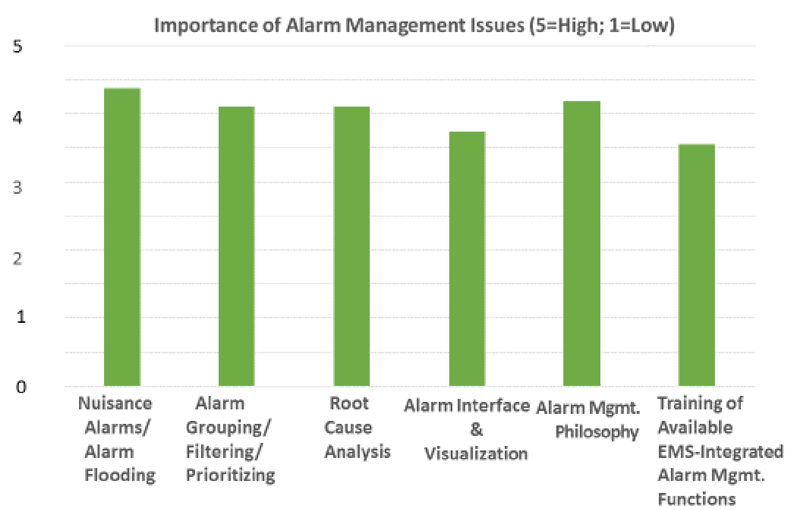

Figure 1: August 2015 Survey of TCC Staff on Important Alarm Management Issues [1]

2. TCC Alarm Management Practices – Observations and Improvement Opportunities

2.1 Alarm Management Philosophy

2.1.1 Observations

TCCs do not seem to have a formal alarm management philosophy document as a reference that provides a comprehensive set of guidelines for the development, implementation, operation, maintenance, and modification of TCC alarms. In accordance with the ISA-18.2 and IEC 62682 international standards on Alarm Management, such a document provides a consistent process and an optimum basis for alarm selection, priority setting, configuration, response, handling methods, system monitoring and other alarm management issues.

A properly configured and maintained alarm system reduces operator distraction that could lead to potential errors.

Developing an alarm philosophy is integral to a successful alarm management program and should be one of the first tasks completed as part of any alarm management program. It should be noted that some of the companies have started to develop such a document.

2.1.2 Improvement Opportunities

Reference [4] gives principles and details of alarm management practices. It also contains an example Alarm Philosophy Document structure and content [6,9]. This material was prepared in response to the high priority assigned by TCC staff surveyed for developing an alarm management philosophy document per Figure 1 [1]. It is hoped that this material will provide a reference for TCCs to compare their current alarm management practices with the ideal practices, and to revise their current practices as they find appropriate.

2. 2 What Constitutes an Alarm?

2.2.1 Observations

TCC alarms consist of scrolling data strings on operator consoles that can be categorized as:

- actionable in immediate timeframe (within 30 minutes); or
- system status information for operators' situational awareness; or
- pass through information that does not require any operator awareness or action.

The operator response time could, in current practice, range from immediate (e.g. within 30 minutes) to several hours, to days, depending upon the nature of the alarm condition. However, best practices for alarm systems are that an alarm should carry a sense of urgency, and the time frame should be relatively short. In its current state, specific response to an alarm from an operator could be:

- to immediately operate supervisory-controlled equipment,
- to immediately dispatch a field crew,
- to revisit or re-evaluate the alarm condition hours or days later,
- to simply passing on the alarm condition to equipment personnel,
- or to do nothing.

It seems that a very low percentage of TCC alarms fall into the "actionable" category. In 2017, further analysis of several million alarm records from TCCs has verified this to be true. A vast majority of alarms consist of "system status information" such as equipment status, substation door status, voltage magnitudes that do not represent an abnormal condition, etc. Some alarms appear routinely (e.g. early morning voltage alarms), and are only acknowledged, requiring no action. A field crew working at a substation can generate door or equipment status alarms, which are acknowledged and then ignored or revisited as necessary. An example of "pass through" alarms includes performance issues of a non-critical equipment that need to be addressed by field crews at their discretion (i.e. not requiring immediate dispatching by the operator).

