Managing Generation Risk at a Coal-Fired Power Station

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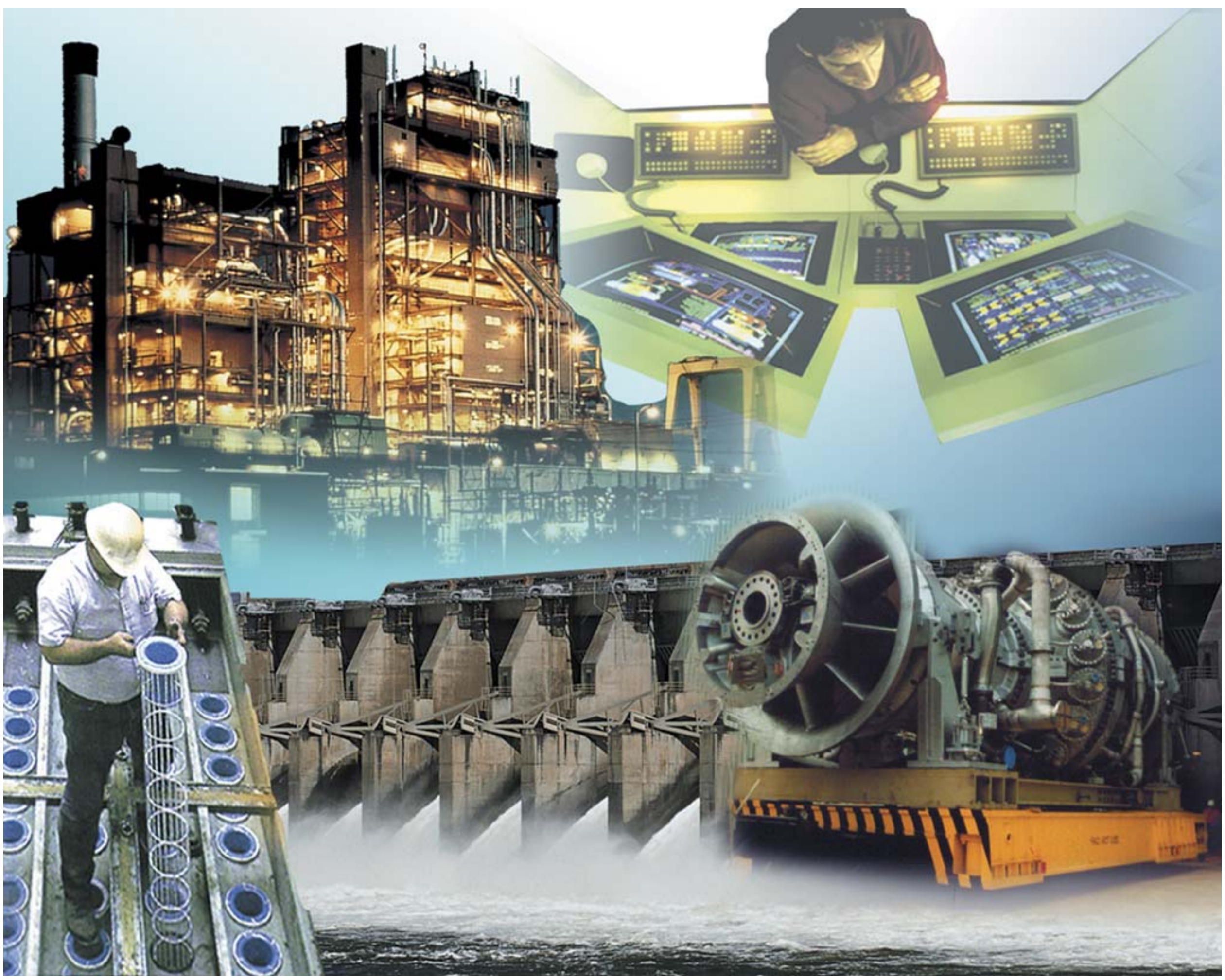

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Technical Update, December 2010

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ABSTRACT

Generation risk assessment (GRA) models have been developed for trial application at several nuclear power stations. These models use the modeling approaches and tools used to develop safety-focused risk assessment models. However, the GRA evaluates the risk to continued plant generation (for example, unplanned shutdown and power reductions).

Previous Electric Power Research Institute (EPRI) research has shown that risk-informed decision-making methods and tools can also be of benefit to fossil-fueled power stations. In this project, the existing GRA technology has been applied to a coal-fired power station to determine the feasibility of using such models and to determine the effort required to develop the models and to use the model in day-to-day operations. Equipment out of service (EOOS[1]) configuration risk management software was developed by EPRI to support nuclear power plant needs, including the evaluation of generation risk. Although the current version of the program was used in this project, a simplified version of the software should suit the GRA needs of the fossil power station community and would make the software easier to use.

Based on initial feedback from the host power station, these models and the EOOS software tool can offer a significant benefit to the plant. Possible uses of the products include advisory support for the shift supervisor, helping to plan and review upcoming maintenance activities, and providing training to junior staff on the impacts of maintenance on plant operation and on the dependencies between plant systems.

Keywords
Generation risk assessment (GRA)
Risk-informed decision making
Trip monitors

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[1] *EOOS* is a trademark of EPRI and Data Systems and Solutions, LLC.

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1 INTRODUCTION

Risk management is the process by which risk is assessed and managed to maximize the likelihood of a successful outcome. Risk management is used in many industries, including the power generation industry. The Electric Power Research Institute (EPRI) report *Using Risk Management as Input to Operational Decisions* (1008251) [1] noted that fossil-fueled power stations use risk management, but it is often through the use of informal, undocumented processes. Risk management is often performed by the shift supervisor, who uses his or her experience to qualitatively assess what would be the best course of action to take for a given situation.

The report [1] noted that maintenance planning and the tagging of equipment for maintenance work are areas in which a more formal process might be a worthwhile investment. Maintenance planning often occurs some period of time prior to when the actual maintenance work is performed. Risks may be assessed during the planning period based on expected plant conditions when the work is to be performed. However, when the equipment is to be tagged out and the work package is to be performed, plant conditions may differ and the risk should again be considered in light of any changes from the assumed conditions.

Nuclear generating stations use risk management of maintenance actions on a routine basis, but most of the activities are focused on maintaining public safety. Some nuclear plants have extended these risk management concepts to include the consideration of economic risks, including the risk of loss of generation capability. A structured, formal assessment of generation risk would equally apply to fossil-fueled generating stations.

This report describes a demonstration project that was conducted at a coal-fired power station. The purpose of the project was to see whether existing tools and modeling techniques that have been developed by EPRI and the nuclear industry could be applied in a cost-effective manner that would assist plant management and operations personnel in implementing a more formal risk management process. The model and tool developed simplifies the process of assessing risk; plant staff must then act to manage that risk through changes in the planned maintenance, implementation of contingency plans, or other measures.

The support provided by the host plant is gratefully acknowledged; the plant personnel provided requested information in a timely manner and are now providing insights that will help to further improve the initial model and should benefit other plants that choose to implement a generation risk assessment (GRA) model in the future.

2 GRA METHODOLOGY

The evaluation of the risks to continued plant generation can use many of the same tools and methods that have been developed to assess safety risk. The nuclear power industry has refined various analysis techniques (such as fault tree analysis) and has developed software tools to allow risk to be quantitatively evaluated by operations and maintenance (O&M) personnel. Several power stations have developed generation risk models and have used these models on at least a trial basis. The EPRI reports *Generation Risk Assessment (GRA) Plant Implementation Guide* (1008121) [2] and *Trip Monitor Customization and Implementation Guideline* (1009112) [3] cover the process used to develop such models and how they can be implemented in a software tool for use by plant personnel.

The primary purpose of the models developed for this project was to implement a tool to assist plant personnel in planning maintenance and in evaluating the relative risk of an undesired event as a result of maintenance actions. These undesired events could occur either because the removal of equipment from service could have a direct impact on the plant or because the removal of equipment from service could make the plant more vulnerable to the effects of an additional component failure.

A secondary objective is to provide training reference material to capture risk knowledge from senior operations staff to be used to train new staff. Experienced plant personnel already understand the impacts of various component outages on plant operation; however, less experienced personnel may not fully understand these impacts.

Several distinct types of generation risk can be considered. Two principal categories addressed in this project are the risk of an unexpected plant shutdown and the risk of a forced power reduction. These events could be due to random component failures, human errors that resulted in abnormal system operation, maintenance actions, changes in system operating alignment, or the presence of specific environmental conditions that can impact plant operation.

The development of a generation risk model is similar to that developed for safety models. However, the model structure is focused on determining the expected frequency of the initiating event (that is, a plant trip/shutdown or derate).

The first step of the process is to determine which systems can cause a plant trip or derate. Although many plant systems can have these effects, not all plant systems need to be considered. Some system failures may still permit plant operation for some period of time; in such cases, time may be available to align backup systems or to make repairs.

The modeling of the specific systems that can cause a trip or derate can be simplified to some degree, because most systems involved in power generation have limited redundancy. So, the system models may only need to reflect a failure of any component within a flow path. As an example, a flow path can contain several valves and a pump but could be represented by only a single event, such as failure of a component in flow path *x*. Regardless of the complexity of the model, inclusion of any support systems or other dependencies that could affect system operation is very important. These system dependencies can be easily incorporated into the fault tree models by linking one system to another (for example, circulating system failure can occur due to failure of 4kv bus 1A or 1B, where each of these buses has its own specific model developed).

Although a key objective of this generation risk model is to determine the impacts of maintenance activities on the plant, the model also calculates a frequency of plant trip or derate due to random equipment failures. Each failure event in the model must be assigned a failure probability (over a one-year period, in this case). Reliability data for fossil-fueled power stations are not as readily available as compared with nuclear generating stations; however, the nuclear data can be used to some degree, coupled with engineering judgment.

Another key contributor to system failure can be human error. Possible errors could include improper alignment of plant systems or errors introduced while performing maintenance (for example, isolating the wrong component). For this project, human errors were not specifically evaluated; however, these could be added in a later phase of the model development process.

Environmental conditions can also play a role in influencing the possibility of an event. For example, a different number of cooling water pumps may be required during hot weather versus cooler weather or there may be an increased likelihood of intake screen clogging under certain conditions. Such conditions can also be reflected in the model to help plant personnel in deciding whether it is acceptable to remove equipment from service under various conditions.

3
OVERVIEW OF PROJECT ACTIVITIES

This section provides an overview of the tasks performed to develop the GRA models for this project. The intent of this section is to give the reader an understanding of the process so that it can be applied at other plants. Specifics of the system modeling that are unique to the host plant are generally not covered, because they are primarily of concern only to the host plant's staff. In addition to the information presented here, a separate documentation package was prepared for the plant staff that discusses the details of the models and the key assumptions used to develop the GRA models.

3.1 Kick-Off Meeting and System Screening

The project began with a kickoff meeting at the plant site to define the objectives of the project, to collect plant design and operating information, and to demonstrate the equipment out of service (EOOS) configuration risk management software.

The primary objective of this project, as agreed during the meeting, was the development of a useful risk management tool to assist in planning and executing maintenance O&M activities. A secondary objective was to develop a tool that captures the knowledge of career employees at the plant (in terms of understanding of system/component interdependencies, and so forth) that can assist in transferring this knowledge to the next generation of employees.

During the meeting, current processes for maintenance planning and scheduling were discussed. In general, advanced scheduling of maintenance activities is not currently performed. However, a basic weekly schedule is prepared, and the plant does have a daily work plan.

The plant also holds maintenance meetings and plant management meetings every day, in which upcoming activities are discussed. These meetings currently identify potential issues due to the sharing of tribal knowledge. It is hoped that the GRA model will help to identify many of these issues prior to conducting the daily planning/review meetings.

Another topic that was discussed was the impact of environmental and other conditions that can affect plant operation. It was noted that when river water is sufficiently cool (during the winter), the plant can operate with fewer circulating water pumps and service water pumps. Also, if coal quality is poor, derating must often occur. Both of these conditions would be reflected in the GRA model.

The host plant is a two-unit site. Unit 2 was selected to be the focus of this project. However, a number of Unit 2 systems and components rely on Unit 1 support systems (for example, electrical buses). As a result, maintenance activities in Unit 1 can also have an impact on Unit 2 operation.

The first thing that needed to be decided was exactly what would be evaluated by the GRA models. Systems (and their failures or configuration changes) that do not impact the functions addressed by the models were not considered further in the project. The specific functions to be considered were determined to be the risk of plant trip/shutdown within 2 hours given an adverse condition and the derate of greater than 10% within 2 hours given an adverse condition.

The 2-hour criterion used was a subjective one. The plant can continue to operate for some period of time with various systems temporarily out of service. The intent was to indicate system outages or failures that would either require very rapid response (which might not be possible) or situations that would result in an immediate shutdown or power reduction.

The next step of the process for developing a generation risk model is to review the plant systems to determine which ones need to be considered within the model. The primary selection criteria used to determine those to be modeled are based on the top events to be evaluated in the model. Those that are selected for inclusion in the model will be further examined to determine minimum system requirements for power operation, support systems needed, potential for alternative operating configurations, and so forth. Table 3-1 summarizes the selection process. Of the 34 common and unit-specific systems in the plant, 24 of these were determined to be capable of impacting the functions to be considered in the generation risk model.

Table 3-1
System selection process

Plant System	Include in Models?	Comments
Coal handling (common)	No	System can be out of service for more than 2 hours without impacting power operation.
Continuous emission monitoring (common)	No	Alternative measurement means may be used if system is out of service. Does not have an immediate impact on power operation.
Control air (common)	Yes	System is required to support plant operation.
Electrical (common)	Yes	System is required to support plant operation. Specific subsystems to model include AC, DC, Essential Services, and 120-v Vital AC. Lighting buses will not be considered, because it is assumed that plant operation can continue with emergency lighting sources.
Generator power distribution (common)	Yes	System is required to support plant operation.
Lube oil storage and distribution (common)	No	System can be out of service for more than 2 hours without impacting power operation.
Natural gas system (common)	No	System is used primarily for startup. Is sometimes used to provide supplemental heating (for example, when wet coal is being used). This system may be modeled in a future update.
Nitrogen blanketing system (common)	No	System can be out of service for more than 2 hours without impacting power operation. Most functions of system are used for shutdown conditions.
Service water (common)	Yes	System support operation of various plant systems. Failures have caused transients in the past.
Sootblowing air (common)	Yes	System is required to support plant operation.
Station air (common)	Yes	System is required to support plant operation.

Table 3-1 (continued)
System selection process

Plant System	Include in Models?	Comments
Station heating and ventilation (common)	No	System failures/equipment outages are not expected to directly affect short-term plant operations.
Sumps and drains (common)	No	System failures/equipment outages are not expected to directly affect short-term plant operations.
Water treatment (common)	No	System failures/equipment outages are not expected to directly affect short-term plant operations.
Well water (common)	Yes	System support operation of various plant systems.
Unit 2 ash handling system	Yes	System is required to support plant operation. Only short outages of this system can be tolerated during power operation.
Unit 2 bearing cooling water supply	Yes	System is required to support plant operation.
Unit 2 boiler coal system	Yes	System is required to support plant operation.
Unit 2 boiler water and steam system	Yes	System is required to support plant operation.
Unit 2 chemistry control system	No	System failures/equipment outages are not expected to directly affect short-term plant operations.
Unit 2 circulating water system	Yes	System is required to support plant operation.
Unit 2 combustion air and flue gas system	Yes	System is required to support plant operation.
Unit 2 condensate system	Yes	System is required to support plant operation.
Unit 2 condenser air removal system	Yes	System is required to support plant operation.
Unit 2 extraction steam and heater drains system	Yes	System is required to support plant operation.
Unit 2 feedwater system	Yes	System is required to support plant operation.
Unit 2 generator and generator excitation system	Yes	System is required to support plant operation.
Unit 2 generator hydrogen gas and oil cooling water system	Yes	System is required to support plant operation.
Unit 2 generator hydrogen gas system	Yes	System is required to support plant operation.
Unit 2 generator seal oil system	Yes	System is required to support plant operation.

Table 3-1 (continued)
System selection process

Plant System	Include in Models?	Comments
Unit 2 lube oil system	Yes	System is required to support plant operation.
Unit 2 main steam turbine system	Yes	System is required to support plant operation.
Unit 2 natural gas system	No	System is used primarily for startup. Is sometimes used to provide supplemental heating (for example, when wet coal is being used). This system may be modeled in a future update.
Unit 2 turbine hydraulic control system	Yes	System is required to support plant operation.

3.2 Model Development

For each of the systems identified as having a potential plant impact, the system design documentation was reviewed and a concise summary was prepared, showing the success criteria for each system (that is, what must operate to allow full power operation), the major components in the system (particularly those that can be removed from service at-power, any alternative system alignments that can be used or seasonal variations, and the support systems that the system needs to support operation. Appendix B provides several examples of this documentation. These system summaries were then reviewed by plant staff prior to model development to ensure that the systems (and their dependencies) were properly understood.

Two interdependent fault tree models were developed to support this project. The first is the plant trip/shutdown model. This model considers all combinations of system operating conditions (including environmental conditions) that would require a plant shutdown. The second model is the derate model, which specifically models those system and environmental conditions that would result in a power reduction, but not a plant trip. Because failure of many plant systems results directly in a shutdown, the number of systems that can cause only a derate is significantly less. In particular, the derate model only includes modeling of nine of the 24 plant systems.

Figure 3-1 shows the logic that exists at the very top of the plant trip/shutdown model. Each of the major causes of plant shutdowns is shown. Each of the major trip categories is then further subdivided down the system level and then down to the major component level. Figure 3-2 shows the top of the plant derate model. The structure of this model is similar to the plant shutdown model. In many cases, the system models used for this tree are similar to those of the shutdown model; however, the logic often differs in terms of the number of components that need to fail to result in the top event. For example, failure (or removal from service) of one circulating water pump would cause a derate, but failure of both pumps would be necessary to result in a plant shutdown.

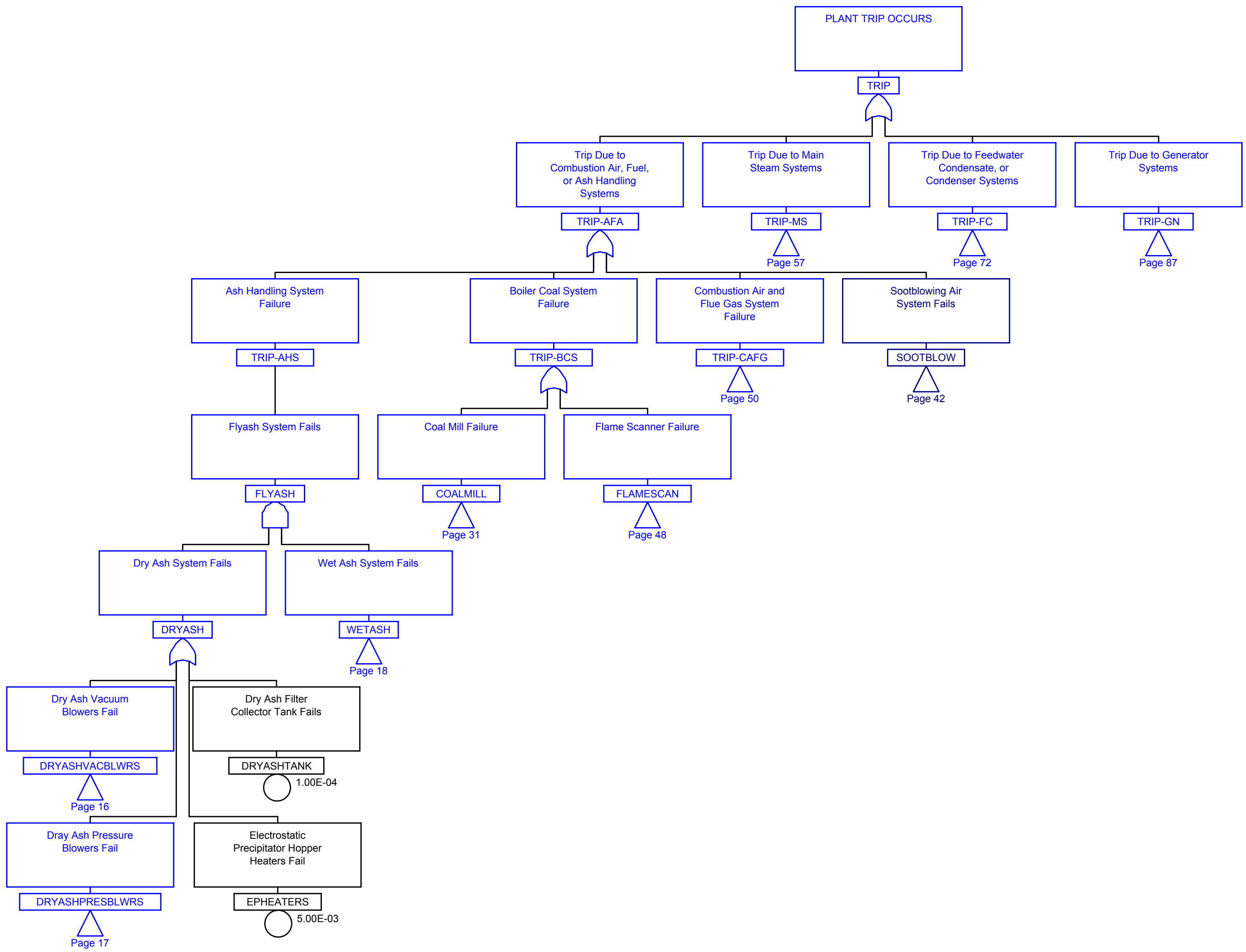


Figure 3-1
Trip/shutdown model top logic

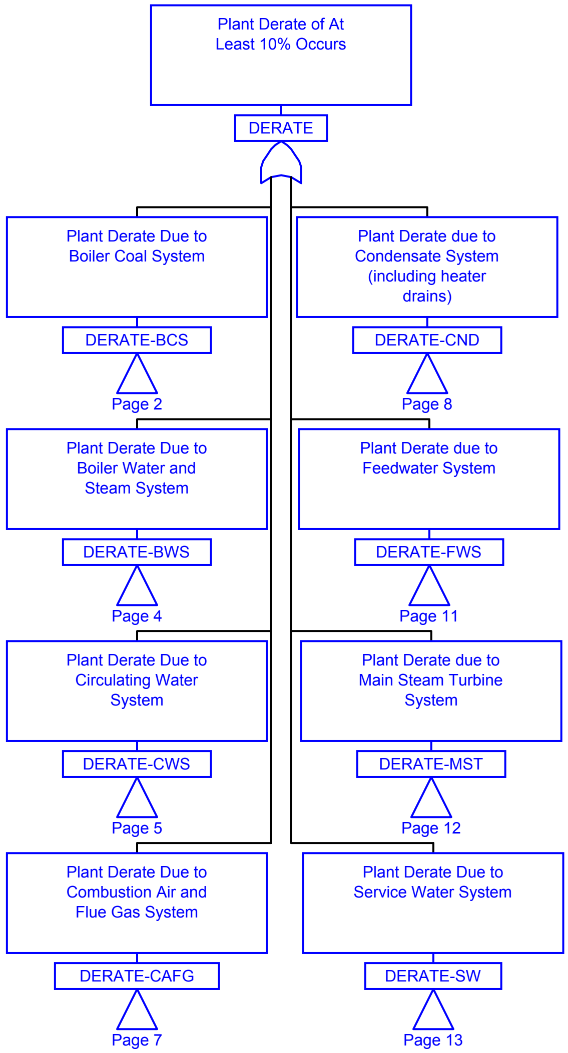


Figure 3-2
Derate model top logic

Figure 3-3 shows an example of a system-level fault tree for the service water system. Because this system can operate with fewer pumps during winter conditions, logic for winter conditions and non-winter conditions was developed. The model does not explicitly consider every component in the system; rather, the major components are modeled as well as linkages to the other systems needed to support operation of the system's components (for example, electric power and cooling water). Even when no components are out of service, the top event (shutdown or derate) can occur if plant components fail while in operation. The possibility of any component failing is represented by the probability value shown for each event. The development of plant-specific data to model each component can be a labor-intensive activity. For this project, only order-of-magnitude failure estimates were inserted into the model based on engineering judgment. Use of such data should be adequate to provide insights to plant staff, particularly concerning the impacts of planned maintenance activities. Each probability shown is the likelihood of failure over the course of a plant operating year.