These occurrences of TCC alarms differ from the definition of an alarm in International Society for Automation (ISA) and International Electrotechnical Commission (IEC) standards [7,8], which is as follows: *An alarm is "a visible and audible notification to the operator, of an equipment malfunction, process deviation, or abnormal condition, requiring a timely operator response."*

Per the ISA/IEC definition followed in many process industries, an alarm is a "push notification" to the operator, an annunciation designed to intentionally interrupt the operator to bring his/her attention to the condition disclosed by the alarm.

To be effective, an alarm system should be reserved only for items fully meeting the definition of an alarm, and anything not meeting the definition, particularly miscellaneous status information, should be separated from the alarm system and indicated using other methods. This separation allows the operator to focus on issues needing immediate attention without any distraction or potential for obscuration, while indicating the system status or status change type information (for situational awareness) separately, since it is usually of lesser importance than the "actionable" alarms.

2.2.2 Improvement Opportunities: Segregation of Actionable Alarms from Status Notifications

EMSs have the capability to sort and filter these combined notifications received by the alarm systems. The following actions could make the EMS alarm system more effective:

- The actionable alarms in the EMS must be identified. These are the notifications that meet the ISA definition of an alarm. They must receive coding that allows them to be segregated in the EMS and displayed on a filtered list that shows only these alarms and not the status events. Note that the observed percentage of actionable alarms was quite small compared to the total EMS listings.
- The resulting actionable alarms should be assigned priorities by currently known and widely used best practice methodologies.
- The chosen alarms should be rationalized to ensure that their set-points or the logic conditions driving their annunciation always produce actual alarms. Operator input is essential for effective alarm rationalization.
- The EMS must then be configured such that a separate actionable alarm-only window can be displayed. This could be called the TCC ALARM SYSTEM.
- A different EMS window (or windows) is also configured to contain all other status notifications that are currently designated as "alarms" in the EMS. The actionable alarms will not be shown in this window(s). This could be referred to as the TCC STATUS INDICATION SYSTEM.
- The notifications indicating pass through information that does not require any operator awareness or action must be segregated, even from the TCC STATUS INDICATION SYSTEM, and passed on directly to the interested staff. Large quantities of irrelevant notifications act to obscure the items of importance to the operator.

The result of the segregation is intended to be the following:

- No changes in Operator HMI methodologies are needed for this step. Operators continue to have everything they currently have, just better segregated.
- No new hardware or software is needed.
- Nothing is lost to the operator.
- Alarms needing operator action become prominent.
- Alarms become easy to find.

Visually, Figure 2 shows the segregation into: 1) EMS Alarm System; and 2) EMS Status Indication System.

2.3. EMS Alarm System

The segregated Alarm System is expected to have far fewer occurrences of alarms, compared to the existing system. Further, the alarms can be divided into various priority bands and arranged in reverse chronological order, as shown in bottom left part of Figure 2.