Appendix C presents the complete fault tree models for this project.

When maintenance is to be performed on plant components, the failure probability for the appropriate model event is set to a logical TRUE (basically, equivalent to a 1.0 probability). The impact of the component being out of service is then propagated through the models, and the overall probability of plant shutdown or derate can be determined.

The resulting models (and supporting data files) were then loaded into the EOOS software tool. A hierarchical set of status panels was developed to both indicate the current availability status of each system and to allow for plant users to easily change the availability status of individual plant components. Figure 3-4 shows the main EOOS display screen during a condition in which two coal mills are out of service. All systems are shown as green because no system is completely degraded. However, the red indicator at the bottom right of the Boiler Coal System box indicates that there are unavailable components in this system. The meter display on the upper left of the screen shows that the risk of a plant shutdown is 0.74 per year (which is about 30% higher than the normal *no maintenance* level of 0.57 per year) and that a derate will occur in this situation (therefore, the red thermometer display for the derate meter). The list in the upper right of the display summarizes which plant equipment is currently out of service.

Figure 3-5 shows the main display when a Unit 1 480v bus is removed from service. In this case, removal of this bus (in the other unit at the station) impacts multiple systems in Unit 2, resulting in a plant trip condition. In this situation, the circulating water system is impacted because one traveling screen loses power (which in turn fails the generator H_2 and oil cooling water system and turbine lube oil system, which are support systems for the main turbines and the generator hydrogen system), and one well water pump is made inoperable because it relies on this Unit 1 bus for power.

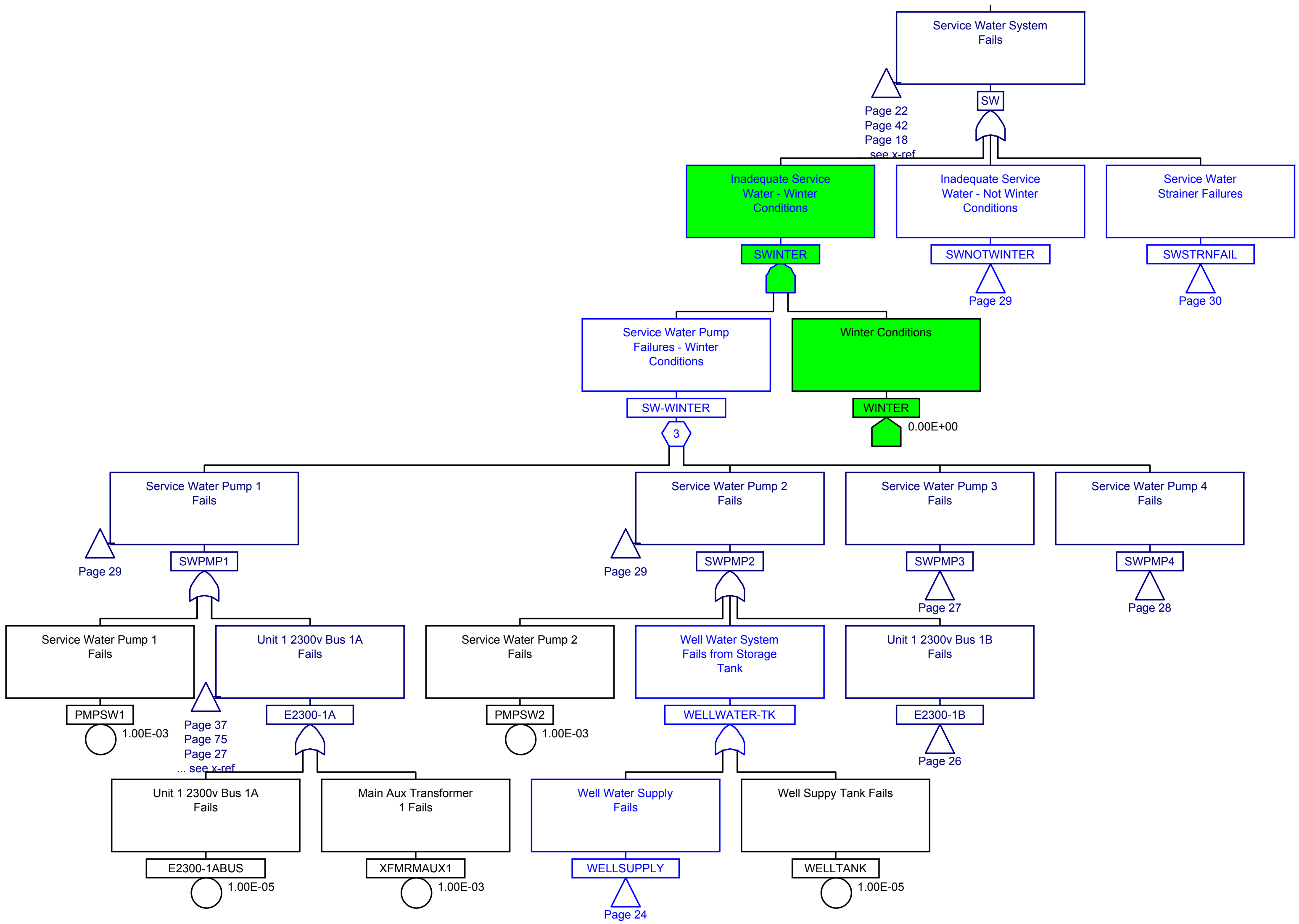


Figure 3-3
An example of system-level fault tree logic

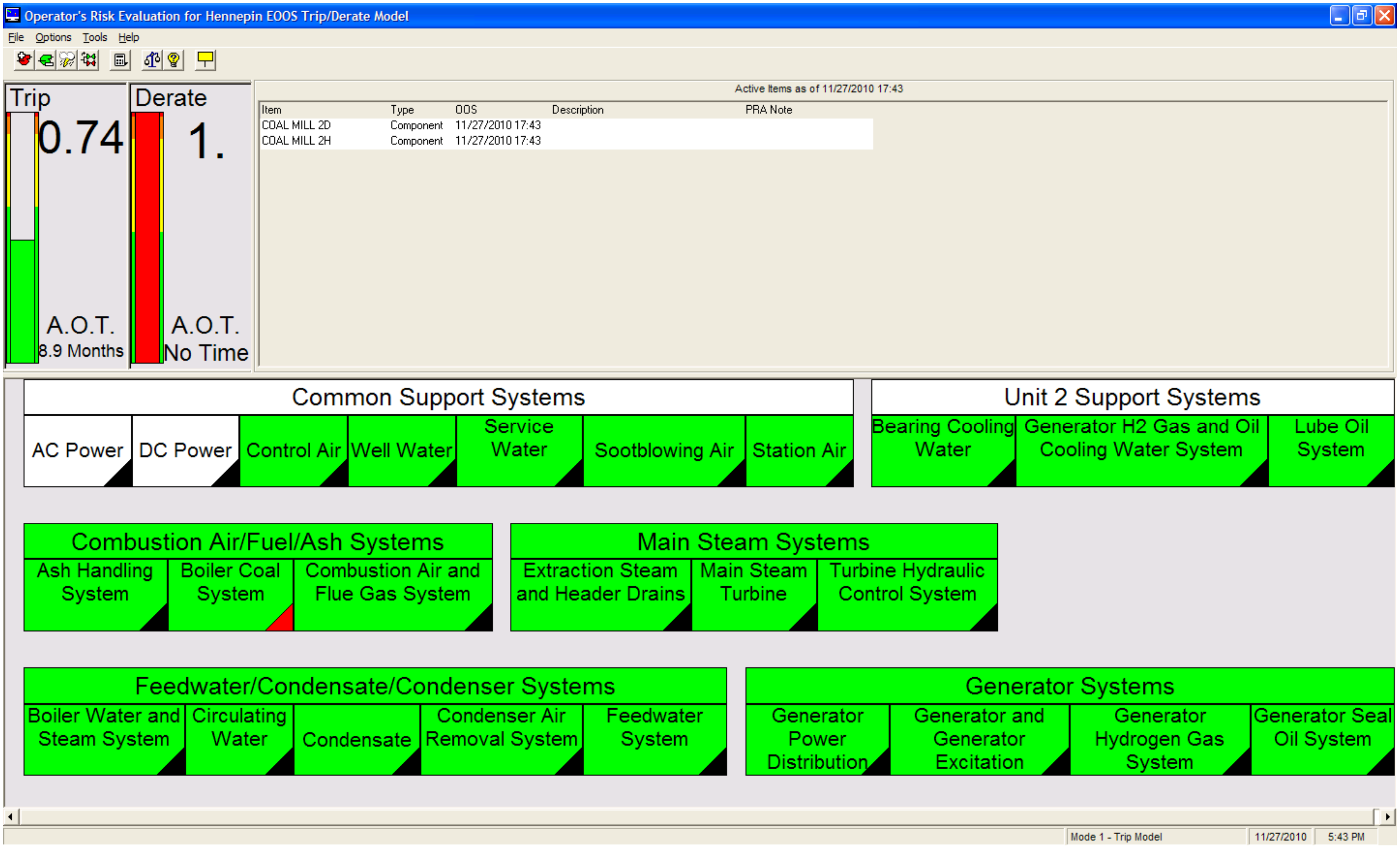


Figure 3-4
EOOS display showing derate condition

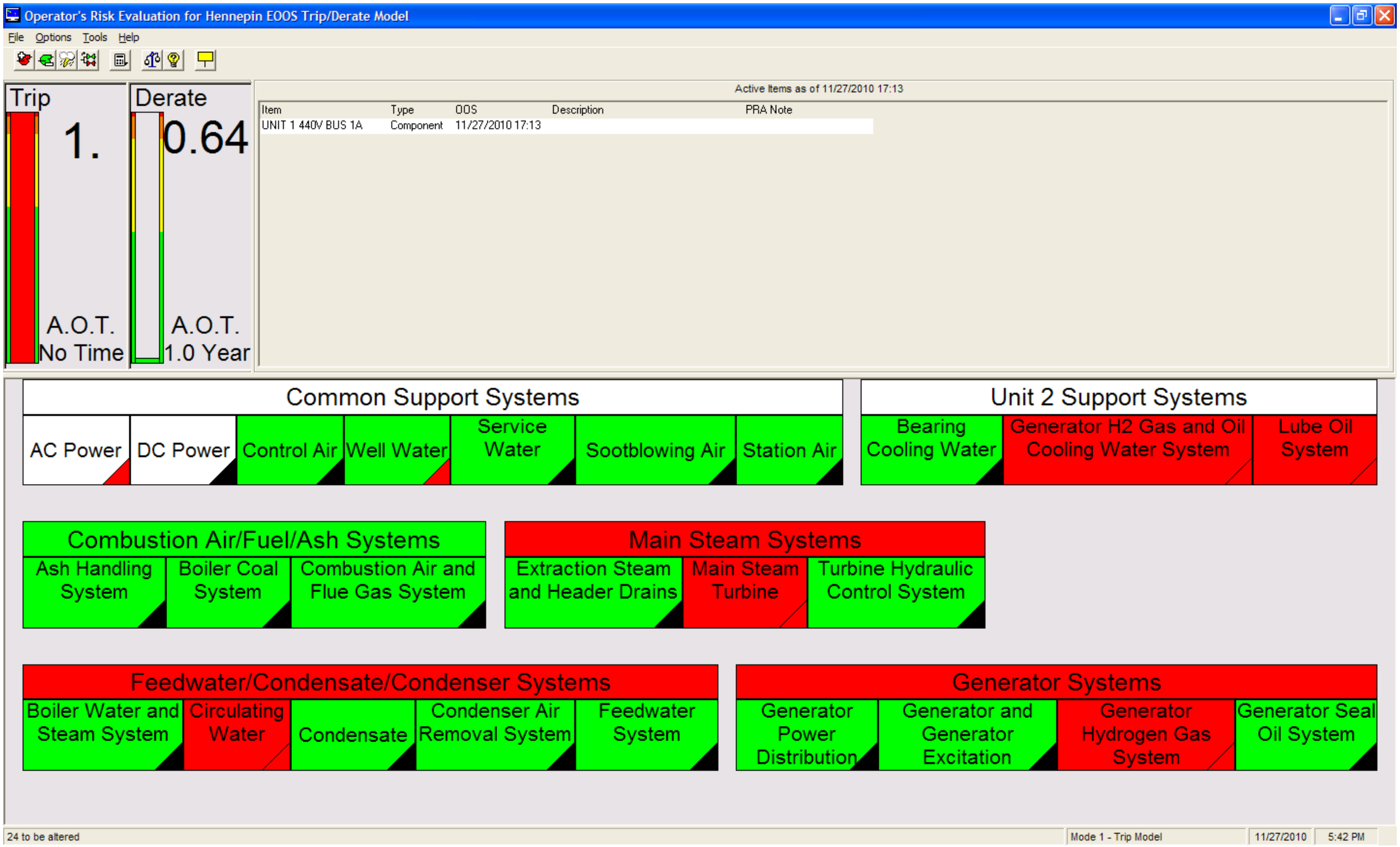


Figure 3-5
EOOS display showing a plant trip condition

In addition to providing useful information to plant O&M staffs concerning the impacts of maintenance actions, the model can also be solved to determine the chief contributors to a shutdown or derate (assuming that no maintenance is underway). Table 3-2 lists the top equipment failures that could lead to a plant shutdown. All of these are single-point failures, with the exception of failure of two coal mills. Table 3-3 lists the top equipment failures that could lead to a plant power reduction. All of these are also single-point failures. This risk ranking information may be helpful in prioritizing preventive maintenance to focus attention on the equipment that can have the greatest impact. Although these single-point failures dominate the overall risk of a plant shutdown or derating, risk of a generation loss event can further increase during periods when systems that have built-in redundancy have that redundancy removed because of failures or planned maintenance.

Table 3-2
Key component failures contributing to plant shutdown

Component Failure
Condenser tube leak
Superheat furnace tube leak
Reheat furnace tube leak
Steam leak causes plant shutdown
Turbine hydraulic control system fails
Two coal mills fail (one in the superheat furnace and one in the reheat furnace)
Boiler control system fails
Oil booster pump fails
Feedwater regulating valve fails
Clogging of the generator hydrogen and oil cooling water system strainer
Failure of generator seal oil mail oil pump
Failure of generator seal oil recirculating oil pump
Failure of one of the turbines (high-pressure, intermediate-pressure, or low-pressure)
Failure of a traveling screen during non-winter conditions
Failure of the shaft-driven lube oil pump

Table 3-3
Key component failures contributing to power reduction

Component Failure
Failure of one coal mill (one of eight mills)
Failure of one boiler circulating water pump (one of three pumps)
Failure of one condensate pump (one of three pumps)
Failure of one circulating water pump during non-winter conditions (one of two pumps)
Failure of a forced draft fan (one of two fans)
Failure of a feedwater pump (one of three pumps)
Failure of an induced draft fan (one of two fans)

In some cases, it may be possible to identify potential design changes to help remove specific vulnerabilities. However, it may not be cost-effective to implement meaningful changes in many of the major plant systems. Because the host plant has two furnaces (one for superheat steam and one for reheat steam) and two turbine-generator sets, failures in either half of these two-part systems can cause a plant trip or power reduction. Plants that have only a single furnace and/or a compound turbine-generator arrangement may have a somewhat higher reliability, because the number of failures that is necessary to cause a plant trip may be reduced. On the other hand, if plant modifications could be performed to allow the plant to operate with only one furnace or one turbine-generator set available (at reduced power output), overall reliability might be improved.

For the power reduction analysis, the requirement to reduce power output if any coal mill fails is the dominant contributor to plant derating (according to this analysis). Having a spare coal mill that could be aligned to either furnace as needed could reduce the frequency of plant power reductions (assuming that it is practical to make such a modification).

3.3 Implementation Effort

The total labor effort required of the plant staff to develop this initial GRA model was only about one workweek. This included initial data collection, support of a kickoff meeting, and responding to questions during the model development phase. Because the plant had an extensive set of system descriptions and drawings, the amount of time required of the plant staff was reduced considerably. However, during the course of the project, it was discovered that some of the reference material did not reflect recent design changes; as a result of this project, changes to the references were noted for future updates to the documentation.

The development of the GRA model and its implementation within EOOS required about one work month of consultant effort. It is expected that the models and supporting EOOS files developed for this project can be used as a template for development of models for other plants. This should reduce the effort to perform a similar project at another plant, but the amount of labor savings would depend on how well the host plant’s design reflects the plant being modeled.

3.4 Insights from Initial Implementation

The host plant received the initial model only a few weeks before this report was prepared. It is evaluating the model and will continue to provide insights over the coming months. Among the initial insights that were discussed during an on-site meeting to review the GRA model were the following:

- The GRA model and EOOS tool can be very helpful for maintenance planning and for the review of the daily work plan during the senior staff meeting held each morning.
- The status panel display provides an effective means of getting a snapshot of current plant status (for example, showing systems with components out of service). The plant operations staff discusses plant configuration during each shift turnover and can generate a text listing of components that are currently out of service. However, the ability to see the status information in a color-coded display would help to more quickly assess the current plant condition.
- The senior staff recognized that the GRA model could be an effective training tool for new staff.
- The plant currently does not use maintenance-scheduling software for its daily and weekly work-planning activities; however, it was recognized that the use of the EOOS schedule analysis functions (see Appendix A) could also be very useful for longer-term maintenance planning.

The plant staff is now using the GRA model on a trial basis, both to identify any possible necessary refinements to the model and to see how the tool could be used on a daily basis within the plant. It is expected that the software will be used by the shift supervisor, the production management personnel, and the engineering personnel.

3.5 Future Research

Some initial areas for further research were discussed with the plant staff following the installation of the initial model at the plant. Among the possible areas of future research and model enhancement discussed were the following:

- Inclusion of additional electrical bus alignments that may be used during maintenance activities that would allow plant operation to continue without a power reduction or trip.
- Consideration of possible human errors to include to the model. For example, if there is an increased potential for a plant trip during certain activities, these could be added to the model to provide a more complete assessment of the plant's generation risk.
- When a plant shutdown occurs due to a failure, development of a model that would help plant staff assess which systems remain available and which repairs should be completed to support plant restart could be very helpful. Additional systems needed for plant startup, such as the natural gas system, would also need to be added to the model to support this.
- Further refinement of the failure data used in this model may also be of benefit, particularly if the model is also to be used to guide possible design improvements and to focus preventive maintenance tasks on critical equipment. As noted previously, only order-of-magnitude estimates, based on engineering judgment, were used in the initial model.

- Although the current version of the EOOS software readily supports the evaluation of GRA models, it could be modified to better support the needs of fossil plants. This would include the removal of functions currently included to support nuclear safety and regulatory requirements. Removing unnecessary function will make the software even easier to use for fossil plant personnel.

4
CONCLUSIONS

GRA can help power stations to improve reliability while managing the impacts of maintenance while the plant is operating. Most fossil-fueled power plants currently perform risk management in at least an informal sense, relying on the experience of the shift supervisor and other senior staff members to identify risk-significant situations and to take appropriate actions to minimize the risk. The use of a quantitative GRA logic model can capture the knowledge and experience of senior staff and provide a computerized tool that can be used by less experienced plant personnel.

The results of this project demonstrate that a reasonably complete GRA model can be developed for a fossil-fueled power station with a modest effort. The model, implemented in the EOOS risk management software, can provide plant staff with insights concerning the risk impacts of planned maintenance and unplanned failures.

The completed GRA model has been implemented at the host plant on a trial basis, and the staff is evaluating its usefulness for a range of applications, including maintenance planning and staff training. It is expected that insights from this initial use can be used to further improve the model and the EOOS software for use in fossil plant applications.

In addition to the use of the GRA model to evaluate risk changes during changes in plant configuration, the base models can also be used to identify the dominant contributors to plant unreliability. This information may also be of use in recommending design changes and in enhancing preventive maintenance programs.

It should be stressed that this project implemented an initial model that will undergo further refinement through plant usage over a period of time. It is hoped that the finalized models and EOOS displays can then be used to develop plant-specific models for other stations on a cost-effective basis.

5 REFERENCES

1. *Using Risk Management as Input to Operational Decisions*. EPRI, Palo Alto, CA: 2005. 1008251.

2. *Generation Risk Assessment (GRA) Plant Implementation Guide*. EPRI, Palo Alto, CA: 2004. 1008121.

3. *Trip Monitor Customization and Implementation Guideline*. EPRI, Palo Alto, CA: 2004. 1009112.

A
EOOS SOFTWARE DESCRIPTION

EOOS is a computer program for monitoring safety at industrial facilities, where operations involve complex tradeoffs between safety, plant economics, and equipment availability.

Description

EOOS uses a safety or risk model of the plant, based on fault tress and minimal cutsets, such as those developed in a probabilistic risk assessment (PRA). EOOS wraps a user-friendly interface around these reliability-analysis tools to make them accessible to non-probabilistic safety assessment experts. EOOS communicates in the language of its users—using the familiar terminology of components, trains, systems, tests, and clearances.

Using the current plant configuration, EOOS can propagate information through the model and quantify risk measures. EOOS translates fault tree results into color-coded status panels, timelines, and lists of relevant and risk-significant activities. Within seconds, an EOOS user can identify a safety problem and the specific work activities that cause it. The EOOS user will then have the information to decide whether the problem is significant enough to warrant special contingency actions.

Benefits and Value

EOOS can help reduce O&M costs by the following:

- **Reducing the chance of a costly operational mistake**. Because unplanned events creep into a well-planned work schedule, you run the risk of unexpected reductions in plant safety. EOOS detects these safety problems that routinely escape the scrutiny of safety reviews based on train-level work windows.
- **Reducing the labor needed to perform safety reviews**. An EOOS model integrates the safety impact of all work tasks affecting all risk significant safety functions into concise screen presentations and printed reports.
- **Providing credible, risk-based insights that minimize unnecessarily conservative requirements**. EOOS results can become the basis for eliminating requirements that increase outage duration, without a commensurate safety benefit.

A.1 Introduction

What Is EOOS?

EOOS is a computer program for monitoring safety. It is a tool for industrial facilities, where operations involve complex tradeoffs between safety, plant economics, and equipment availability. It is commonly used in many applications, especially in power plants and aerospace.

EOOS is designed for two types of users, each with a distinct set of needs. The first, an operator, is a user concerned with current plant status. The second type of user, a scheduler, is concerned with scheduling future equipment outages.

Although EOOS is tailored specifically for these user types, it can also be used by other staff members with different responsibilities. EOOS is often used by plant engineers responsible for monitoring regulatory commitments. For example, power plant licensing engineers use EOOS to monitor the availability of important systems, structures, and components.

EOOS users can share information across a computer network. EOOS also has access control features to allow these groups to protect their data (which may be required for quality assurance). The combination of access control and the two user metaphors makes it easy for users with different needs to apply a common, powerful set of reliability-assessment tools.

Why Use EOOS?

EOOS helps meet the following three performance goals:

- EOOS can guide you to measurable improvements in plant safety and reliability.
- EOOS can help you demonstrate operational awareness to outside observers, such as plant management and corporate risk assessors.
- EOOS can help you achieve measurable savings in O&M costs.

EOOS can help reduce O&M costs as follows:

- **EOOS reduces the chance of a costly operational mistake**. Because unplanned events creep into a well-planned work schedule, you run the risk of unexpected reductions in plant safety. First-time EOOS users often discover work orders buried deep within a schedule that have unanticipated effects on plant safety and reliability. EOOS detects these problems that routinely escape the scrutiny of reviews based on train-level work windows or hammocks.
- **EOOS reduces O&M costs by reducing the labor effort needed to perform operational reviews**. An EOOS model accounts for the safety impact of all work tasks affecting all risk-significant safety functions. It integrates all this information into concise screen presentations and printed reports. Labor effort previously spent on data collection can be devoted instead to safety management.

- **EOOS reduces O&M costs by providing credible, risk-based insights that help you eliminate unnecessarily conservative planning requirements**. An EOOS model is an extension of a plant's PRA. As such, it provides results that you can use with confidence in cost-benefit calculations. EOOS results can become the basis for eliminating requirements that increase outage duration.

EOOS provides these benefits by using fault trees and cutsets—the basic tools of reliability analysis. EOOS wraps a user-friendly interface around these reliability-analysis tools to make them accessible to non-risk experts. Fault trees represent basic events, but EOOS communicates in the language of its users—using the familiar terminology of components, trains, systems, tests, and clearances.

Fault trees can propagate logical values of TRUE and FALSE and quantify risk measures. EOOS translates fault tree results into color-coded status panels, timelines, and lists of relevant and risk-significant activities. Within seconds, an EOOS user can identify a problem and the specific work activities that cause it. An EOOS user also has enough information to decide whether the problem is significant enough to warrant special contingency actions. Users find EOOS easy to learn, use, maintain, and upgrade.

A.2 EOOS for Operators

The Operator's Job

Operators make decisions about when to perform tests and maintenance tasks over a period of hours or days. These activities affect plant safety and reliability. For example, operators may disable a system for a short time so that workers can perform tests or maintenance on the equipment. During a period when a system is disabled, the plant will be less reliable. If multiple systems were disabled, reliability would be even more impaired. Accordingly, several administrative constraints prevent operators from performing too many tasks at the same time. Faced with these constraints, operators use their detailed knowledge of plant systems to decide which combinations of work activities to avoid.

An operator's job is complicated by the need to accommodate unscheduled events. Equipment sometimes breaks down. Operators must support system alignments change. The environment sometimes changes (for example, bad weather) and induces more risk. Scheduled activities finish early or late. The combinations of scheduled and unscheduled events require operators to constantly reevaluate plant status.

Another factor influencing operators is the utility's desire to minimize plant downtime. This operating objective leads to two types of decisions, which sometimes conflict with one another. On one hand, utilities want to maximize system availability during power operation to minimize the chance of a plant transient or forced outage. On the other hand, utilities also want to minimize the duration of scheduled plant outages to reduce expenditures on replacement power. With increasing frequency, operators are being asked to shift test and maintenance tasks from scheduled outages to power operation. Consequently, operators must find the balance between plant safety and economics.

EOOS helps operators focus on safety and reliability. The combined effect of many simultaneous work activities can have a significant impact on front-line safety systems. With each new task, operators make a complex decision to act based on their perception of how it affects plant safety. The EOOS plant risk monitor screen helps operators make these decisions by the following:

- Showing a numerical measure of plant status known as a *plant status index* (PSI) that reflects changes in equipment status
- Showing the maximum time allowed in a particular plant configuration based on the PSI value
- Showing the status of plant systems affected by various test and maintenance activities (providing measures of defense-in-depth)
- Showing a list of current activities that affect plant equipment
- Showing lists of in-service and out-of-service items, ranked by their importance to safety and reliability
- Quickly recalculating these safety measures for a variety of what-if tests

The Operator’s Screen

Figure A-1 shows the EOOS screen for operators.

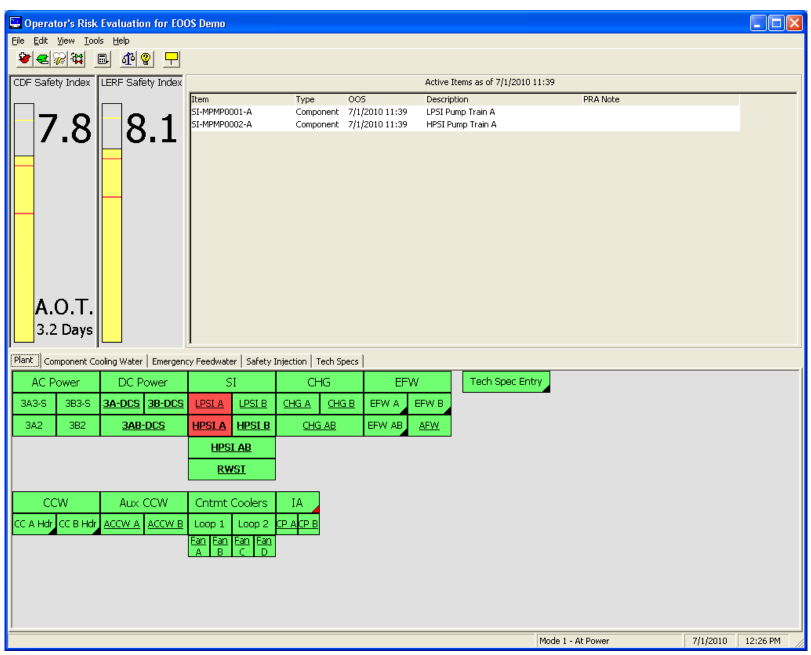


Figure A-1
EOOS screen for operators

The features of the screen for operators are described in this section. The version of EOOS installed at different plants will be similar but will have different component IDs, numerical values, and layout of the status panel.

The Risk Meter(s)

The upper left corner of the plant risk monitor's screen shows a summary measure of plant reliability. Double-click in this area to show a pop-up window (see Figure A-2) with more plant safety statistics.

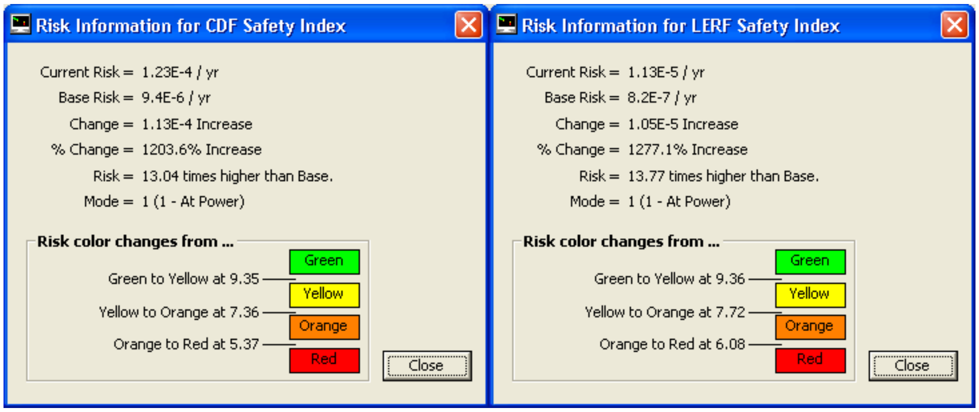


Figure A-2
Plant status statistics

Four different safety and reliability measures are available for display. In each case, EOOS shows the measure as both a number and as a color-coded meter. The usual measure is the PSI. The PSI ranges from 0 to 10. Within that range, the PSI as follows is related to the ratio of current risk to plant base line risk.

The PSI changes as you add and remove items from the Current Items list. The PSI falls when equipment is removed from service. It rises when equipment is returned to service. A high PSI value implies a high level of safety: 0 is good, and 0 is bad.

The analog display is a vertical bar to the left of the plant safety measure. Like a thermometer, this bar fills from the bottom up. The fill color is red, orange, yellow, or green. Red appears with low PSI values, green with high PSI values, and orange and yellow with intermediate values.

The risk meter color can be used to trigger various types of contingency actions. Table A-1 lists one scheme for linking operator actions to colors.

Table A-1
Typical operator actions linked to risk meter colors

PSI Condition	Operator Action
Low risk (green)	Proceed normally
Small increase in risk (yellow)	Include reliability-assessment insights in pre-shift meetings
Intermediate increase in risk (orange)	Invoke contingency actions Hasten the restoration of risk important equipment Notify plant management
Large increase in risk (red)	Notify plant management Suspend all new work orders Invoke contingency actions Hasten the restoration of risk important equipment

The Active Items List

The right side of the plant risk monitor screen shows a list of active items. These are work activities or plant configuration characteristics that might affect the reliability or availability of plant equipment. This list, when processed by the EOOS logic model, determines EOOS's outputs. System alignments are not shown.

The Status Panel

The bottom part of the risk monitor screen is the status panel. This panel contains color-coded buttons that show the current status of plant systems and functions.

The status panel determines your defense-in-depth or level of system redundancy. A status panel button can appear in any of several colors. The standard convention is for green to indicate *available* and red to indicate *unavailable*. Yellow and orange indicate two degrees of *degraded, but available* equipment. (For example, a three-train system might appear green when all trains are available, yellow with one train unavailable, orange with two trains unavailable, and red with all three trains unavailable.) Table A-2 shows some of the possible ways to use the status panel indicators.

Table A-2
Examples of ways to use status panel displays

Item Monitored	What the Colors Mean		
System status	Red	=	System unavailable
	Green	=	System available
Reliability function status	Red	=	Functional requirements not met
	Green	=	Function requirements met
Compliance with equipment technical specifications	Red	=	Plant is not in compliance
	Green	=	Plant is in compliance

What-If Situations

EOOS can perform what if analyses. The new window (see Figure A-3) shows two parallel displays—current (actual) plant status on the left and the status resulting from an anticipated equipment change on the right.

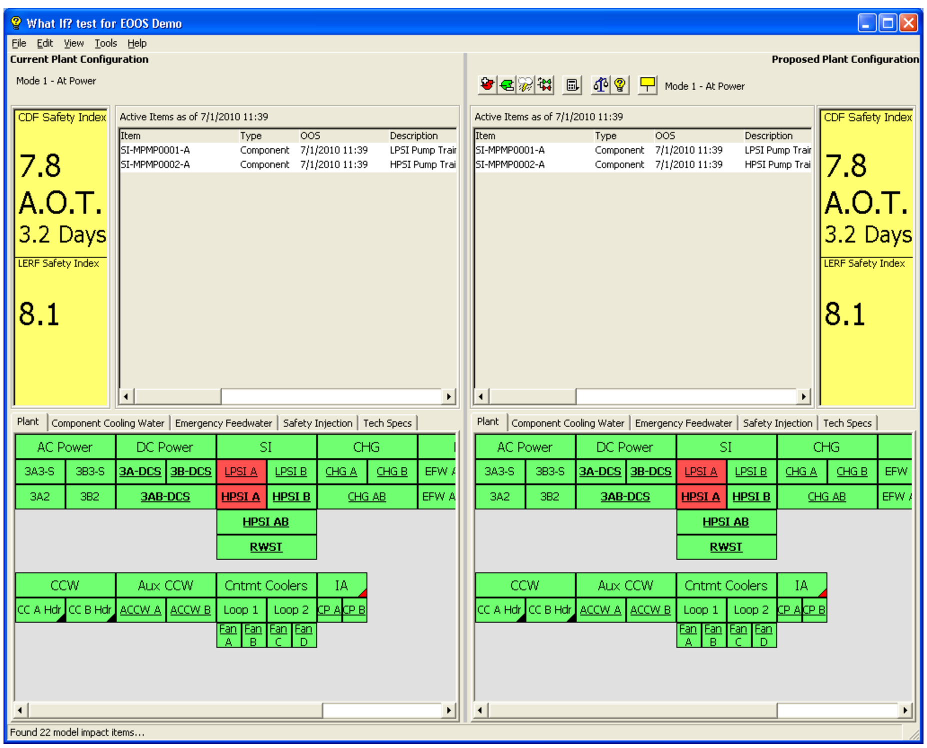


Figure A-3
What-if window

A.3 EOOS for Schedulers

The Scheduler's Job

The EOOS scheduler's screen shows how plant operations affect safety and reliability over a period of time. A typical user is a plant scheduler who makes decisions about when to perform testing and maintenance (T&M) on plant equipment over periods of several weeks or months.

These activities affect plant reliability and often involve disabling a system so that workers can safely gain access to the equipment. Several administrative constraints prevent scheduling too many activities or the wrong combination of activities at the same time. Faced with constraints such as the limiting conditions for operation, schedulers determine the most effective sequence of activities.

The work involved in scheduling T&M activities is complicated. Schedulers often use a computer program (for example, P3 or ProjectView) to orchestrate thousands of work orders. The computer program helps schedulers identify critical path activities and monitor the demands for critical resources. These are the standard analytic tools for project management.

EOOS helps schedulers focus on safety and reliability. The combined effect of many simultaneous T&M activities occasionally has an unexpected impact on front-line systems. To avoid this, schedulers spend a good deal of time performing operational reviews. EOOS helps schedulers perform these reviews by the following:

- Generating timelines showing the changing status of plant systems and safety functions
- Generating a timeline for a plant risk measure
- Identifying the specific equipment and activities that have the strongest influence on safety and reliability

This information helps schedulers decide whether and how to change a schedule to optimize plant risk.

EOOS supports two types of schedulers. The first is a scheduler with a distant time horizon—someone who has no interest in the current state of the plant. The second type of scheduler is one with a short-term time horizon—someone who must consider current plant activities alongside scheduled activities. EOOS can help both types of users.

The Scheduler's Screen

The EOOS display for schedulers appears in Figure A-4.

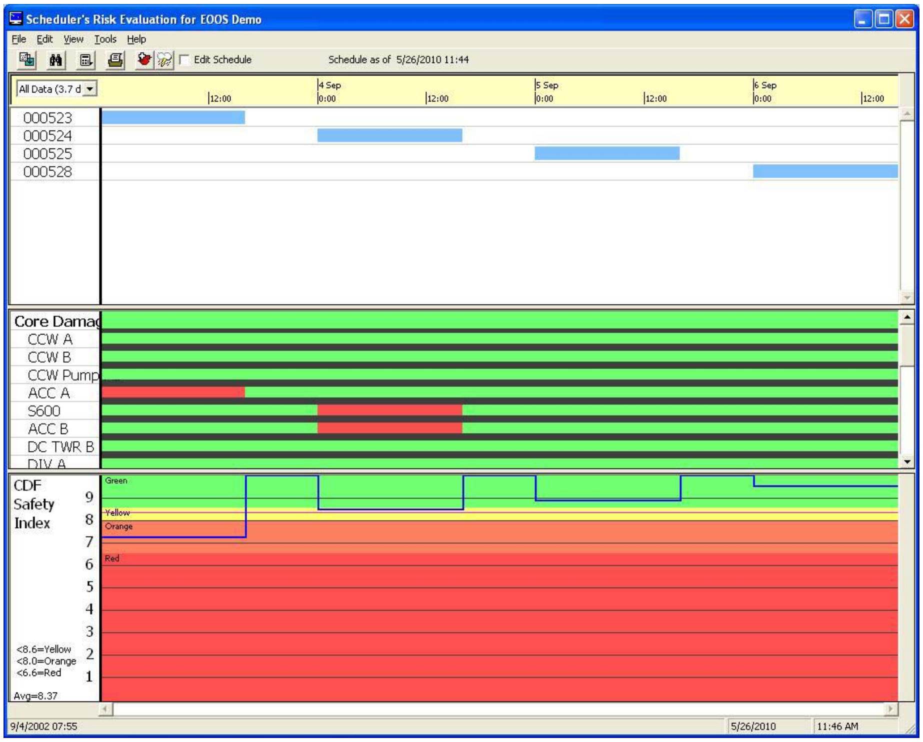


Figure A-4
EOOS scheduler's screen

The display shows three types of timeline charts. From top to bottom they are known as the *Schedule Chart* (see Figure A-5), *Status Chart* (see Figure A-6), and *Risk Profile Chart* (see Figure A-7). All three charts share a common horizontal axis, which is measured in units of time. The menu and tool bar provide commands to manipulate each chart. Also, each chart supports a set of point-and-click operations that provide details about the chart.

Schedule Chart Features

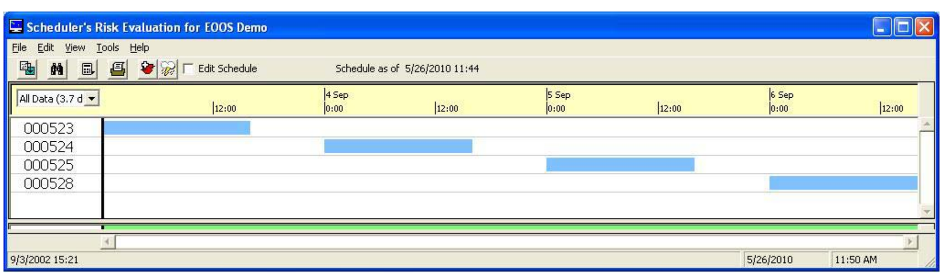


Figure A-5
Schedule Chart details

The Schedule Chart is a simplified Gantt chart. The chart shows data fields for each scheduled activity and timeline bars representing the start and finish dates for each task. You can create the Schedule Chart data manually or by using data from an external source, such as a scheduling software program. On the EOOS screen, schedule data appear as blue bars connecting the start and finish times for each activity.

Status Chart Features

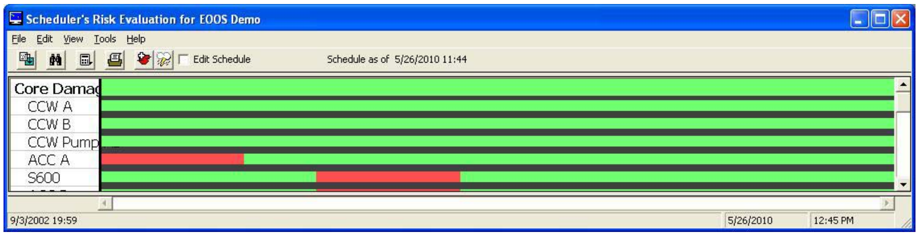


Figure A-6
Status Chart details

The Status Chart shows the results from an evaluation of schedule data. The Status Chart (see Table A-3) shows output from an EOOS calculation.

Table A-3
Example color code definitions in a four-color system

Item Monitored	What the Colors Mean		
Boiler feedwater control function	Green	=	All inventory control systems available
	Yellow	=	One or more systems unavailable, but still a margin above technical specifications minimum
	Orange	=	Technical specifications minimum number of systems available.
	Red	=	Less than technical specifications minimum available
Relative plant risk	Green	=	Plant status correlates with minimum accident risk value
	Yellow	=	Plant status correlates with small increase in accident risk value
	Orange	=	Plant status correlates with highest allowable accident risk value
	Red	=	Plant status exceeds highest allowable accident risk value

A multicolor system allows more flexibility in assessing plant status. EOOS assigns colors according to component availability. EOOS assigns green if all are in-service, red if out of service, and yellow if one is available. EOOS assigns a gradient of orange proportional to the number of out-of-service components.

The Status Chart shows the relationship between scheduled activities and plant status. You can define any number of plant characteristics to monitor. Possibilities include the following:

- Plant configuration characteristics, such as the operating mode or boiler feedwater level
- The availability of plant systems, organized by function, division, or both
- The status of compliance with requirements, such as technical specifications, environmental restrictions, or voluntary commitments

Risk Profile Chart Features

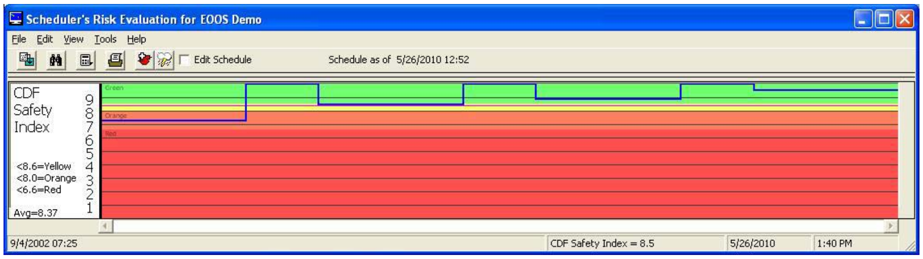


Figure A-7
Risk Profile Chart

The Risk Profile Chart shows one of four measures of plant safety and reliability. One measure is the PSI, which is a value that ranges from 0 to 10, which represents the ratio of current risk to baseline risk. Because risk changes with differing component availability, the profile will go up and down accordingly. High-risk states are usually represented by red and lowest state by green. If the projected risk level is unacceptable according to management guidelines, a scheduler will rearrange the schedule until the risk profile is acceptable.

B

EXAMPLE SYSTEM DOCUMENTATION

This appendix illustrates several examples of the documentation developed to support the development of the GRA model. The information developed for each system was used to support the fault tree model development for the plant shutdown and power reduction models. System documentation was developed for all of the systems considered in the GRA model.

Unit 2 Boiler Coal System

The boiler coal system pulverizes the coal and delivers it to the two boilers for injection through burner assemblies into the boiler furnace. Coal is fed from a main bunker to eight coal mills by a gravity feed system. If the coal is of good quality, all eight of the mills need to operate to support full power operation. If the coal is of poor quality, a derate would result. Four of the mills feed the reheat furnace, and the remaining four feed the superheat furnace. Both furnaces must have an adequate coal supply to support full power operation.

Coal is fed to the coal mills through coal feeders (one per mill). Each mill is cooled by bearing cooling water. Hot air from the forced draft fan is fed into the mills, which then picks up the coal dust for transport to the furnaces. An exhauster fan that is a part of each coal mill then exhausts the coal dust/air mixture to the burner assemblies. Dampers (tempering and exhauster inlet) control the air flow into the coal mill to ensure proper temperatures and pressures (Operation of the dampers is not considered separately from the coal mill—that is, failure of a damper is assumed to cause failure of the mill.). However, these dampers do not move much during stable operation and could be manually positioned if needed so that mill operation can continue.

Coal from each mill enters both furnaces (reheat and superheat) through four burner assemblies located at the corners of each furnace. It is assumed that all four burner assemblies need to operate in each furnace to permit plant operation. For the model, the nozzles, dampers, and burner tilt components (and their controls) will be considered to be part of an integrated unit. Because the natural gas system is not being modeled, operation of the gas nozzles is not considered.

The flame scanners and the cooling blowers must operate to allow power operation. One blower is necessary to provide cooling of the scanners. The second blower is a backup that starts automatically on low air pressure. The control system for the scanners will be considered as an integral part of the scanners themselves.

System inputs and essential support systems include the bearing cooling water system, forced air draft system, compressed air (for the exhauster shutoff gates, tempering air damper and hot air blast gate on each mill), alternating-current (ac) and direct-current (dc) power. Mills (and associated hot air and exhauster dampers) 2A, 2C, 2E, and 2G are powered from Unit 2 4160v bus 2A. Mills 2B, 2D, 2F, and 2H are powered from Unit 2 4160v bus 2B. DC is provided by the dc control bus; however, because the mills are operating, loss of dc is assumed not to trip the mills. Flame scanner blowers 2A and 2B are powered from the Unit 2 480v essential service motor control center #2. DC is provided by the dc control bus.

Unit 2 Generator Hydrogen Gas and Oil Cooling Water System

This system cools both the generator hydrogen system and the turbine lube oil system. There is a cross-connection to the service water system, which can be used to supplement the flow. For the purposes of this model, the use of the cross-connect will be neglected.

The system consists of two pumps (one of which must operate to provide adequate cooling) that take water from the circulating water system and pass it through generator hydrogen coolers (four coolers for each of the two generators) and the turbine lube oil tank (two coolers inside the tank). The pumps are started and stopped manually. A common suction strainer filters the circulating water prior to entry into the pumps. The strainer has a single basket self-cleaning strainer.

Flow to the various coolers is adjusted using air-operated control valves; however, these valves could be manually controlled (using bypass valves) if the air supply were lost. One generator cooler can be isolated on each generator while operating, but a derate must occur. The two turbine oil coolers each provide 100% capacity; therefore, one cooler can be removed from service without impacting power operation.