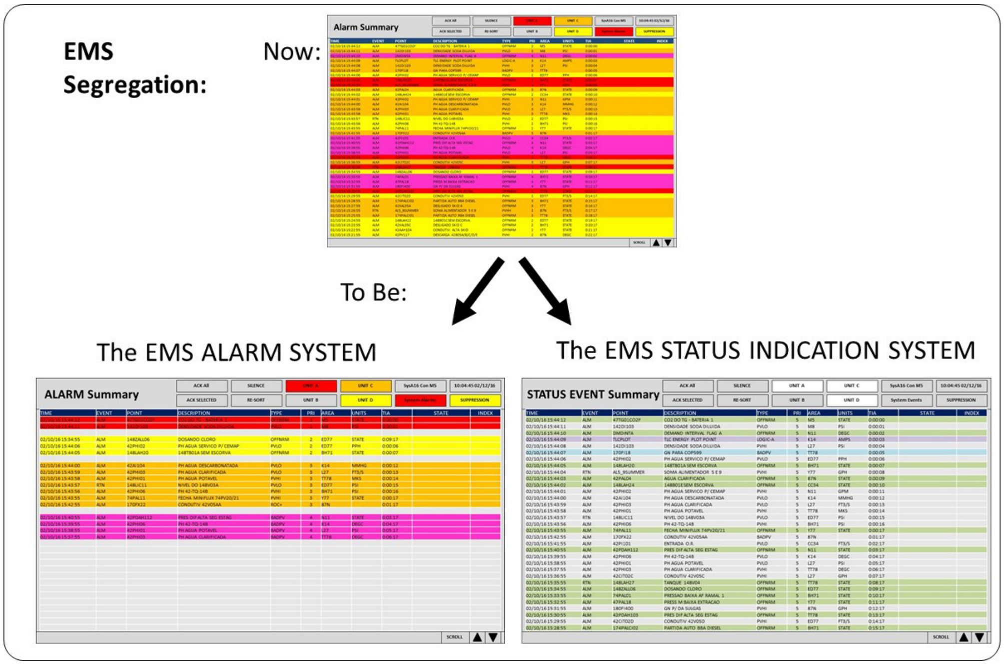

Figure 1: EMS Alarm Data Segregation

The EMS Alarm System will exclusively contain the “actionable” category of alarms that meet the ISA and IEC accepted definition of an alarm.

- Proven Alarm Rationalization practices are used to identify existing items that meet every element of the definition of an alarm.
- The alarms placed in TCC Alarm System can utilize four meaningful priorities determined by known best-practice principles.
- Alarm setpoints of analog values will be based on the boundary of the value achieving an abnormal condition for which operator action is needed. The same will be true for alarms based on logic conditions. Alarms are not to occur when the process is within the normal, expected range of operation.
- Methods for the controlled temporary suppression of alarms are provided.
- Operators are trained as to the importance of actual alarms and how they are dealt with.

2.4 The EMS Status Indication System

This system will house the system status indications for <u>operator situational awareness</u> that <u>do not meet</u> the definition of an alarm. This separate system or view, indicated in the bottom right corner of Figure 2, is still part of the operator’s toolset.

- A separate EMS screen (or screens) filtered to only these items is created.
- If possible, the "pass through" category of alarms will not be a part of the TCC Status Indication System; ultimately, these categories of notifications can be routed directly to those who need that information, mainly equipment owners/operators, maintenance dispatch, and field crews.
- The categorization method will be applied to enable this segregation, and depend on the capabilities of the particular EMS.
- Sorting of status indication events by type, category, chronology or other desirable attributes should be enabled.

It may not be desirable to have multiple "priorities" in the System Status Indication part of the EMS. Note that other industries do not "prioritize" non-alarmed status changes in equipment. It is therefore recommended that there be no status indication priorities. (Note: If the EMSs require priorities to be defined, all notifications in this part of the system should use the same priority, or priority might be used simply as a sorting mechanism but only if another key is not available.)

2.5 Alarm Priority – Observations and Improvement Opportunities

TCC Alarm priority is currently used inconsistently, and is usually associated with the "type" or "category" of alarm and not the specific alarm's "importance." In some cases, priority was simply another sorting mechanism on the display, not conveying importance. In one reported scenario, all alarms were termed to be important and therefore Priority 1, which defeats the useful nature of having priorities.

The purpose of alarm priority is to convey relative importance of an alarm. As shown in Table 1 [9], a best practice use of priority is based on the nature and severity of the consequence if the alarm does not get a response, and the time available to the operator to make that response. The intent is that the operator will always be doing the right thing by responding to alarms in priority order.

Table 1: Alarm Priority Determination Criteria

Alarm Priority Determination				
	Severity of Consequences			
Time Available	None	Minor	Major	Severe
> 30 Min	No Alarm	Re-engineer Alarm for Urgency, else use P3		
15 - 30 Min	No Alarm	Priority 3	P3	P2
5 - 15 Min	No Alarm	P3	P2	P2
<5 Min	No Alarm	P2	Priority 1	Priority 1

A desirable distribution among priorities is as follows [6,7,8,9]:

- Priority 1: 5% (Immediate Action; Largest Consequences)
- Priority 2: 15% (More time to react, but still important; Lesser Consequences)
- Priority 3: 80% (Still more time to react; Minor Consequences)

2.6 Alarm System Performance Monitoring: Observations and Improvement Opportunities

In other industries, alarm system performance metrics commonly include the following key performance indices (KPIs): alarms per day, per hour, alarm floods, frequent alarms, stale alarms, chattering and fleeting alarms, alarm suppression, etc. [1]. Monitoring of such metrics is an industry-wide common practice and is a requirement of international standards.

The TCCs do not routinely keep track of such metrics. No reports are produced and it is not clear, for some EMSs, whether there exists a way to generate such reports. (Note that third-party software to accomplish this is available, if the EMS vendor does not supply the capability.) Various TCCs estimated the number of alarms received by an operator ranging from several hundreds to over a thousand per day.

Since those estimates, further ongoing work in analyzing several million records of alarm data from different TCCs indicates that alarm rates of several thousand per day are common, with peaks into the tens of thousands.

It was observed that alarm naming conventions were inconsistent and some of the alarms had been in effect for days/ weeks/ months.

Table 2, taken from the ISA-18.2 standard [7], summarizes performance metrics. Note that the standard describes the “minimum acceptable” and not the “optimum.” One of the first steps in improving the TCC alarm system is to baseline its existing performance using the metrics of Table 2.

Table 2: Alarm System Performance Metrics (ISA Standard 18.2)

Alarm Performance Metrics Based upon at least 30 days of data		
Metric	**Target Value**	
Annunciated Alarms per Time	Target Value: Very Likely to be Acceptable	Target Value: Maximum Manageable
Annunciated Alarms Per Day per Operating Position	~150 alarms per day	~300 alarms per day
Annunciated Alarms Per Hour per Operating Position	~6 (average)	~12 (average)
Annunciated Alarms Per 10 Minutes per Operating Position	~1 (average)	~2 (average)
Metric	**Target Value**	
Percentage of hours containing more than 30 alarms	~<1%	
Percentage of 10-minute periods containing more than 10 alarms	~<1%	
Maximum number of alarms in a 10 minute period	≤10	
Percentage of time the alarm system is in a flood condition	~<1%	
Percentage contribution of the top 10 most frequent alarms to the overall alarm load	~<1% to 5% maximum, with action plans to address deficiencies.	
Quantity of chattering and fleeting alarms	Zero, action plans to correct any that occur.	
Stale Alarms	Less than 5 present on any day, with action plans to address	
Annunciated Priority Distribution	3 priorities: ~80% Low, ~15% Medium, ~5% High or 4 priorities: ~80% Low, ~15% Medium, ~5% High, ~<1% "highest" Other special-purpose priorities excluded from the calculation	
Unauthorized Alarm Suppression	Zero alarms suppressed outside of controlled or approved methodologies	
Unauthorized Alarm Attribute Changes	Zero alarm attribute changes outside of approved methodologies or MOC	

2.7 Graphics/HMI

The combination of the process graphics and the alarm system makes up the HMI – the Human-Machine Interface between the operator and the process. Alarms cannot be discussed without taking into consideration the accompanying graphics. A proper response to an alarm will involve examining the process around the alarmed condition. [10,11]

The TCC graphics contain many opportunities for improvement and optimization. They primarily consist of multiple tables of numbers, and of one-line drawings. It is a best practice that any alarmed condition is also shown on any graphic depicting that part of the process. However, the EMS alarm conditions are not always indicated in the tables, and rarely on the one-line diagrams. When alarm conditions are shown, it is usually via color only, which is not in accordance with effective best practices. Per best practices [5,10,11], color must be used consistently. People have several types of common color-detection deficiency (e.g., red-green, white-cyan, green-yellow). For this reason, the most important rule for color is this: ***Color, by itself, is never used as the sole differentiator of an important condition or status.***

The current best practices in HMI have shown that it is difficult for an operator to easily achieve a sustained, high level of situation awareness by periodically looking at multiple tables of numbers, dozens of graphics covered in numbers, and at scrolling lists of status changes. Much better methods for providing operator situational awareness are now known.