System inputs and essential support systems include the circulating water system, control air (not modeled due to ability to manually bypass the air-operated valves), and the ac and dc power systems. Cooling Water Pump 2A is powered from Unit 2 4160v bus 2A. Cooling Water Pump 2B is powered from Unit 2 4160v bus 2B. DC for the pumps and the various cooler regulating valve controls is provided by the dc control bus.

Service Water (Common)

The service water system consists of four service water pumps (1–4), two service water strainers, and the distribution headers to provide service water to various Unit 1 and Unit 2 loads. Pumps 1 and 3 are powered from Unit 1 2.3kv Bus 1A, Pump 2 is powered from Unit 1 2.3kv bus 1B, and Pump 4 is powered from Unit 2 4kv bus 2B. The strainers (A and B) are self-cleaning and are powered from 440v switch group 2A. It is assumed that a loss of power to the strainers would require a plant shutdown due to eventual strainer clogging. DC power for the service water pump controls from the dc control bus; however, because most of the pumps are normally already operating, loss of the dc control power is assumed to not cause a trip of any running pump.

Three pumps must normally operate to provide adequate cooling water flow to the system for full power operation at the station. It will be assumed that operation with less than three pumps would result in a need to derate Unit 2. Because of the cooler water, there is less service water required in the winter. It is assumed that only two pumps are required when the river water temperature is sufficiently low.

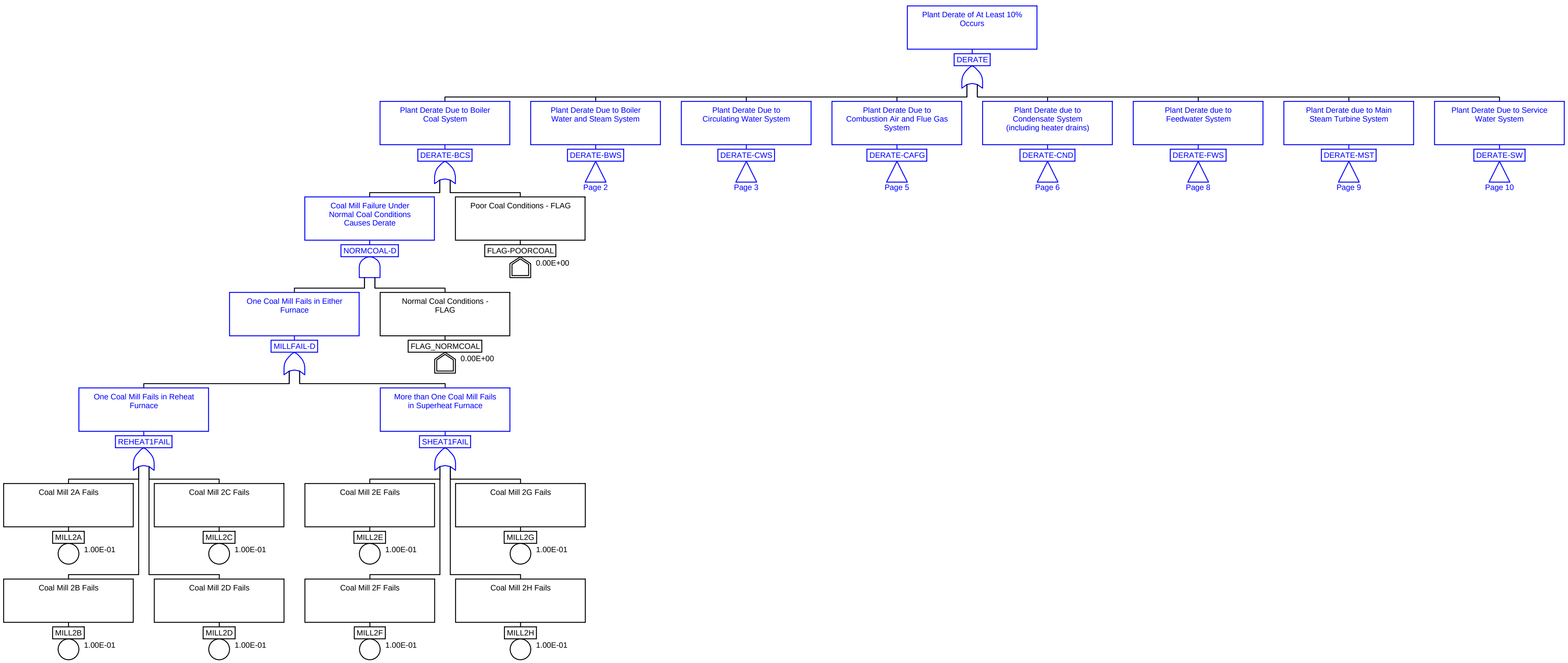
It is assumed that one strainer train can be isolated for maintenance without disrupting power operation. Motor-operated valves are used to isolate and un-isolate the strainers. However, the power supplies for these valves can be ignored, because these valves are not controlled by any automated control system.

In addition to ac power, the system relies on water in the service water bay. The traveling screens need to function properly to provide water for this system. (The screens are addressed as part of the circulating water system).

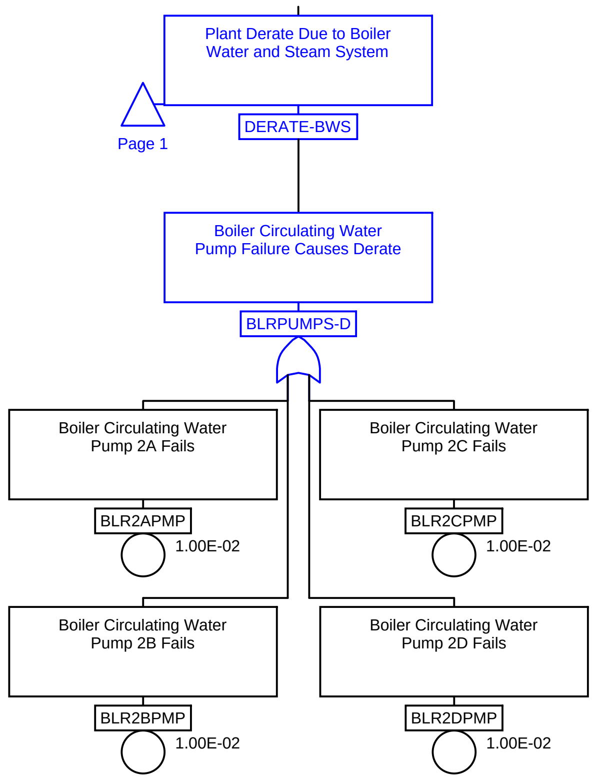
Other than pump and strainer operational choices, there are no alternative system alignments to consider.

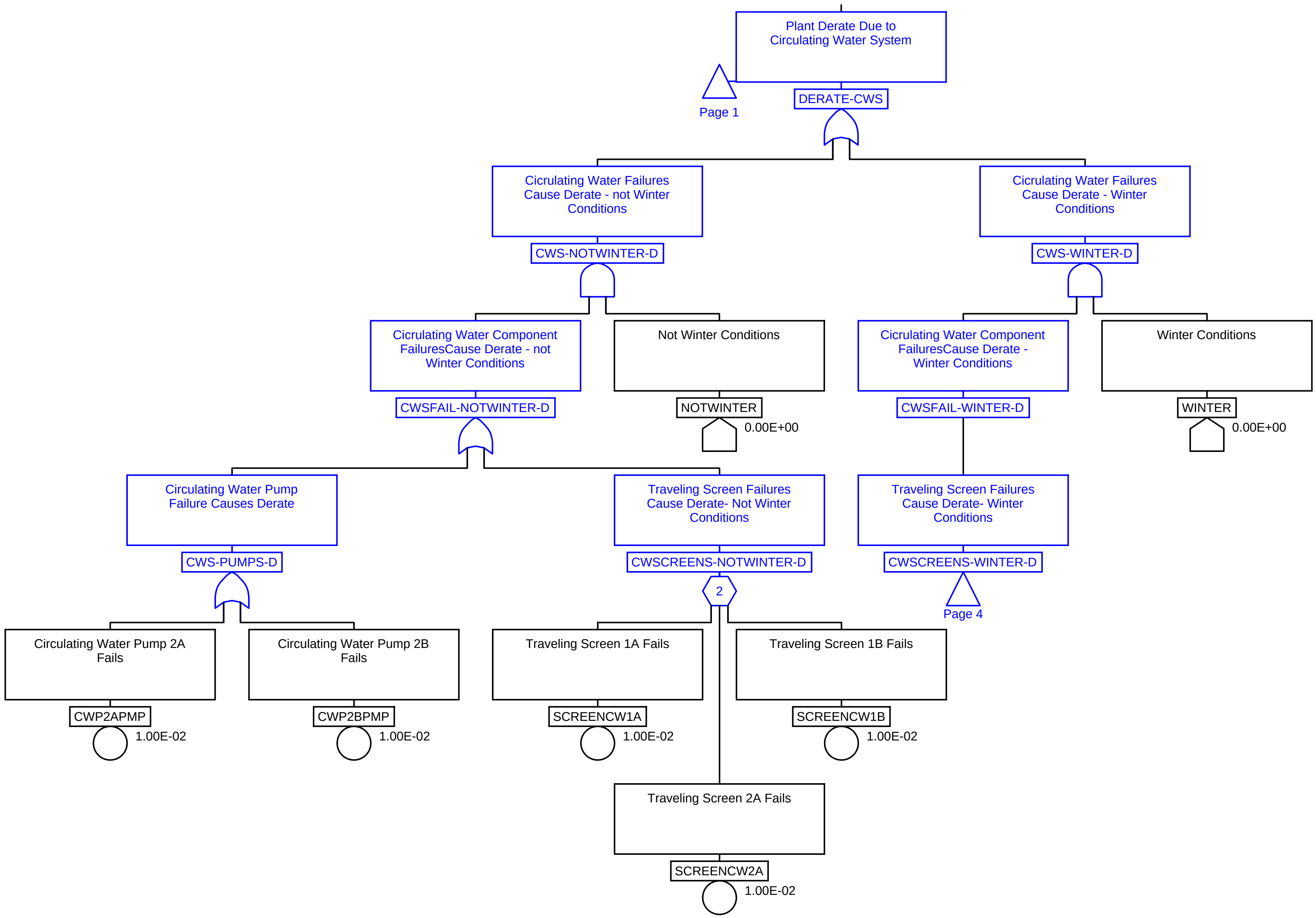
C
GRA MODELS

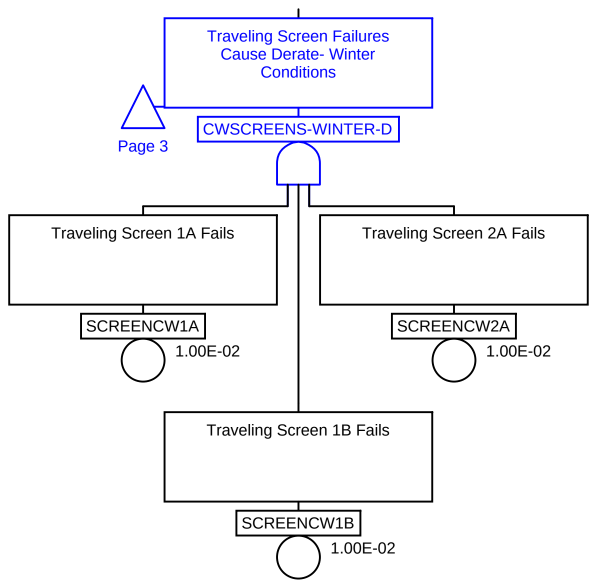
This appendix presents the fault tree used to evaluate the risk of plant shutdown or derate. Although plant-specific models may differ, this overall structure should be appropriate for most power plants. Note that this model contains two top events, trip (plant shutdown occurs) and derate (power reduction occurs).

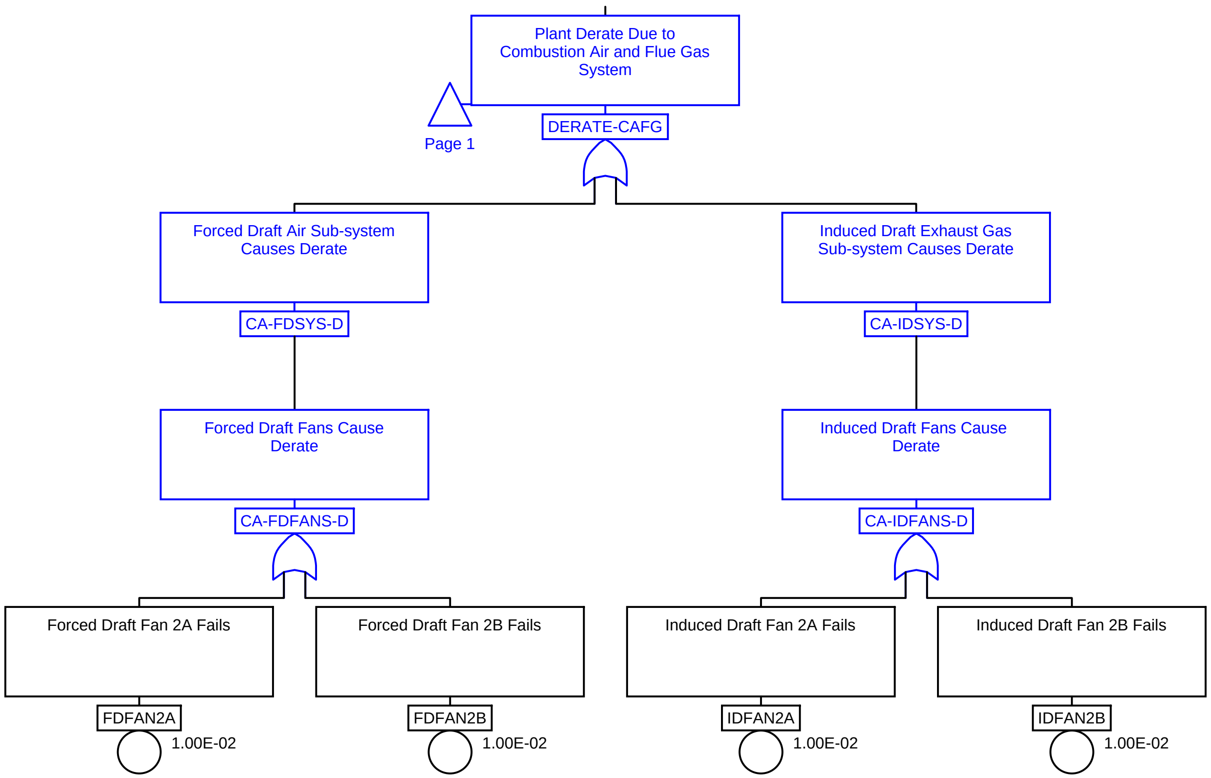


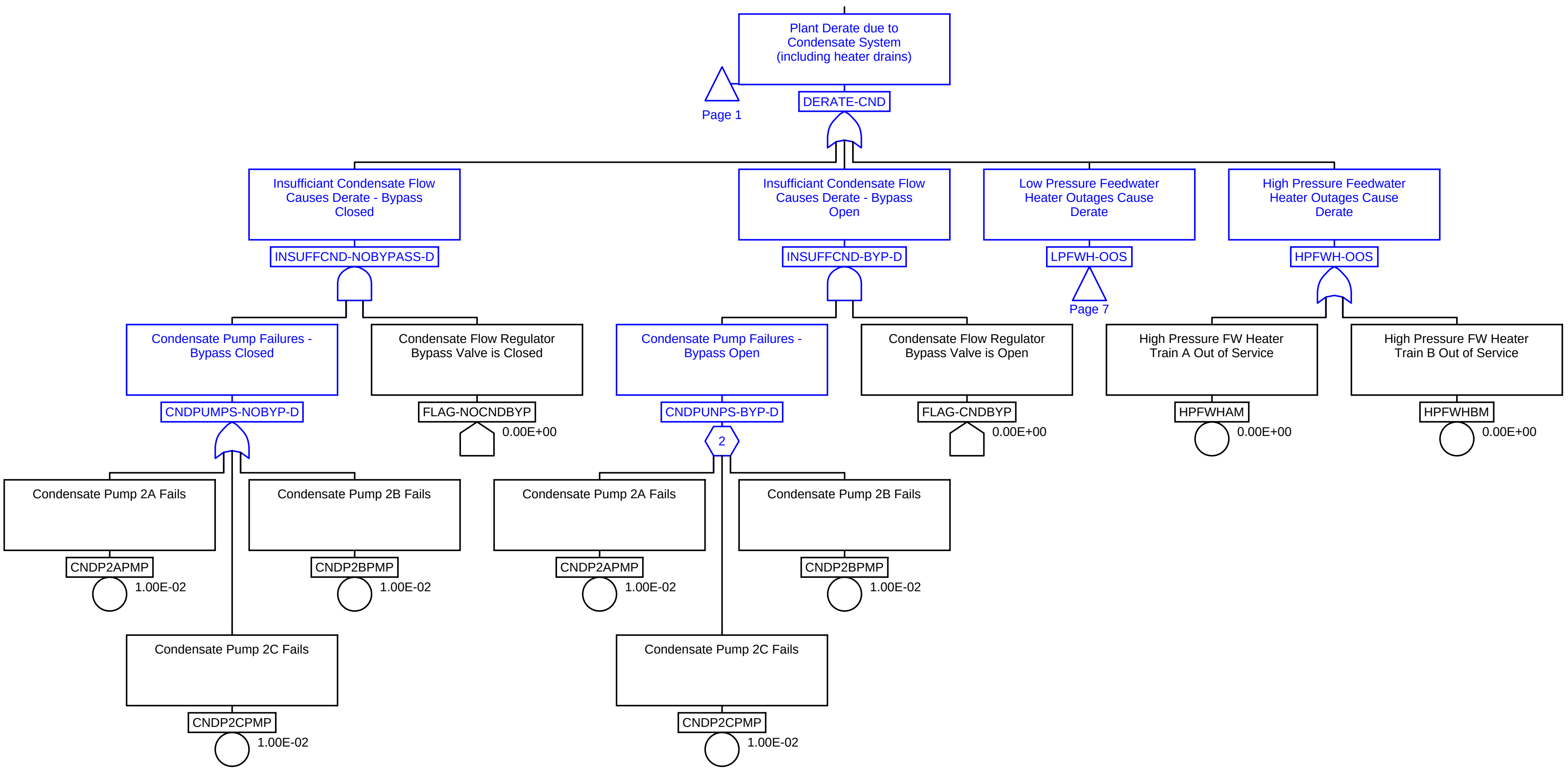
Plant Derate of At Least 10% Occurs
DERATE
Plant Derate Due to Boiler Coal System
DERATE-BCS
Plant Derate Due to Boiler Water and Steam System
DERATE-BWS
Page 2
Plant Derate Due to Circulating Water System
DERATE-CWS
Page 3
Plant Derate Due to Combustion Air and Flue Gas System
DERATE-CAFG
Page 5
Plant Derate due to Condensate System (including heater drains)
DERATE-CND
Page 6
Plant Derate due to Feedwater System
DERATE-FWS
Page 8
Plant Derate due to Main Steam Turbine System
DERATE-MST
Page 9
Plant Derate Due to Service Water System
DERATE-SW
Page 10
Coal Mill Failure Under Normal Coal Conditions Causes Derate
NORMCOAL-D
Poor Coal Conditions - FLAG
FLAG-POORCOAL
0.00E+00
One Coal Mill Fails in Either Furnace
MILLFAIL-D
Normal Coal Conditions - FLAG
FLAG_NORMCOAL
0.00E+00
One Coal Mill Fails in Reheat Furnace
REHEAT1FAIL
More than One Coal Mill Fails in Superheat Furnace
SHEAT1FAIL
Coal Mill 2A Fails
MILL2A
1.00E-01
Coal Mill 2C Fails
MILL2C
1.00E-01
Coal Mill 2E Fails
MILL2E
1.00E-01
Coal Mill 2G Fails
MILL2G
1.00E-01
Coal Mill 2B Fails
MILL2B
1.00E-01
Coal Mill 2D Fails
MILL2D
1.00E-01
Coal Mill 2F Fails
MILL2F
1.00E-01
Coal Mill 2H Fails
MILL2H
1.00E-01

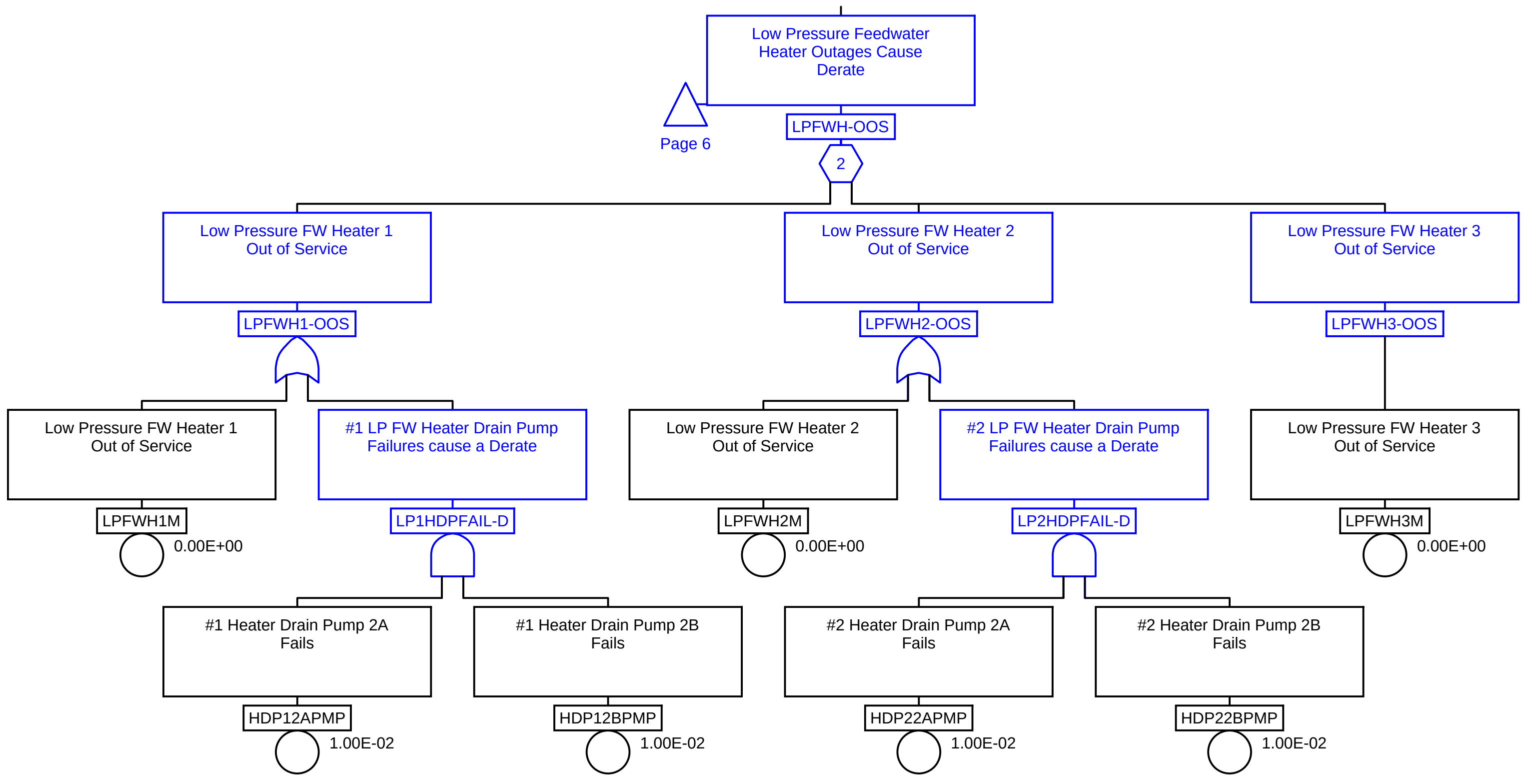

Plant Derate Due to Boiler Water and Steam System
DERATE-BWS
Page 1
Boiler Circulating Water Pump Failure Causes Derate
BLRPUMPS-D
Boiler Circulating Water Pump 2A Fails
BLR2APMP
1.00E-02
Boiler Circulating Water Pump 2C Fails
BLR2CPMP
1.00E-02
Boiler Circulating Water Pump 2B Fails
BLR2BPMP
1.00E-02
Boiler Circulating Water Pump 2D Fails
BLR2DPMP
1.00E-02