Transmission is alone in industry in the use of scrolling lists of status changes as the primary method by which operators manage alarms and maintain situation awareness. In other industries, the operator is provided a set of process control graphics that represent the process they are responsible for controlling. Changing conditions are shown on the graphics – process values, equipment states (on/off, etc.), trends, quality parameters, etc. In general, these depictions show the process in a diagrammatic view.

In other industries, alarms appear on an alarm summary list, similar to that in a TCC alarm system. The operator's response to the alarm is to investigate to determine the reason for the alarm and the right action to take. This is done via the graphics – the operator examines the part of the process where the alarm is occurring. The graphics provide the investigatory interface and the capability to take control actions. All alarmed conditions are shown on the graphics – the intent is that it should be easy to see the "what and where of the alarm condition" when viewing a graphic [10,11].

In recent years, many deficiencies in "traditional" graphics have been identified (including in power generation), and much-improved methods for operator situation awareness via graphic display are being adopted throughout all these industries [4, 10, 11].

2.7.1 Observations

The TCC "graphics" primarily consist of multiple tables of numbers, and of one-line drawings. It is a best practice that any alarmed condition is also shown on any graphic depicting that part of the process. However, the practice of indicating EMS alarm conditions in the tables or on the one-lines is not followed uniformly across various TCCs.

The TCC one-line drawings are surprisingly uniform across multiple TCCs and different EMS vendors. In general, the one-lines present substantial opportunity for improvement, to be in alignment with modern practices now becoming common in other industries. This is for the following reasons related to the one-line diagrams:

- They depict raw data, with little informational context. The operator's individual mental map, obtained through years of experience and significantly variable between operators, is the only source of operational context.
- They should show if any elements depicted are in an alarm condition. Alarm conditions should be clearly shown on any operating graphic in a way that stands out.
- The designs are complex "wiring diagrams" that could be improved by following human factors design principles of element visibility, contrast, logical arrangement, minimal line crossings, and containing operational context.
- The dynamic elements on the screen should be clear in their presentation, and not be tiny, difficult to see, and with little visual distinction when different states are shown (such as being small squares that are either red or green, with no other recognition coding).
- Displayed text should be readable without considerable "zooming-in" to be legible, which can result in the surrounding portions of the process to be off-screen.
- The "size" of a graphic, when the text is legible, should be such that considerable 2-way scrolling (horizontal and vertical) is not necessary. If zooming in/out and scrolling is required to use a graphic, it can easily be an impediment to an operator's evaluation and resolution of an abnormal situation. A proper design practice is that graphics are designed

to fit on the physical screen, be logically arranged, and be legible to the operator at normal screen zoom. The need for vertical scrolling should be very rare. The need for horizontal scrolling should be eliminated.

- Element labeling should be consistent, and the arrangement of various elements on the one-line should not be haphazard.
- Graphic navigation should be consistent and straightforward. It should not involve multiple clicks, choices, and typed entry of text names. There are practices by which an operator can navigate from any screen to any other screen in two clicks.
- The one-line diagrams are all at the highest level of detail and have no hierarchy, basically reflecting a Level 3 view. That is not an issue – Level 3 graphics are needed. But, an operator should have screens providing a good overview of their area of responsibility, consisting of more than just tables of numbers. The generally accepted principle is that graphics should be designed and supplied in a hierarchy (Level 1, 2, 3, 4) to show progressively more detail of the system, as needed by the operator.
- Displayed trends should be in abundance as they are vital for providing situational awareness. There is a significant paucity of trends on display in the TCCs surveyed. This reflects that the 'trend-on-demand" capability of an EMS is underutilized. Embedded trends are preferred.
- Analog representations of important values, which provide for significantly better situational awareness, should be used.
- Color must be used consistently and appropriately. Color should be used to increase the visibility of abnormal conditions. Poor color choices and use can actually impede the ability for abnormal conditions to stand out on the graphics.
- Important conditions should not be shown by simple color change, particularly using recognized-as-suboptimum color choices. Redundant coding is a necessary component in the proper use of color.

A TCC graphic improvement effort could substantially improve the operator's ability to obtain and maintain situational awareness, and is highly recommended [10,11].

2.7.2 Improvement Opportunities and TCC HMI Path Forward

TCCs do not need to modify or "get rid of" any graphic representations that already exist, in order to make an improvement.

Current best practices in HMI have shown that it is difficult for an operator to easily achieve a sustained, high level of situation awareness by periodically looking at multiple tables of numbers, and at scrolling lists of status changes. Better methods for providing operator situational awareness are detailed in References [4,10,11]. These methods have been successfully deployed by other industries to redesign their HMIs.

This report recommends the addition of 20 to 30 new Level 1 and 2 graphics, specifically designed in accordance with modern HPHMI principles, to be added to a TCC EMS. Such an addition is neither expensive nor disruptive.

Based on experience in power generation and other industries, it is likely that such new graphics will significantly increase operator situational awareness, and enable better detection and resolution of abnormal situations.

When improvement is demonstrated, then over time, changes and improvements in other EMS graphics, such as the one-line diagrams, could be evaluated and phased in.

2.8 Summary

The following steps are suggested to improve the performance and efficiency of the TCC alarm system:

1. Develop and adopt an Alarm Philosophy Document.
2. Monitor the Alarm System Performance via key performance indices (KPIs) commonly accepted and utilized in other industries.
3. Identify and resolve the most frequent and nuisance alarms, and have on ongoing responsibility to address such conditions.
4. Perform a specific type of Alarm Documentation and Rationalization, resulting in the identification of actual alarms in the EMS.
5. Segregate the EMS into two sections – the ***EMS Alarm System*** and the ***EMS Status Indication System***.
6. Implement Management of Change of the alarm system configuration.
7. Application of Advanced, Real-Time Alarm Management techniques and strategies if needed after the basics are accomplished.
8. Add new Level 1 and 2 graphics (~20 in total), designed in accordance with the proven high-performance principles, to the EMS.

3. Baselining of FirstEnergy's Akron TCC Alarm System

The first step in improving a TCC alarm system is to baseline ifs performance usina the KPIs mentioned in section 2.6. Accordingly, historical alarma data of sévira Tics have been analyte to compare how well they match with ideal alarm management practices and what specific steps should be taken for improvement. Frequent and nuisance alarms have also been identified for potential quick success. The baselining analysis performed for FirstEnergy's Akron TCC alarm system is discussed below.

3.1 FirstEnergy Transmission Control Center Background

FirstEnergy has approximately 17000 miles of transmission lines and a peak load of over 35,000 MW. The system is broken into three control areas, West, East and South that operate out of two control centers. Each control area is broken into three switching desks and one reliability coordinator desk. The four desks are each manned by one operator 24/7 with additional operators on switching desks during normal business days. Alarms that are received at each desk are controlled by area of responsibility (AOR) designation that are assigned to each device.

For the baselining analysis, one of the switching desks in the West control area was chosen to analyze the alarms received over a six-month period during October 2016 to April 2017. This area is composed of 345KV and 138 KV Bulk Electric System lines and substations with some 69 KV and 36 KV sub-transmission.

3.2 Baselining Analysis Objective and Scope

The metrics presented in Table 2 were used to analyze a total of 275,565 alarms received at a switching desk for a period of six months. It should be noted that not all these alarms have to be acknowledged by the operator, but all are presented in the alarm viewer. The scope included:

a) measure the performance using Table 2 KPIs,
b) identify frequent, nuisance and chattering alarms for potential quick success improvement,
c) identify alarms that seemed problematic for various reasons or to be indications falling outside the definition of an alarm, and
d) review the alarm priority assignment.