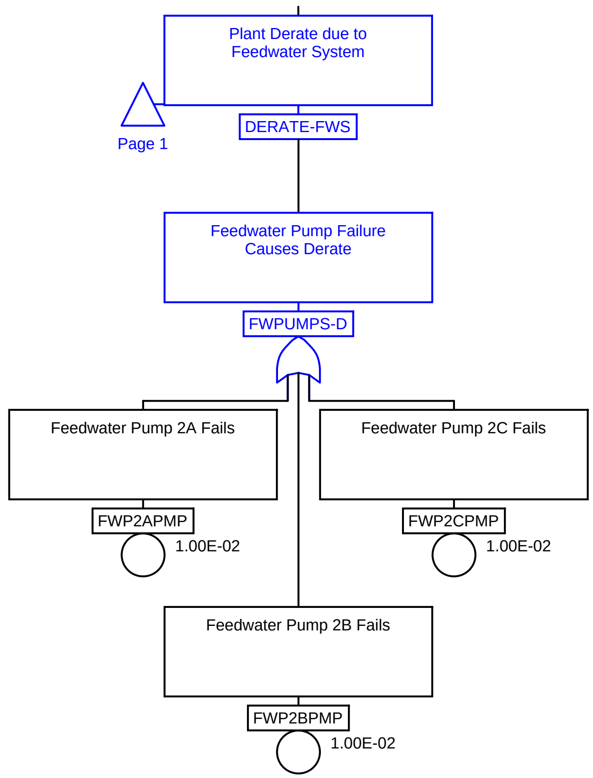

Plant Derate Due to Circulating Water System
DERATE-CWS
Page 1
Circulating Water Failures Cause Derate - not Winter Conditions
CWS-NOTWINTER-D
Circulating Water Failures Cause Derate - Winter Conditions
CWS-WINTER-D
Cicrulating Water Component FailuresCause Derate - not Winter Conditions
CWSFAIL-NOTWINTER-D
Not Winter Conditions
NOTWINTER
0.00E+00
Cicrulating Water Component FailuresCause Derate - Winter Conditions
CWSFAIL-WINTER-D
Winter Conditions
WINTER
0.00E+00
Circulating Water Pump Failure Causes Derate
CWS-PUMPS-D
Traveling Screen Failures Cause Derate- Not Winter Conditions
CWSCREENS-NOTWINTER-D
2
Traveling Screen Failures Cause Derate- Winter Conditions
CWSCREENS-WINTER-D
Page 4
Circulating Water Pump 2A Fails
CWP2APMP
1.00E-02
Circulating Water Pump 2B Fails
CWP2BPMP
1.00E-02
Traveling Screen 1A Fails
SCREENCW1A
1.00E-02
Traveling Screen 1B Fails
SCREENCW1B
1.00E-02
Traveling Screen 2A Fails
SCREENCW2A
1.00E-02

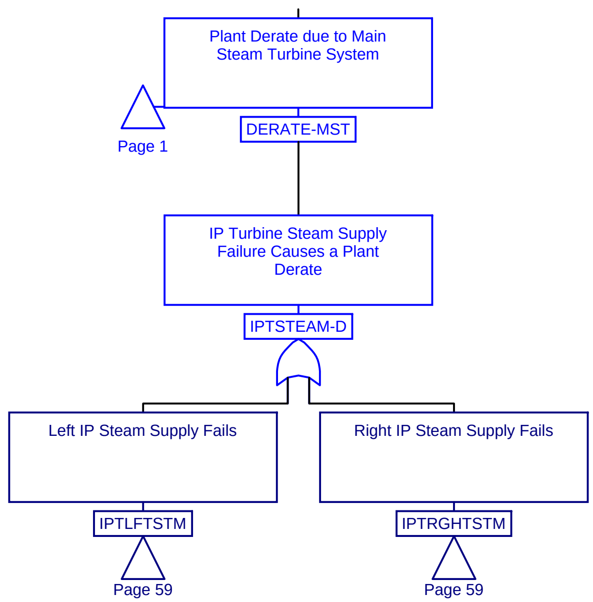

Traveling Screen Failures Cause Derate- Winter Conditions
CWSCREENS-WINTER-D
Page 3
Traveling Screen 1A Fails
SCREENCW1A
1.00E-02
Traveling Screen 2A Fails
SCREENCW2A
1.00E-02
Traveling Screen 1B Fails
SCREENCW1B
1.00E-02

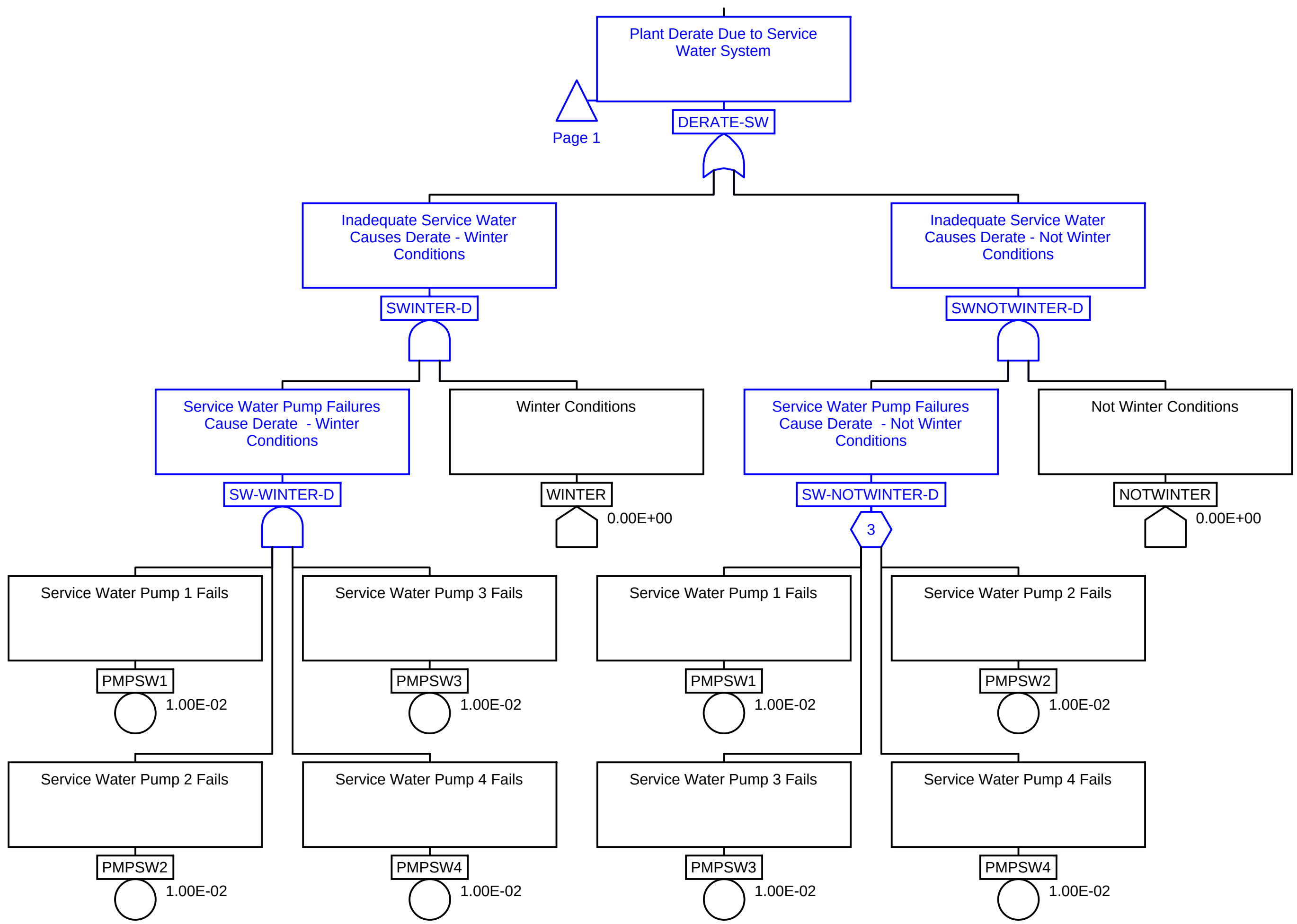

Plant Derate Due to Combustion Air and Flue Gas System
DERATE-CAFG
Page 1
Forced Draft Air Sub-system Causes Derate
CA-FDSYS-D
Induced Draft Exhaust Gas Sub-system Causes Derate
CA-IDSYS-D
Forced Draft Fans Cause Derate
CA-FDFANS-D
Induced Draft Fans Cause Derate
CA-IDFANS-D
Forced Draft Fan 2A Fails
FDFAN2A
1.00E-02
Forced Draft Fan 2B Fails
FDFAN2B
1.00E-02
Induced Draft Fan 2A Fails
IDFAN2A
1.00E-02
Induced Draft Fan 2B Fails
IDFAN2B
1.00E-02


Plant Derate due to Condensate System (including heater drains)
DERATE-CND
Page 1
Insufficiant Condensate Flow Causes Derate - Bypass Closed
INSUFFCND-NOBYPASS-D
Insufficiant Condensate Flow Causes Derate - Bypass Open
INSUFFCND-BYP-D
Low Pressure Feedwater Heater Outages Cause Derate
LPFWH-OOS
Page 7
High Pressure Feedwater Heater Outages Cause Derate
HPFWH-OOS
Condensate Pump Failures - Bypass Closed
CNDPUMPS-NOBYP-D
Condensate Flow Regulator Bypass Valve is Closed
FLAG-NOCNDBYP
0.00E+00
Condensate Pump Failures - Bypass Open
CNDPUNPS-BYP-D
2
Condensate Flow Regulator Bypass Valve is Open
FLAG-CNDBYP
0.00E+00
High Pressure FW Heater Train A Out of Service
HPFWHAM
0.00E+00
High Pressure FW Heater Train B Out of Service
HPFWHBM
0.00E+00
Condensate Pump 2A Fails
CNDP2APMP
1.00E-02
Condensate Pump 2B Fails
CNDP2BPMP
1.00E-02
Condensate Pump 2A Fails
CNDP2APMP
1.00E-02
Condensate Pump 2B Fails
CNDP2BPMP
1.00E-02
Condensate Pump 2C Fails
CNDP2CPMP
1.00E-02
Condensate Pump 2C Fails
CNDP2CPMP
1.00E-02

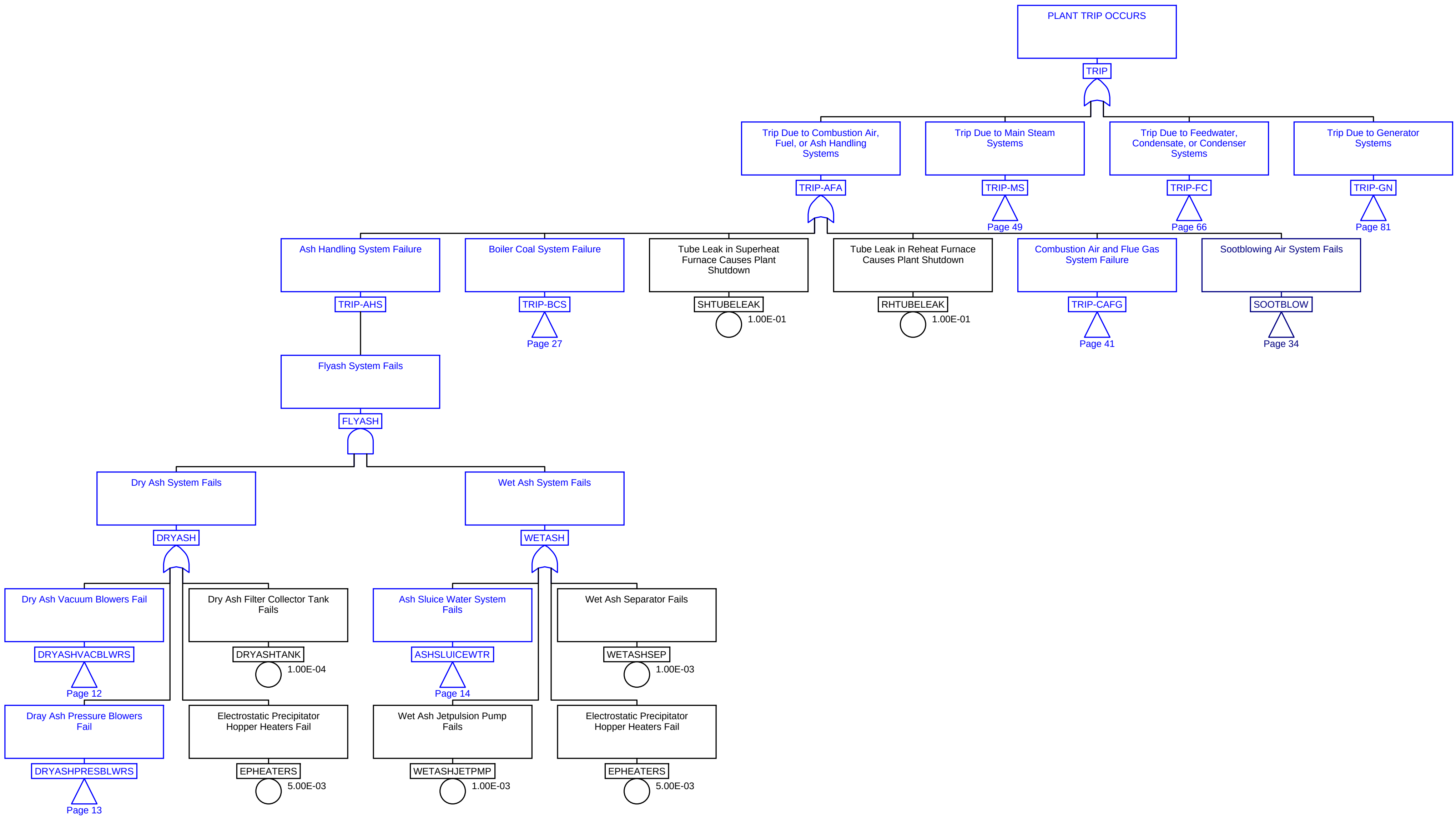

Low Pressure Feedwater Heater Outages Cause Derate
LPFWH-OOS
Page 6
2
Low Pressure FW Heater 1 Out of Service
LPFWH1-OOS
Low Pressure FW Heater 2 Out of Service
LPFWH2-OOS
Low Pressure FW Heater 3 Out of Service
LPFWH3-OOS
Low Pressure FW Heater 1 Out of Service
LPFWH1M
0.00E+00
#1 LP FW Heater Drain Pump Failures cause a Derate
LP1HDPFAIL-D
Low Pressure FW Heater 2 Out of Service
LPFWH2M
0.00E+00
#2 LP FW Heater Drain Pump Failures cause a Derate
LP2HDPFAIL-D
Low Pressure FW Heater 3 Out of Service
LPFWH3M
0.00E+00
#1 Heater Drain Pump 2A Fails
HDP12APMP
1.00E-02
#1 Heater Drain Pump 2B Fails
HDP12BPMP
1.00E-02
#2 Heater Drain Pump 2A Fails
HDP22APMP
1.00E-02
#2 Heater Drain Pump 2B Fails
HDP22BPMP
1.00E-02


Plant Derate due to Feedwater System
DERATE-FWS
Page 1
Feedwater Pump Failure Causes Derate
FWPUMPS-D
Feedwater Pump 2A Fails
FWP2APMP
1.00E-02
Feedwater Pump 2C Fails
FWP2CPMP
1.00E-02
Feedwater Pump 2B Fails
FWP2BPMP
1.00E-02

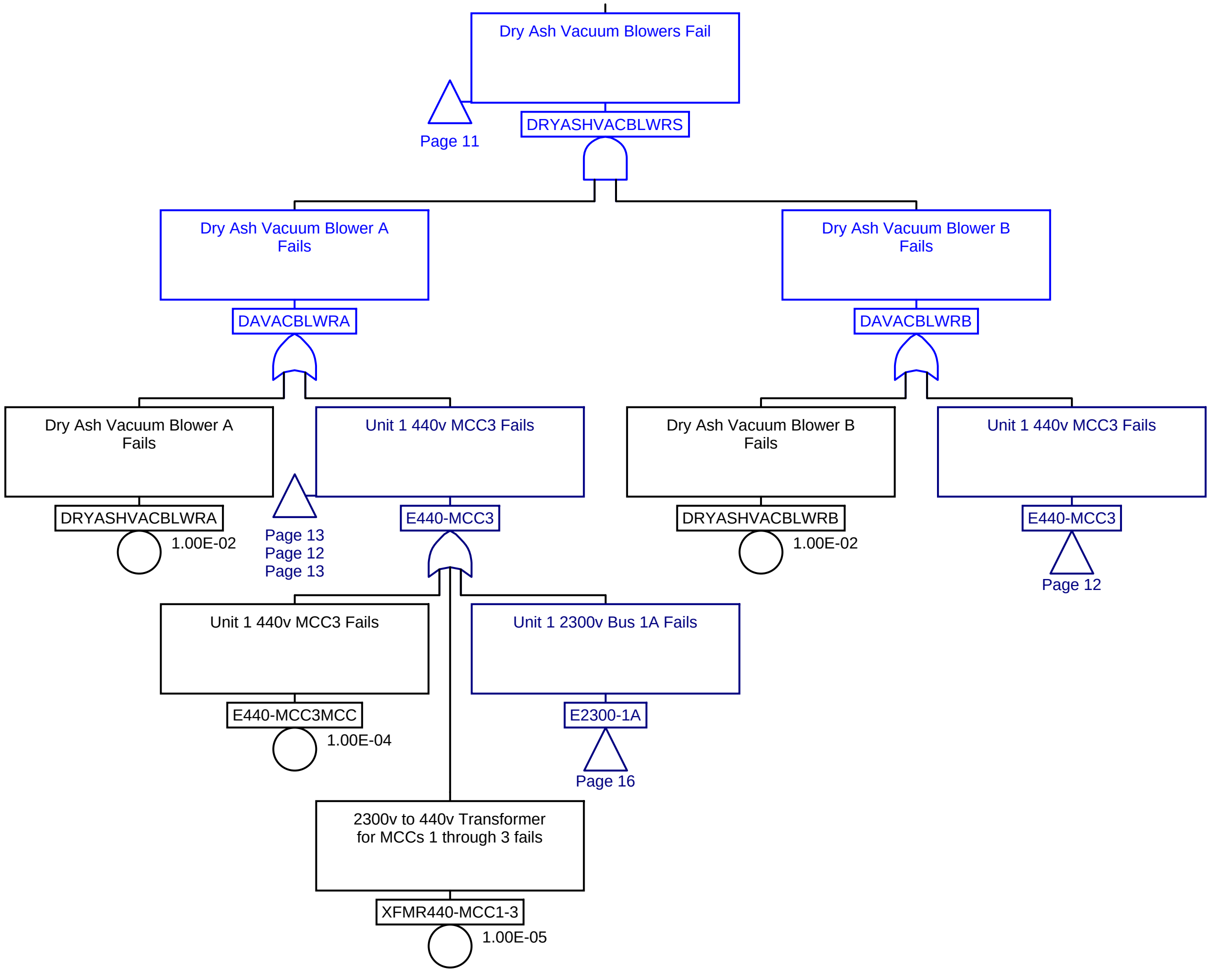

Plant Derate due to Main Steam Turbine System
Page 1
DERATE-MST
IP Turbine Steam Supply Failure Causes a Plant Derate
IPTSTEAM-D
Left IP Steam Supply Fails
Right IP Steam Supply Fails
IPTLFTSTM
IPTRGHTSTM
Page 59
Page 59



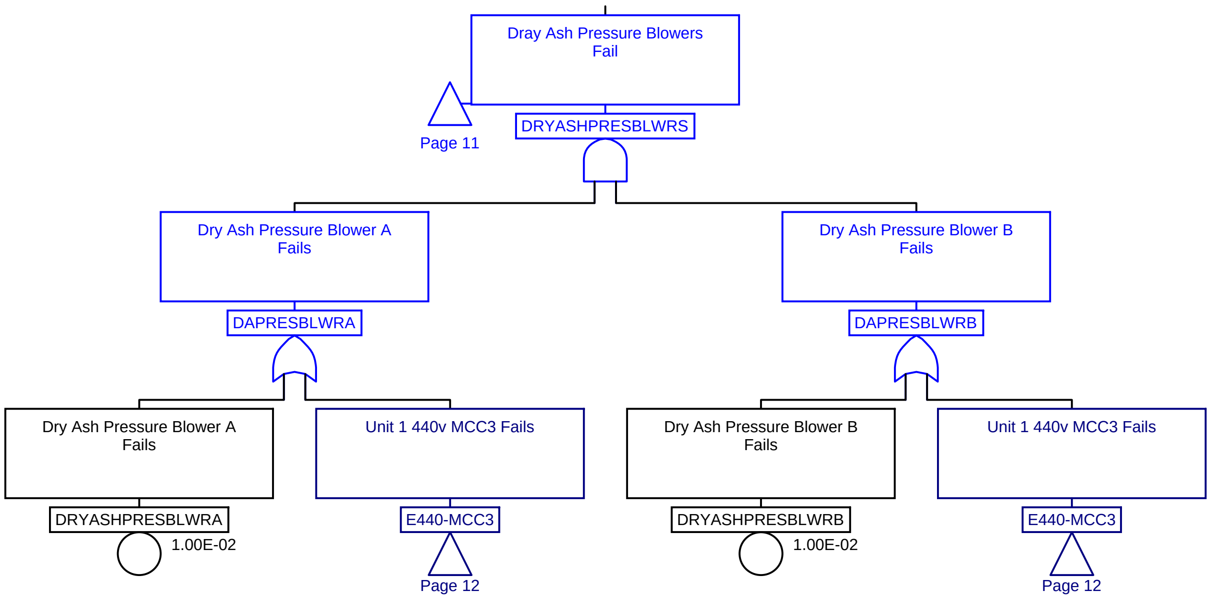
Plant Derate Due to Service Water System
Page 1
DERATE-SW
Inadequate Service Water Causes Derate - Winter Conditions
SWINTER-D
Inadequate Service Water Causes Derate - Not Winter Conditions
SWNOTWINTER-D
Service Water Pump Failures Cause Derate - Winter Conditions
SW-WINTER-D
Winter Conditions
WINTER
0.00E+00
Service Water Pump Failures Cause Derate - Not Winter Conditions
SW-NOTWINTER-D
3
Not Winter Conditions
NOTWINTER
0.00E+00
Service Water Pump 1 Fails
PMPSW1
1.00E-02
Service Water Pump 3 Fails
PMPSW3
1.00E-02
Service Water Pump 1 Fails
PMPSW1
1.00E-02
Service Water Pump 2 Fails
PMPSW2
1.00E-02
Service Water Pump 2 Fails
PMPSW2
1.00E-02
Service Water Pump 4 Fails
PMPSW4
1.00E-02
Service Water Pump 3 Fails
PMPSW3
1.00E-02
Service Water Pump 4 Fails
PMPSW4
1.00E-02