The events were analyzed using the Alarm Analysis module of PAS's PlantState Suite alarm management software. The software imports the supplied event data and provides for multiple analyses including alarms per time period, alarm flooding, most frequent alarms, alarms by type and priority, chattering, fleeting, and stale alarms, and several other categorizations.

3.3 Baselining Analysis Results

Fifty different categories of alarms were analyzed. The analysis showed that 133,305 alarms (48%) were to flag a return-to-normal condition. Such notifications are not truly alarms and can be presented in some other way to reduce operator burden and improve alarm system effectiveness.

3.3.1 Average Alarms Per Day

Table 3 shows the analysis results. Per ISA standards, the alarms per day target should between 150-300 alarms per operating position. The average "non-normal" alarms per day are 5 to 10 times the target values. The operator burden during peak periods was high.

Table 3: Baselining Analysis of FirstEnergy Akron TCC Alarm Data

	Average	Median	Peak	Minimum
All Alarms	1522	1209	7283	381
Events Signifying Return-to-Normal	736	602	2771	210
Rate excluding Return-to-Normal	786	587	6467	171

Further analyses provided for a "what-if" analysis. Examination was made on the effects of eliminating return-to-normal alarms, fixing chattering behavior, resolving the most frequent alarms in several categories, and omitting some alarm categories identified as likely not indicating abnormal conditions. These are all straightforward and achievable tasks.
The results of these changes, shown in Figure 3, illustrate the potential for a significant improvement in alarm system performance. The result would be an average of 337 alarms per day, with many time periods within the ISA guidelines. This is comparable the alarm performance of dozens of power generation plants at their beginning of successful alarm improvement efforts. Power generation plants have consistently achieved industry-standard performance levels by following the principles of alarm management.