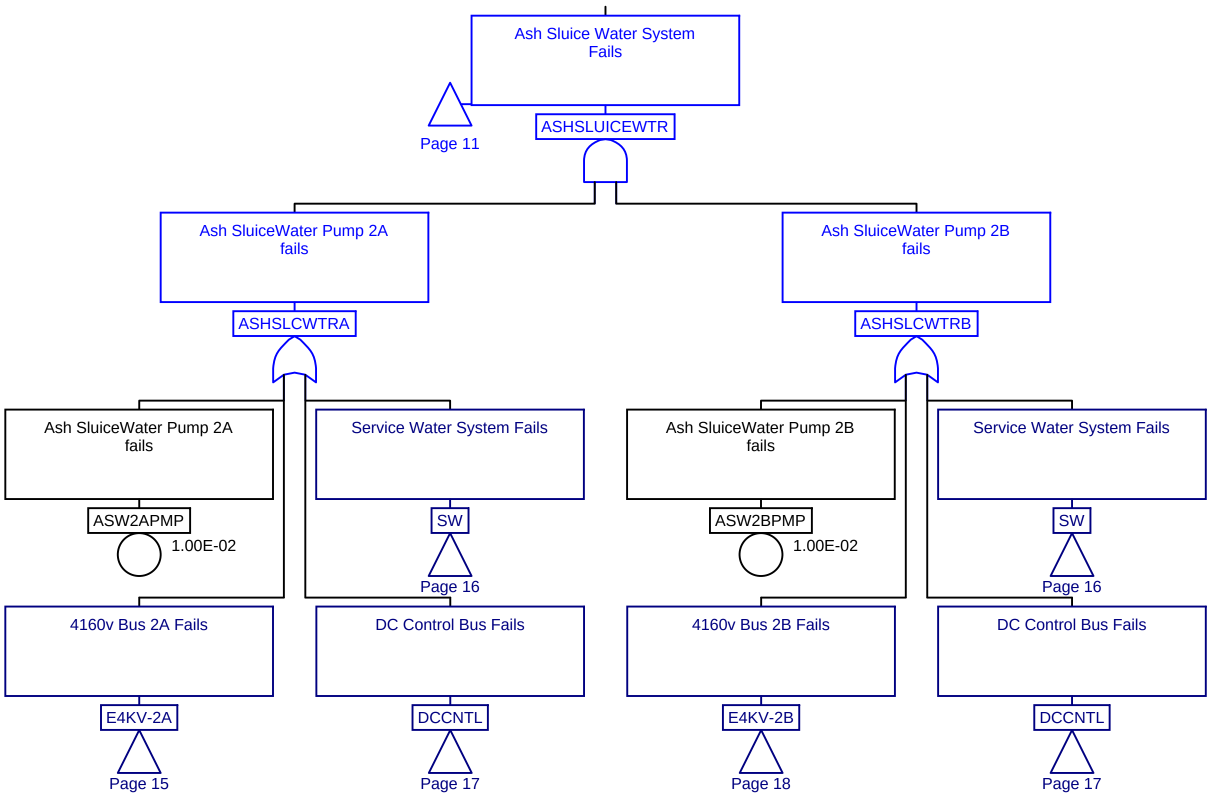


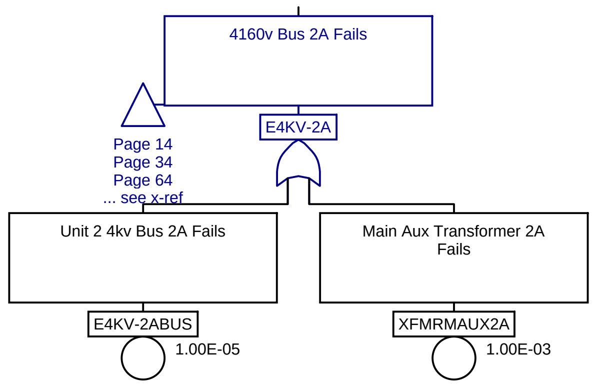
PLANT TRIP OCCURS
TRIP
Trip Due to Combustion Air, Fuel, or Ash Handling Systems
TRIP-AFA
Trip Due to Main Steam Systems
TRIP-MS
Page 49
Trip Due to Feedwater, Condensate, or Condenser Systems
TRIP-FC
Page 66
Trip Due to Generator Systems
TRIP-GN
Page 81
Ash Handling System Failure
TRIP-AHS
Boiler Coal System Failure
TRIP-BCS
Page 27
Tube Leak in Superheat Furnace Causes Plant Shutdown
SHTUBELEAK
1.00E-01
Tube Leak in Reheat Furnace Causes Plant Shutdown
RHTUBELEAK
1.00E-01
Combustion Air and Flue Gas System Failure
TRIP-CAFG
Page 41
Sootblowing Air System Fails
SOOTBLOW
Page 34
Flyash System Fails
FLYASH
Dry Ash System Fails
DRYASH
Wet Ash System Fails
WETASH
Dry Ash Vacuum Blowers Fail
DRYASHVACBLWRS
Page 12
Dry Ash Filter Collector Tank Fails
DRYASHTANK
1.00E-04
Ash Sluice Water System Fails
ASHSLUICEWTR
Page 14
Wet Ash Separator Fails
WETASHSEP
1.00E-03
Dray Ash Pressure Blowers Fail
DRYASHPRESBLWRS
Page 13
Electrostatic Precipitator Hopper Heaters Fail
EPHEATERS
5.00E-03
Wet Ash Jetpulsion Pump Fails
WETASHJETPMP
1.00E-03
Electrostatic Precipitator Hopper Heaters Fail
EPHEATERS
5.00E-03

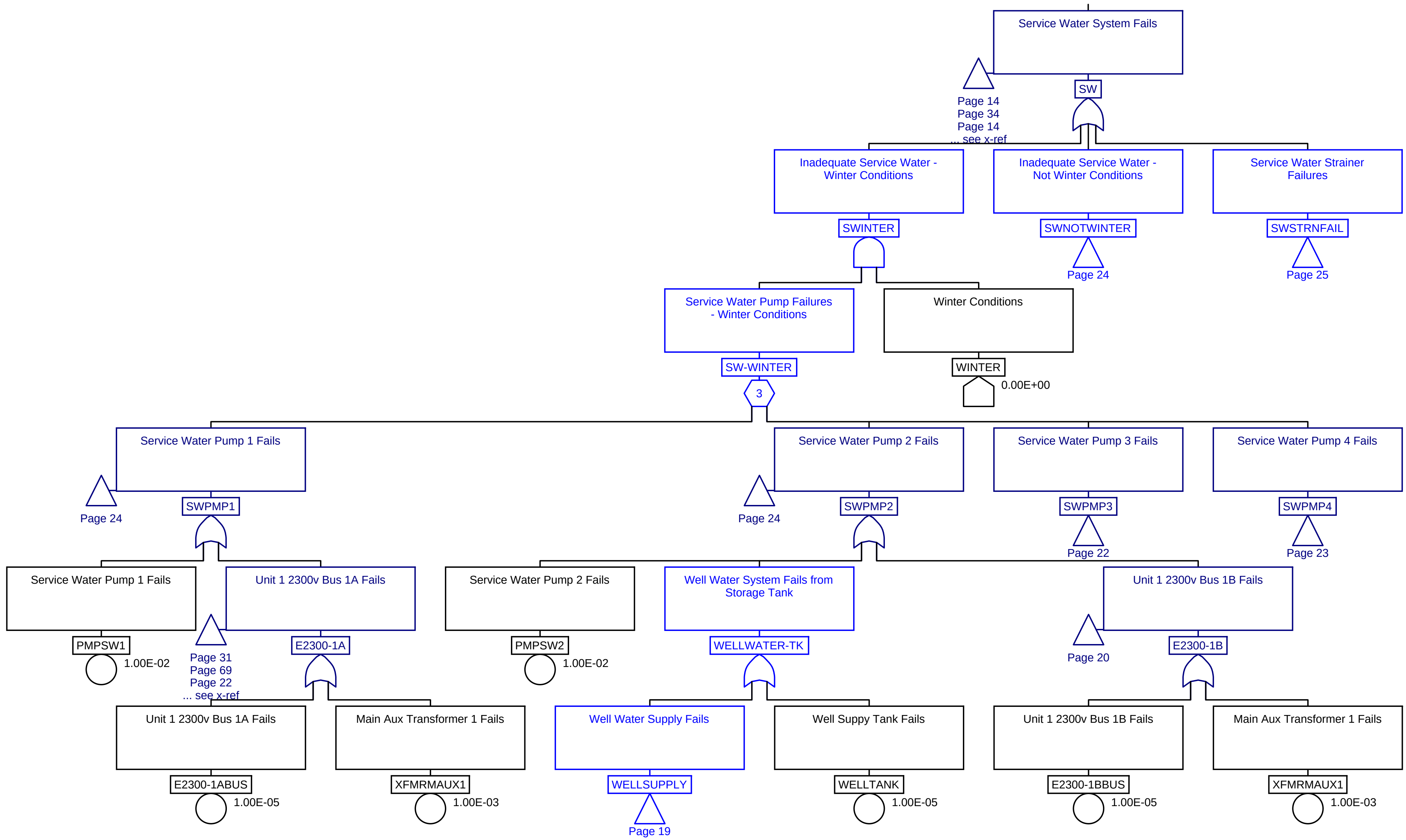


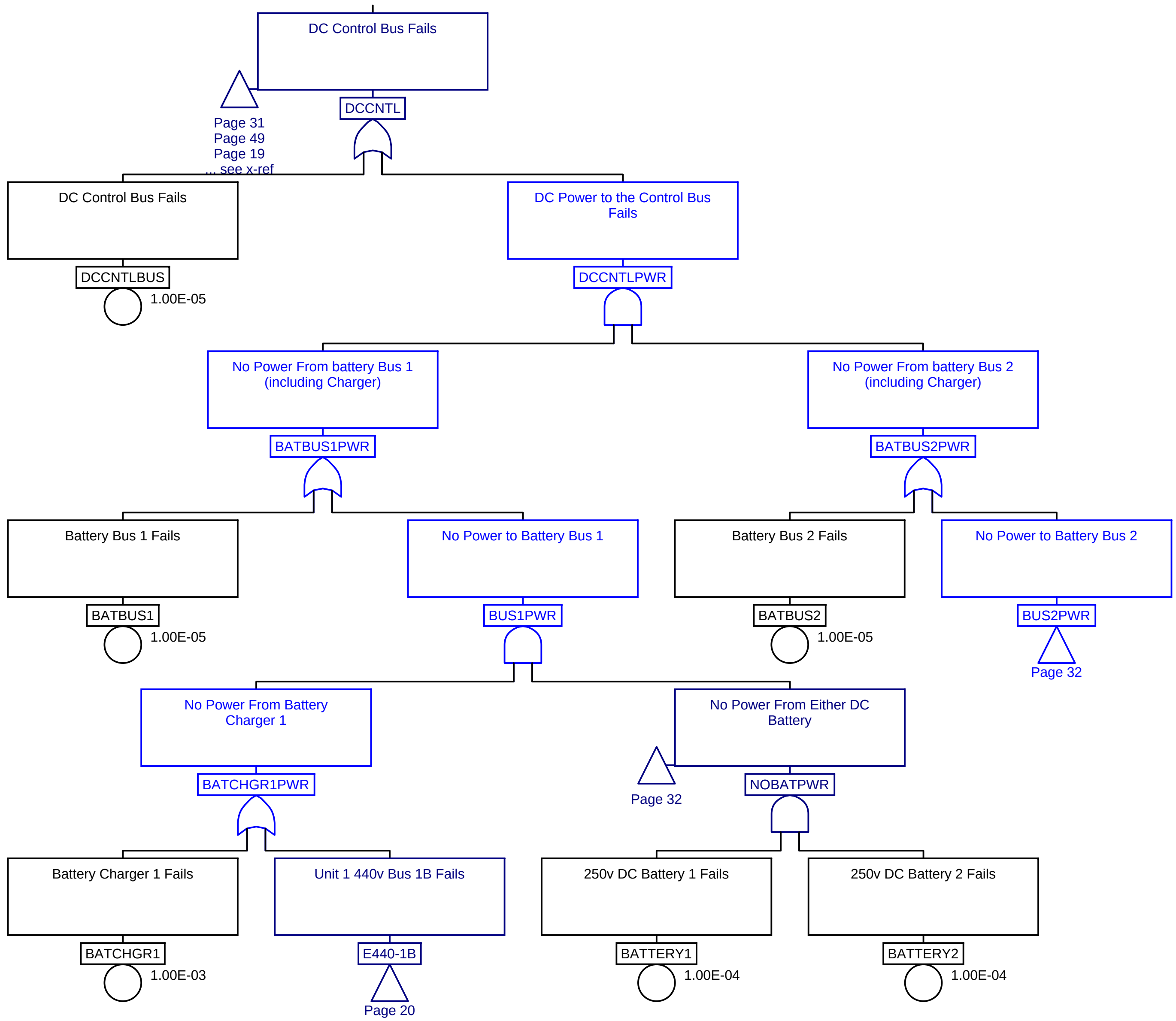
Dry Ash Vacuum Blowers Fail
DRYASHVACBLWRS
Page 11
Dry Ash Vacuum Blower A Fails
DAVACBLWRA
Dry Ash Vacuum Blower B Fails
DAVACBLWRB
Dry Ash Vacuum Blower A Fails
DRYASHVACBLWRA
1.00E-02
Page 13
Page 12
Page 13
Unit 1 440v MCC3 Fails
E440-MCC3
Dry Ash Vacuum Blower B Fails
DRYASHVACBLWRB
1.00E-02
Unit 1 440v MCC3 Fails
E440-MCC3
Page 12
Unit 1 440v MCC3 Fails
E440-MCC3MCC
1.00E-04
Unit 1 2300v Bus 1A Fails
E2300-1A
Page 16
2300v to 440v Transformer for MCCs 1 through 3 fails
XFMR440-MCC1-3
1.00E-05

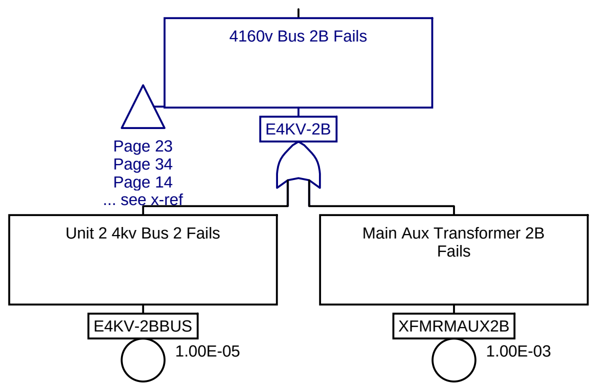

Dray Ash Pressure Blowers Fail
DRYASHPRESBLWRS
Page 11
Dry Ash Pressure Blower A Fails
DAPRESBLWRA
Dry Ash Pressure Blower B Fails
DAPRESBLWRB
Dry Ash Pressure Blower A Fails
DRYASHPRESBLWRA
1.00E-02
Unit 1 440v MCC3 Fails
E440-MCC3
Page 12
Dry Ash Pressure Blower B Fails
DRYASHPRESBLWRB
1.00E-02
Unit 1 440v MCC3 Fails
E440-MCC3
Page 12

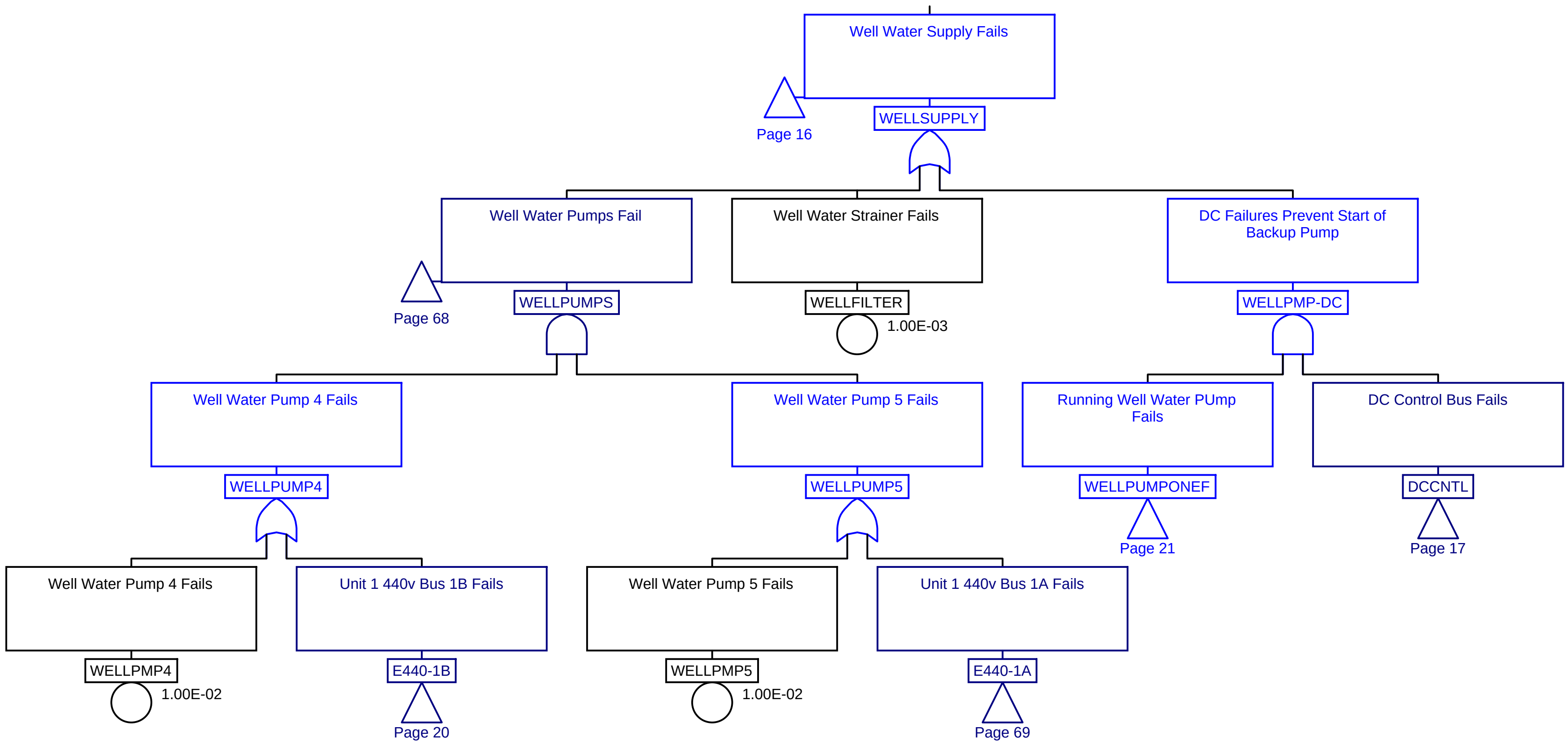

Ash Sluice Water System Fails
ASHSLUICEWTR
Page 11
Ash SluiceWater Pump 2A fails
ASHSLCWTRA
Ash SluiceWater Pump 2B fails
ASHSLCWTRB
Ash SluiceWater Pump 2A fails
ASW2APMP
1.00E-02
Service Water System Fails
SW
Page 16
Ash SluiceWater Pump 2B fails
ASW2BPMP
1.00E-02
Service Water System Fails
SW
Page 16
4160v Bus 2A Fails
E4KV-2A
Page 15
DC Control Bus Fails
DCCNTL
Page 17
4160v Bus 2B Fails
E4KV-2B
Page 18
DC Control Bus Fails
DCCNTL
Page 17

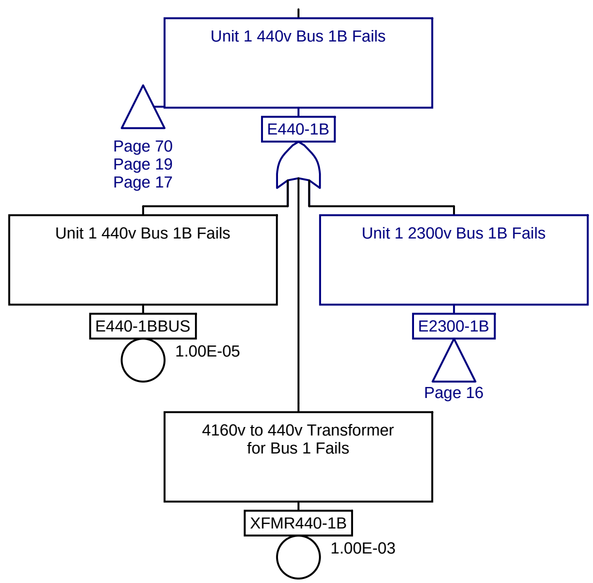

4160v Bus 2A Fails
E4KV-2A
Page 14
Page 34
Page 64
... see x-ref
Unit 2 4kv Bus 2A Fails
E4KV-2ABUS
1.00E-05
Main Aux Transformer 2A Fails
XFMRMAUX2A
1.00E-03

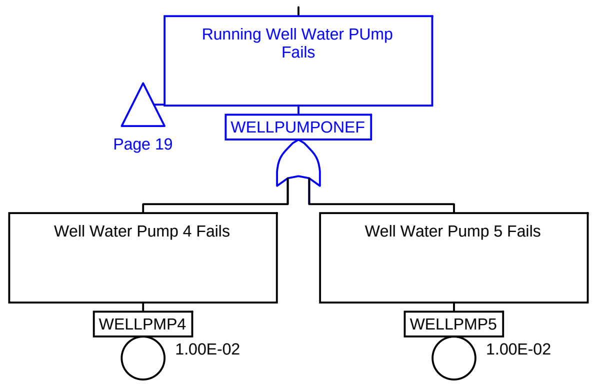

Service Water System Fails
SW
Page 14
Page 34
Page 14
... see x-ref
Inadequate Service Water - Winter Conditions
SWINTER
Inadequate Service Water - Not Winter Conditions
SWNOTWINTER
Page 24
Service Water Strainer Failures
SWSTRNFAIL
Page 25
Service Water Pump Failures - Winter Conditions
SW-WINTER
3
Winter Conditions
WINTER
0.00E+00
Service Water Pump 1 Fails
Page 24
SWPMP1
Service Water Pump 2 Fails
Page 24
SWPMP2
Service Water Pump 3 Fails
SWPMP3
Page 22
Service Water Pump 4 Fails
SWPMP4
Page 23
Service Water Pump 1 Fails
PMPSW1
1.00E-02
Page 31
Page 69
Page 22
... see x-ref
Unit 1 2300v Bus 1A Fails
E2300-1A
Service Water Pump 2 Fails
PMPSW2
1.00E-02
Well Water System Fails from Storage Tank
WELLWATER-TK
Unit 1 2300v Bus 1B Fails
Page 20
E2300-1B
Unit 1 2300v Bus 1A Fails
E2300-1ABUS
1.00E-05
Main Aux Transformer 1 Fails
XFMRMAUX1
1.00E-03
Well Water Supply Fails
WELLSUPPLY
Page 19
Well Suppy Tank Fails
WELLTANK
1.00E-05
Unit 1 2300v Bus 1B Fails
E2300-1BBUS
1.00E-05
Main Aux Transformer 1 Fails
XFMRMAUX1
1.00E-03

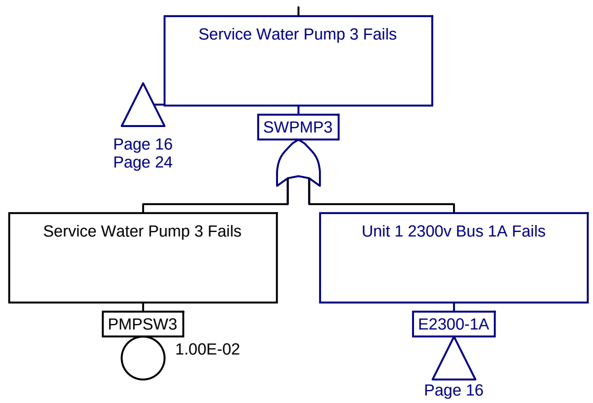

DC Control Bus Fails
DCCNTL
Page 31
Page 49
Page 19
... see x-ref
DC Control Bus Fails
DCCNTLBUS
1.00E-05
DC Power to the Control Bus Fails
DCCNTLPWR
No Power From battery Bus 1 (including Charger)
BATBUS1PWR
No Power From battery Bus 2 (including Charger)
BATBUS2PWR
Battery Bus 1 Fails
BATBUS1
1.00E-05
No Power to Battery Bus 1
BUS1PWR
Battery Bus 2 Fails
BATBUS2
1.00E-05
No Power to Battery Bus 2
BUS2PWR
Page 32
No Power From Battery Charger 1
BATCHGR1PWR
No Power From Either DC Battery
NOBATPWR
Page 32
Battery Charger 1 Fails
BATCHGR1
1.00E-03
Unit 1 440v Bus 1B Fails
E440-1B
Page 20
250v DC Battery 1 Fails
BATTERY1
1.00E-04
250v DC Battery 2 Fails
BATTERY2
1.00E-04


4160v Bus 2B Fails
E4KV-2B
Page 23
Page 34
Page 14
... see x-ref
Unit 2 4kv Bus 2 Fails
E4KV-2BBUS
1.00E-05
Main Aux Transformer 2B
Fails
XFMRMAUX2B
1.00E-03

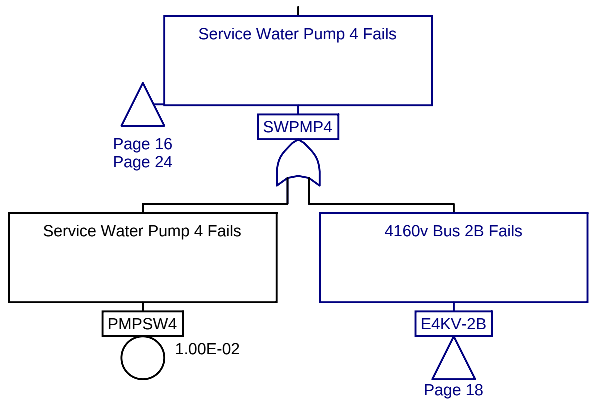

Well Water Supply Fails
WELLSUPPLY
Page 16
Well Water Pumps Fail
WELLPUMPS
Page 68
Well Water Strainer Fails
WELLFILTER
1.00E-03
DC Failures Prevent Start of Backup Pump
WELLPMP-DC
Well Water Pump 4 Fails
WELLPUMP4
Well Water Pump 5 Fails
WELLPUMP5
Running Well Water PUmp Fails
WELLPUMPONEF
Page 21
DC Control Bus Fails
DCCNTL
Page 17
Well Water Pump 4 Fails
WELLPMP4
1.00E-02
Unit 1 440v Bus 1B Fails
E440-1B
Page 20
Well Water Pump 5 Fails
WELLPMP5
1.00E-02
Unit 1 440v Bus 1A Fails
E440-1A
Page 69

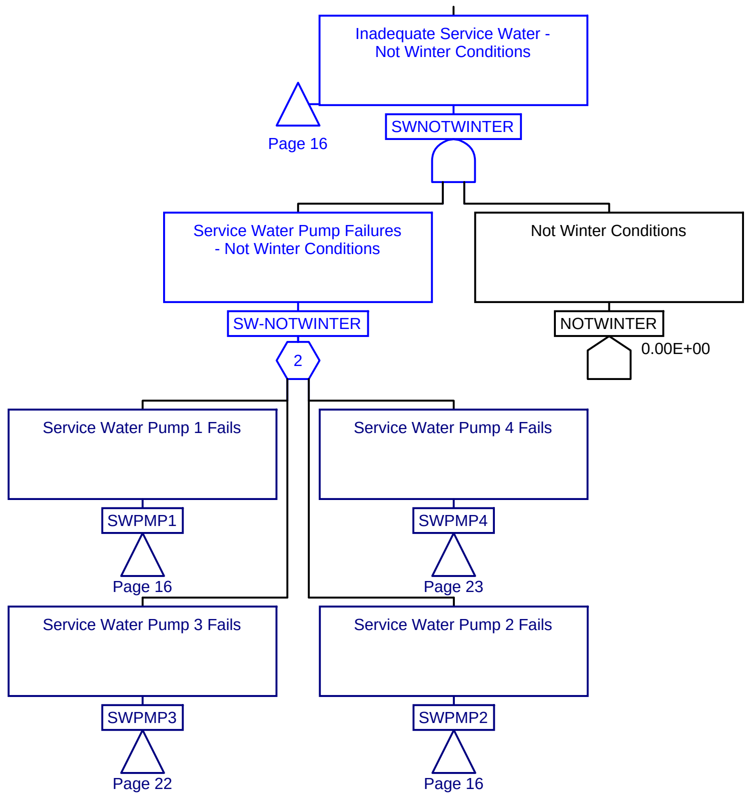

Unit 1 440v Bus 1B Fails
E440-1B
Page 70
Page 19
Page 17
Unit 1 440v Bus 1B Fails
E440-1BBUS
1.00E-05
Unit 1 2300v Bus 1B Fails
E2300-1B
Page 16
4160v to 440v Transformer
for Bus 1 Fails
XFMR440-1B
1.00E-03


Running Well Water PUmp Fails
WELLPUMPONEF
Page 19
Well Water Pump 4 Fails
WELLPMP4
1.00E-02
Well Water Pump 5 Fails
WELLPMP5
1.00E-02

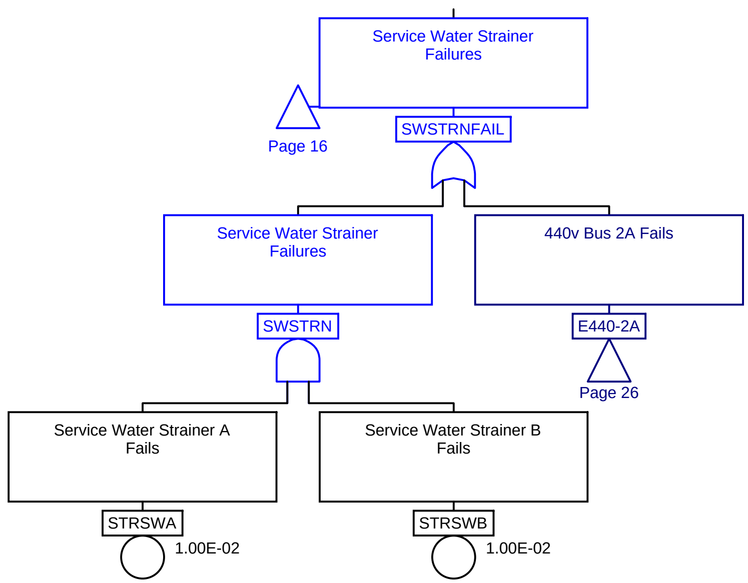


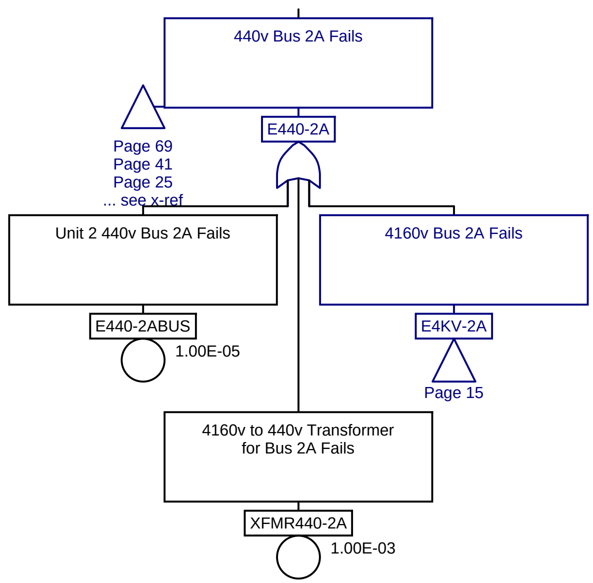
Service Water Pump 3 Fails
SWPMP3
Page 16
Page 24
Service Water Pump 3 Fails
PMPSW3
1.00E-02
Unit 1 2300v Bus 1A Fails
E2300-1A
Page 16


Service Water Pump 4 Fails
SWPMP4
Page 16
Page 24
Service Water Pump 4 Fails
PMPSW4
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18



Inadequate Service Water - Not Winter Conditions
SWNOTWINTER
Page 16
Service Water Pump Failures - Not Winter Conditions
SW-NOTWINTER
2
Not Winter Conditions
NOTWINTER
0.00E+00
Service Water Pump 1 Fails
SWPMP1
Page 16
Service Water Pump 4 Fails
SWPMP4
Page 23
Service Water Pump 3 Fails
SWPMP3
Page 22
Service Water Pump 2 Fails
SWPMP2
Page 16


Service Water Strainer Failures
SWSTRNFAIL
Page 16
Service Water Strainer Failures
SWSTRN
440v Bus 2A Fails
E440-2A
Page 26
Service Water Strainer A Fails
STRSWA
1.00E-02
Service Water Strainer B Fails
STRSWB
1.00E-02


440v Bus 2A Fails
E440-2A
Page 69
Page 41
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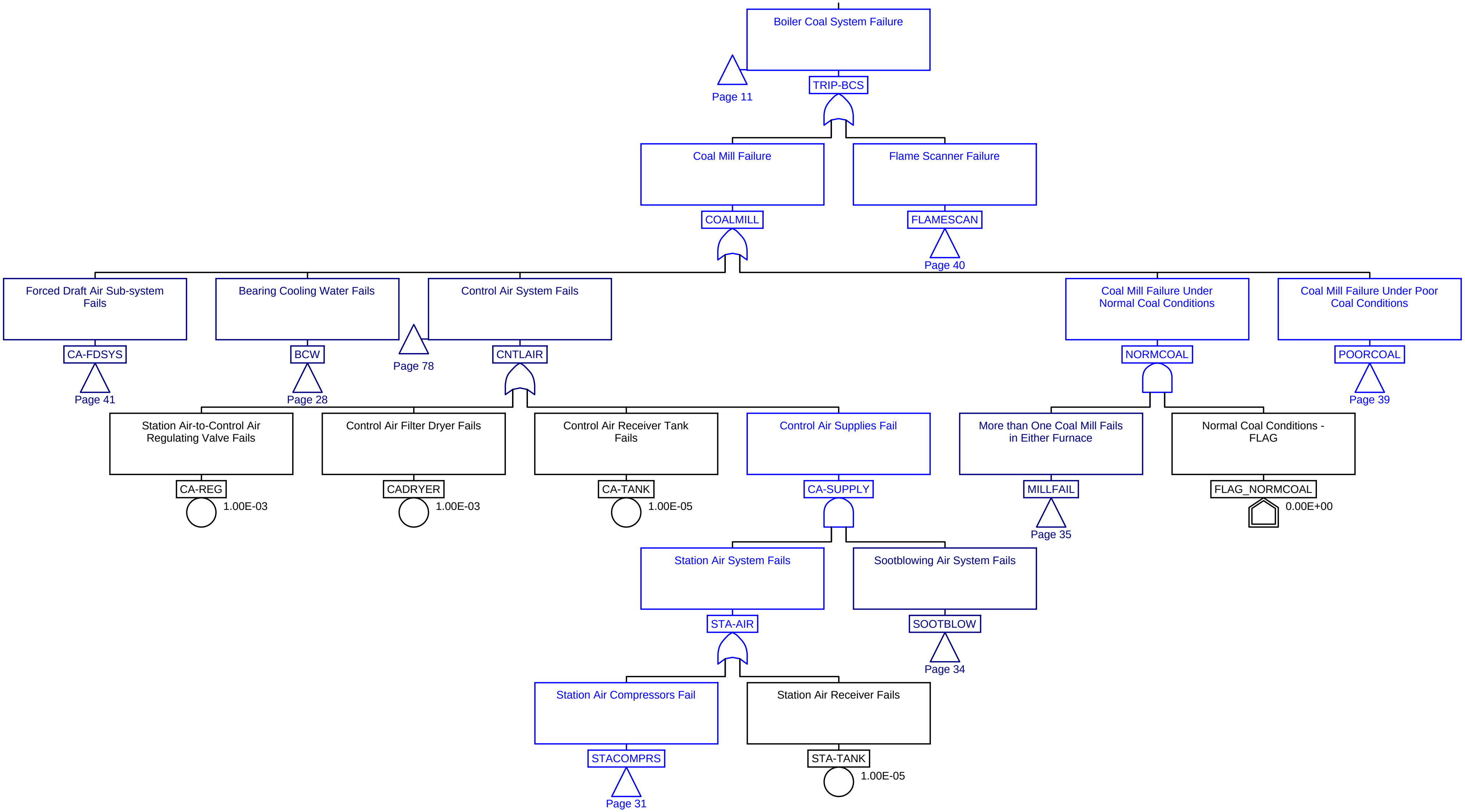
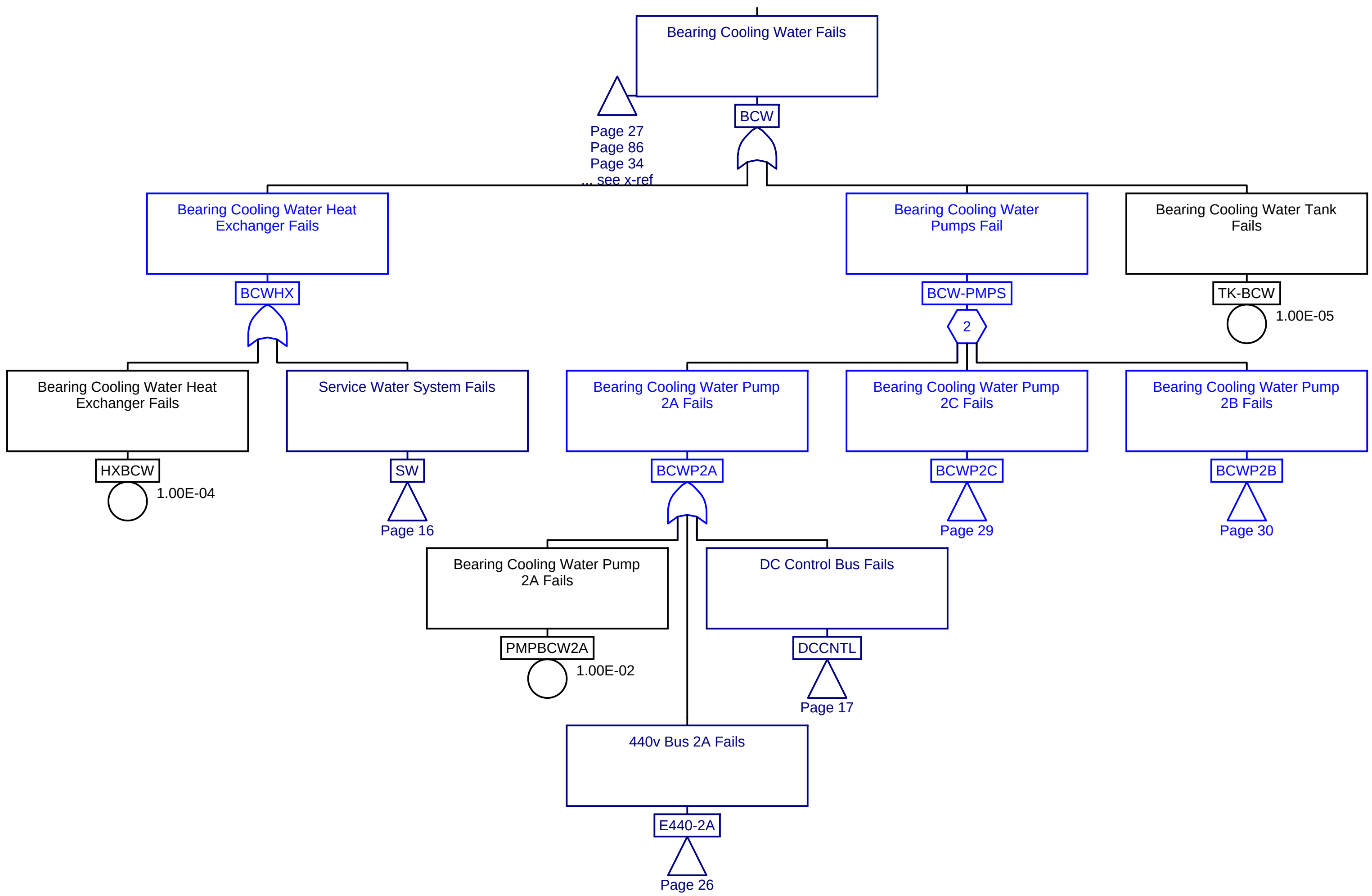
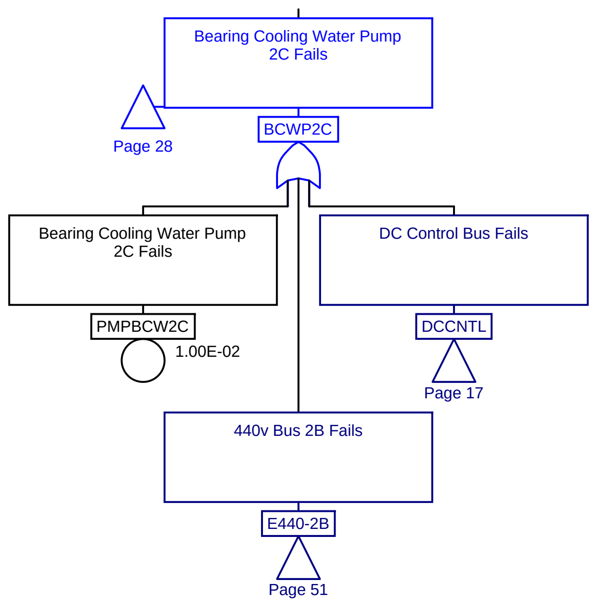
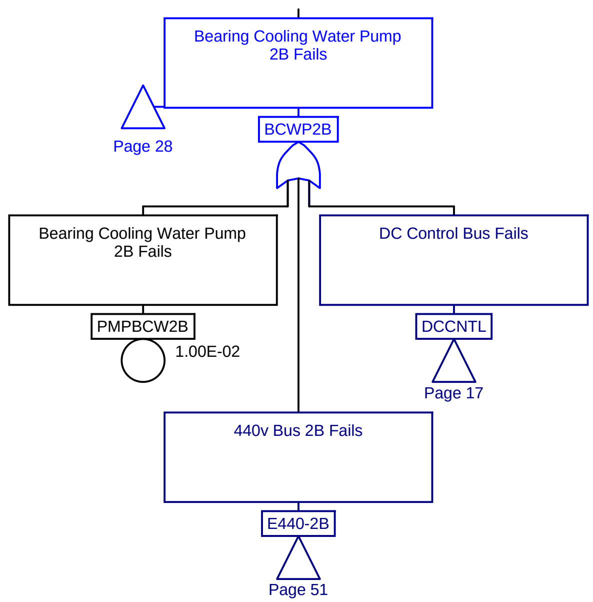
... see x-ref
Unit 2 440v Bus 2A Fails
E440-2ABUS
1.00E-05
4160v Bus 2A Fails
E4KV-2A
Page 15
4160v to 440v Transformer
for Bus 2A Fails
XFMR440-2A
1.00E-03


Boiler Coal System Failure
TRIP-BCS
Page 11
Coal Mill Failure
COALMILL
Flame Scanner Failure
FLAMESCAN
Page 40
Forced Draft Air Sub-system Fails
CA-FDSYS
Page 41
Bearing Cooling Water Fails
BCW
Page 28
Page 78
Control Air System Fails
CNTLAIR
Coal Mill Failure Under Normal Coal Conditions
NORMCOAL
Coal Mill Failure Under Poor Coal Conditions
POORCOAL
Page 39
Station Air-to-Control Air Regulating Valve Fails
CA-REG
1.00E-03
Control Air Filter Dryer Fails
CADRYER
1.00E-03
Control Air Receiver Tank Fails
CA-TANK
1.00E-05
Control Air Supplies Fail
CA-SUPPLY
More than One Coal Mill Fails in Either Furnace
MILLFAIL
Page 35
Normal Coal Conditions - FLAG
FLAG_NORMCOAL
0.00E+00
Station Air System Fails
STA-AIR
Sootblowing Air System Fails
SOOTBLOW
Page 34
Station Air Compressors Fail
STACOMPRS
Page 31
Station Air Receiver Fails
STA-TANK
1.00E-05

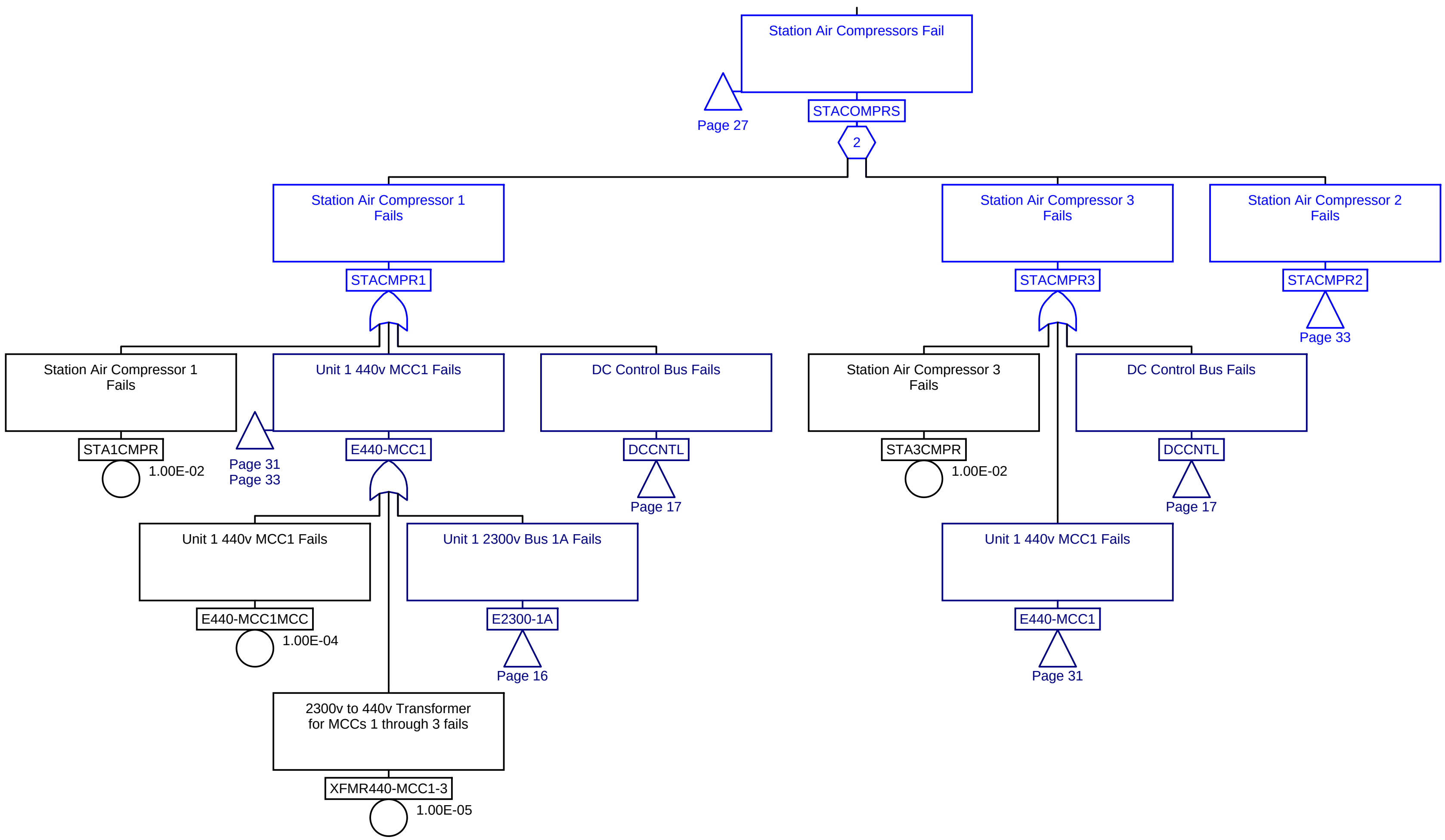

Bearing Cooling Water Fails
BCW
Page 27
Page 86
Page 34
... see x-ref
Bearing Cooling Water Heat Exchanger Fails
BCWHX
Bearing Cooling Water Pumps Fail
BCW-PMPS
2
Bearing Cooling Water Tank Fails
TK-BCW
1.00E-05
Bearing Cooling Water Heat Exchanger Fails
HXBCW
1.00E-04
Service Water System Fails
SW
Page 16
Bearing Cooling Water Pump 2A Fails
BCWP2A
Bearing Cooling Water Pump 2C Fails
BCWP2C
Page 29
Bearing Cooling Water Pump 2B Fails
BCWP2B
Page 30
Bearing Cooling Water Pump 2A Fails
PMPBCW2A
1.00E-02
DC Control Bus Fails
DCCNTL
Page 17
440v Bus 2A Fails
E440-2A
Page 26