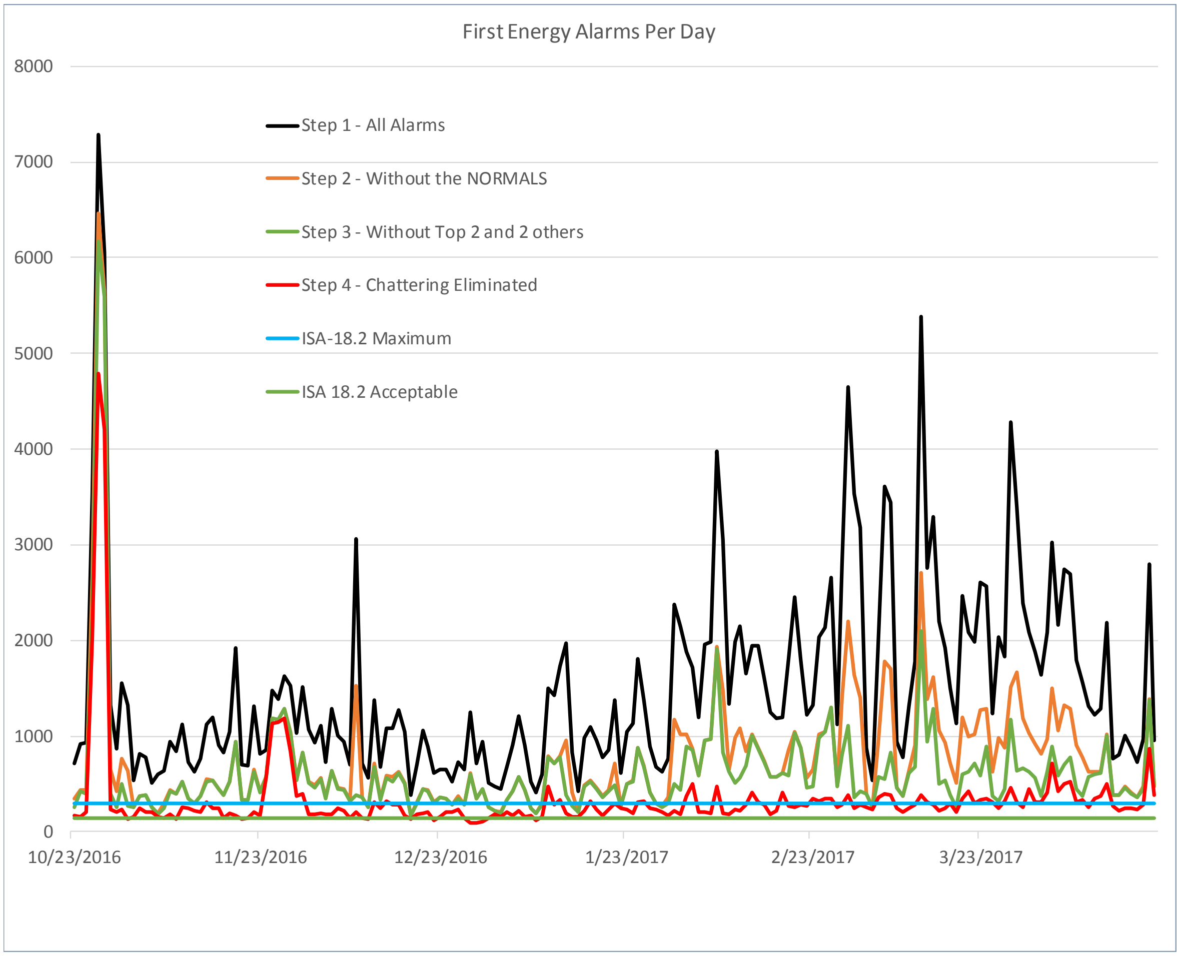

Figure 3: "What-If" Scenarios to Identify Improvement Potential for FirstEnergy Akron TCC Alarm System

3.3.2 Alarm Flooding

ISA standards define alarm flooding as beginning when 10 or more alarms occur in a 10-minute period. If all alarms received are considered (including return-to-normal), this desk was almost in a constant state of alarm flooding. If the return-to-normal alarms are excluded, then the desk was in an alarm flood state 26.3% of the time.

3.3.3 Chattering Alarms/Frequent Nuisance Alarms

A single device at one substation accounted for 11.4% (34,502) of all the alarms. A transformer alarm accounted for 9% (23,772) of all the alarms and 7 door alarms accounted for 10,606 alarms. Door alarms alone averaged 126 per day with a peak of 467. Ideas to make door alarms meaningful were provided with the analysis. The study pointed out the need to regularly benchmark alarms to identify these situations so that they can be corrected.

The following three types of alarms were most most frequently received: 1) Communication Non-Critical 18.8%; 2) Voltage 18.1%; and 3) Other Communication 17.7%. Most of these alarms did not require an action by the operator.

3.3.4 Alarm Categories and Prioritization

Section 2.5 outlines the ideal approach to assign priority to an alarm based on its importance. It also presents a desirable % distribution among various priorities. The analysis showed that FirstEnergy alarm priorities were not assigned based on importance, but were primarily based on categories, assuming all alarms within a category had the same importance. For example, 36% of alarms were priority 2 and included all voltage alarms.

3.3.5 Lessons Learned

- Alarms being received by operators should be reviewed on a regular basis to identify chattering and nuisance alarms.
- Large percentage of alarms are being generated by only a few points.
- The operators are being asked to determine which alarms are most important and which alarms can be ignored. Instead, the alarm system should be designed to automatically flag important and non-important alarms.
- Focusing on a few items at first can make a huge difference in the number of alarms received by operators.

3.3.6 Next Steps

- ■ Address the chattering alarms
- ■ Evaluate the Need for return-to-normal alarms.
- ■ Find better ways to address the following alarms:
  - Voltage Monitoring
  - Door Alarms
- ■ Segregate the current alarms into:
  - Alarms (per ISA/IEC definition)
  - Status Indication Information for Situational Awareness
  - Pass Through Equipment Information
- ■ Develop an alarm management philosophy

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Part II: High Performance HMI Case Studies, Recommendations and Standards