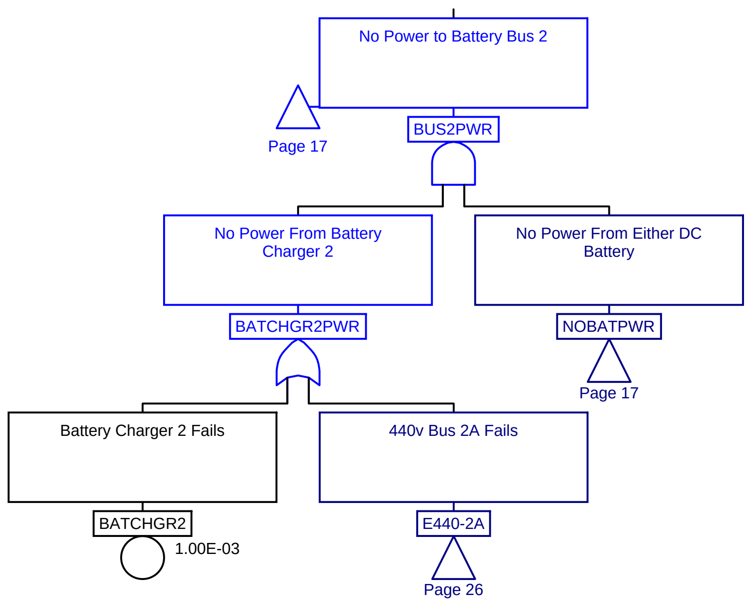
Bearing Cooling Water Pump 2C Fails
BCWP2C
Page 28
Bearing Cooling Water Pump 2C Fails
PMPBCW2C
1.00E-02
DC Control Bus Fails
DCCNTL
Page 17
440v Bus 2B Fails
E440-2B
Page 51

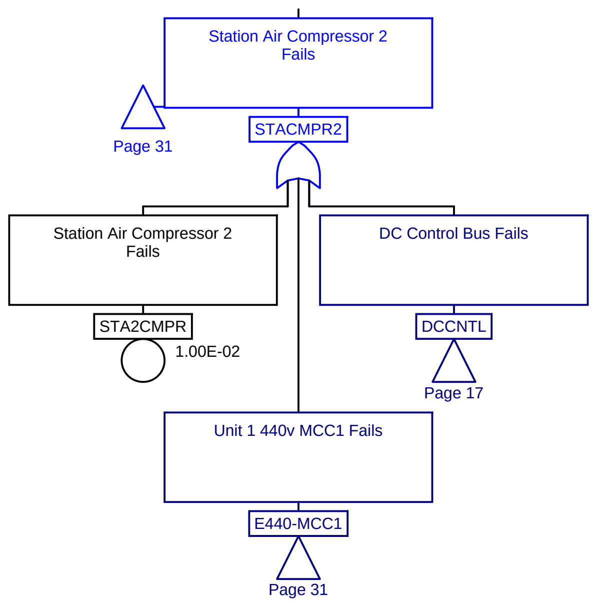


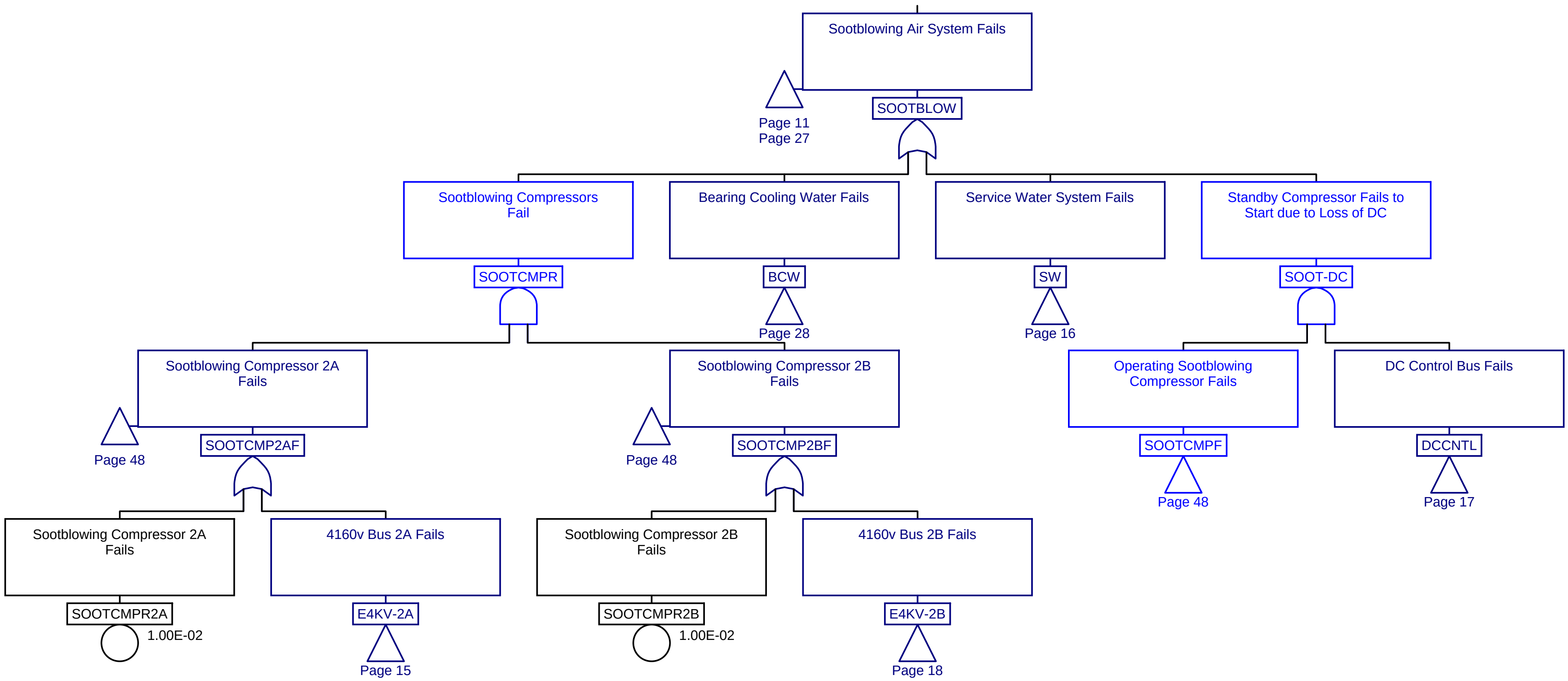
Bearing Cooling Water Pump 2B Fails
Page 28
BCWP2B
Bearing Cooling Water Pump 2B Fails
PMPBCW2B
1.00E-02
DC Control Bus Fails
DCCNTL
Page 17
440v Bus 2B Fails
E440-2B
Page 51

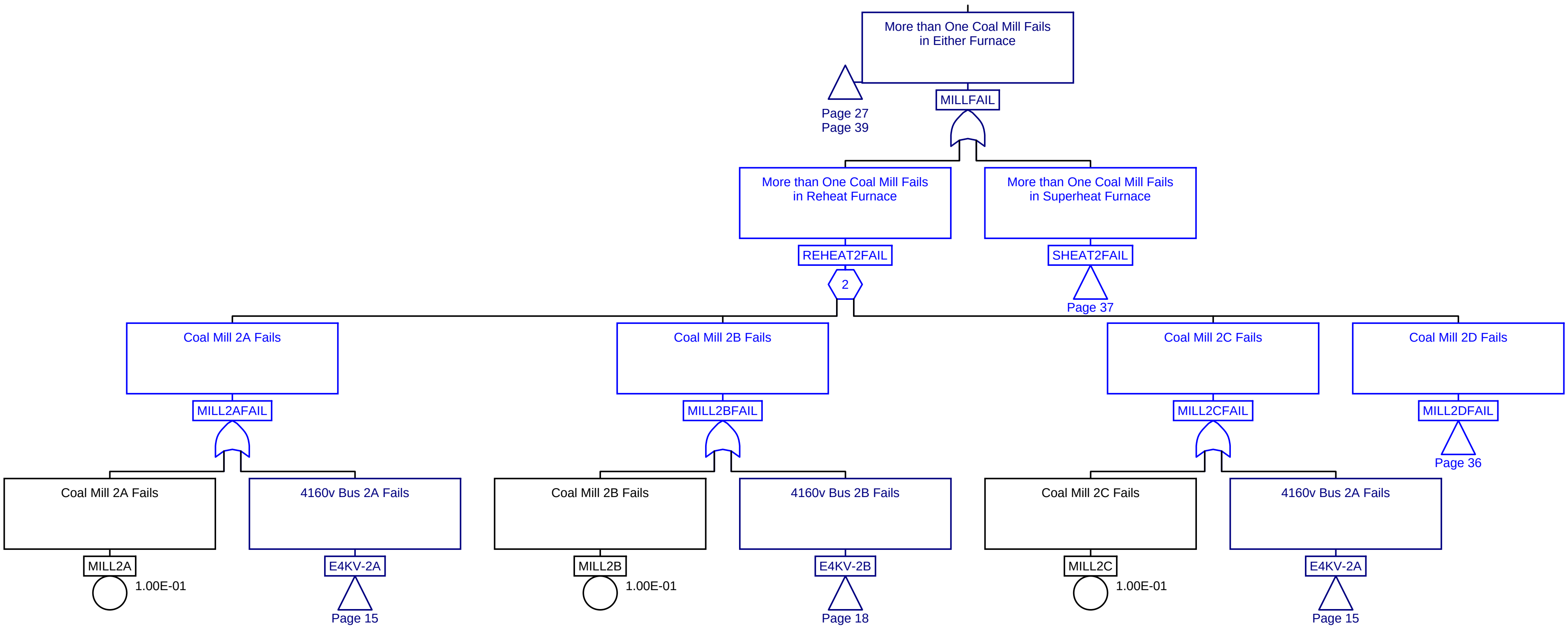


Station Air Compressors Fail
Page 27
STACOMPRS
2
Station Air Compressor 1 Fails
STACMPR1
Station Air Compressor 3 Fails
STACMPR3
Station Air Compressor 2 Fails
STACMPR2
Page 33
Station Air Compressor 1 Fails
STA1CMPR
1.00E-02
Page 31
Page 33
Unit 1 440v MCC1 Fails
E440-MCC1
DC Control Bus Fails
DCCNTL
Page 17
Station Air Compressor 3 Fails
STA3CMPR
1.00E-02
DC Control Bus Fails
DCCNTL
Page 17
Unit 1 440v MCC1 Fails
E440-MCC1MCC
1.00E-04
Unit 1 2300v Bus 1A Fails
E2300-1A
Page 16
Unit 1 440v MCC1 Fails
E440-MCC1
Page 31
2300v to 440v Transformer for MCCs 1 through 3 fails
XFMR440-MCC1-3
1.00E-05

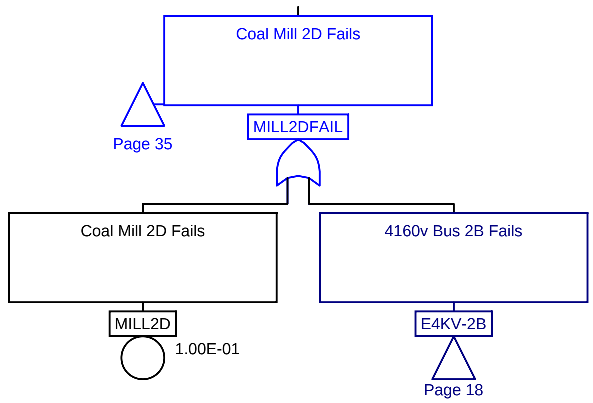

No Power to Battery Bus 2
BUS2PWR
Page 17
No Power From Battery Charger 2
BATCHGR2PWR
No Power From Either DC Battery
NOBATPWR
Page 17
Battery Charger 2 Fails
BATCHGR2
1.00E-03
440v Bus 2A Fails
E440-2A
Page 26

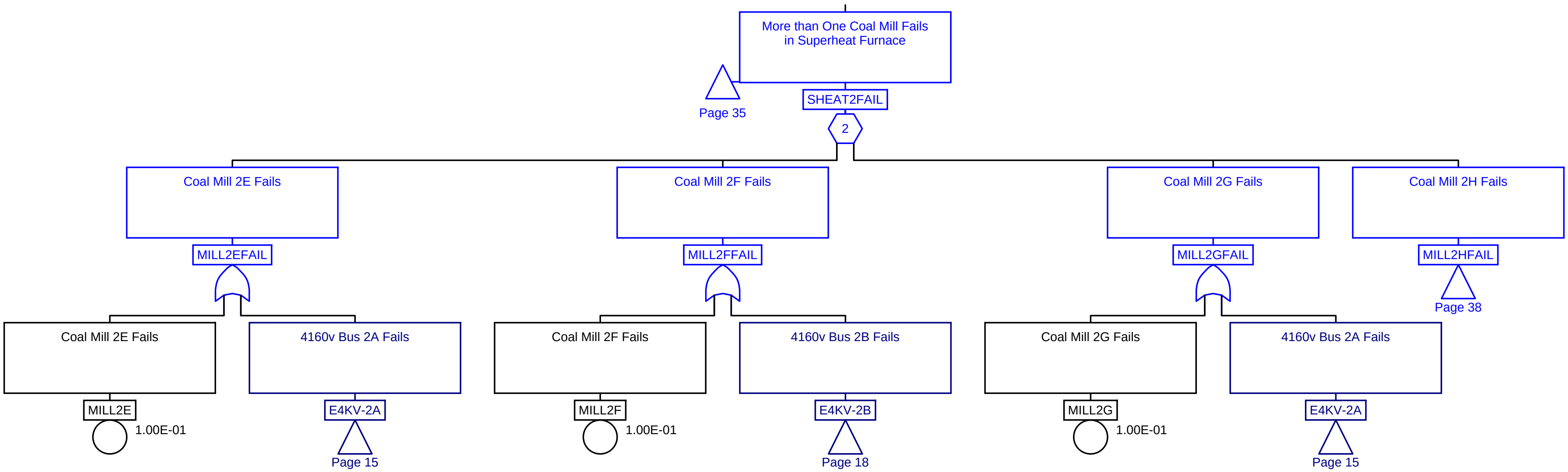

Station Air Compressor 2 Fails
STACMPR2
Page 31
Station Air Compressor 2 Fails
STA2CMPR
1.00E-02
DC Control Bus Fails
DCCNTL
Page 17
Unit 1 440v MCC1 Fails
E440-MCC1
Page 31

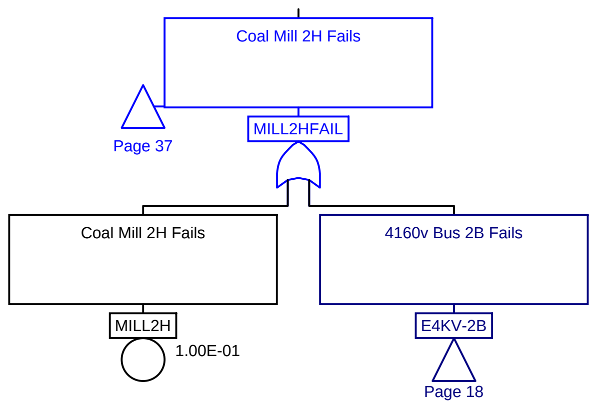

Sootblowing Air System Fails
SOOTBLOW
Page 11
Page 27
Sootblowing Compressors Fail
SOOTCMPR
Bearing Cooling Water Fails
BCW
Page 28
Service Water System Fails
SW
Page 16
Standby Compressor Fails to Start due to Loss of DC
SOOT-DC
Sootblowing Compressor 2A Fails
SOOTCMP2AF
Page 48
Sootblowing Compressor 2B Fails
SOOTCMP2BF
Page 48
Operating Sootblowing Compressor Fails
SOOTCMPF
Page 48
DC Control Bus Fails
DCCNTL
Page 17
Sootblowing Compressor 2A Fails
SOOTCMPR2A
1.00E-02
4160v Bus 2A Fails
E4KV-2A
Page 15
Sootblowing Compressor 2B Fails
SOOTCMPR2B
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18

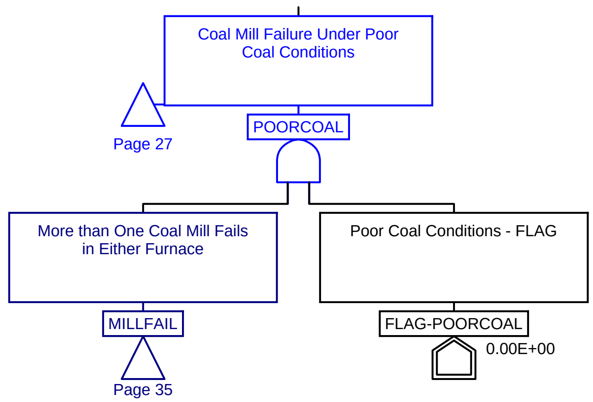


More than One Coal Mill Fails in Either Furnace
MILLFAIL
Page 27
Page 39
More than One Coal Mill Fails in Reheat Furnace
REHEAT2FAIL
2
More than One Coal Mill Fails in Superheat Furnace
SHEAT2FAIL
Page 37
Coal Mill 2A Fails
MILL2AFAIL
Coal Mill 2B Fails
MILL2BFAIL
Coal Mill 2C Fails
MILL2CFAIL
Coal Mill 2D Fails
MILL2DFAIL
Page 36
Coal Mill 2A Fails
MILL2A
1.00E-01
4160v Bus 2A Fails
E4KV-2A
Page 15
Coal Mill 2B Fails
MILL2B
1.00E-01
4160v Bus 2B Fails
E4KV-2B
Page 18
Coal Mill 2C Fails
MILL2C
1.00E-01
4160v Bus 2A Fails
E4KV-2A
Page 15

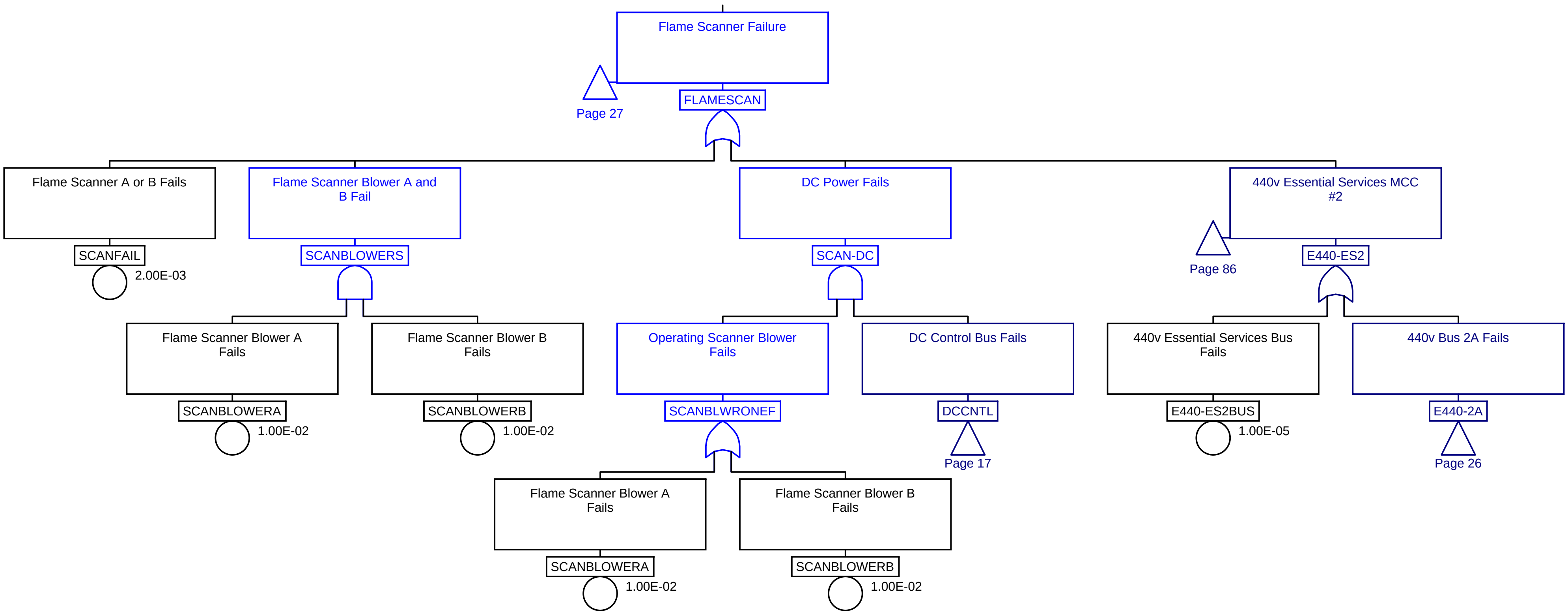

Coal Mill 2D Fails
MILL2DFAIL
Page 35
Coal Mill 2D Fails
MILL2D
1.00E-01
4160v Bus 2B Fails
E4KV-2B
Page 18


More than One Coal Mill Fails in Superheat Furnace
Page 35
SHEAT2FAIL
2
Coal Mill 2E Fails
MILL2EFAIL
Coal Mill 2F Fails
MILL2FFAIL
Coal Mill 2G Fails
MILL2GFAIL
Coal Mill 2H Fails
MILL2HFAIL
Page 38
Coal Mill 2E Fails
MILL2E
1.00E-01
4160v Bus 2A Fails
E4KV-2A
Page 15
Coal Mill 2F Fails
MILL2F
1.00E-01
4160v Bus 2B Fails
E4KV-2B
Page 18
Coal Mill 2G Fails
MILL2G
1.00E-01
4160v Bus 2A Fails
E4KV-2A
Page 15


Coal Mill 2H Fails
MILL2HFAIL
Page 37
Coal Mill 2H Fails
MILL2H
1.00E-01
4160v Bus 2B Fails
E4KV-2B
Page 18



Coal Mill Failure Under Poor Coal Conditions
Page 27
POORCOAL
More than One Coal Mill Fails in Either Furnace
Poor Coal Conditions - FLAG
MILLFAIL
FLAG-POORCOAL
0.00E+00
Page 35


Flame Scanner Failure
FLAMESCAN
Page 27
Flame Scanner A or B Fails
SCANFAIL
2.00E-03
Flame Scanner Blower A and B Fail
SCANBLOWERS
DC Power Fails
SCAN-DC
440v Essential Services MCC #2
E440-ES2
Page 86
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SCANBLOWERA
1.00E-02
Flame Scanner Blower B Fails
SCANBLOWERB
1.00E-02
Operating Scanner Blower Fails
SCANBLWRONEF
DC Control Bus Fails
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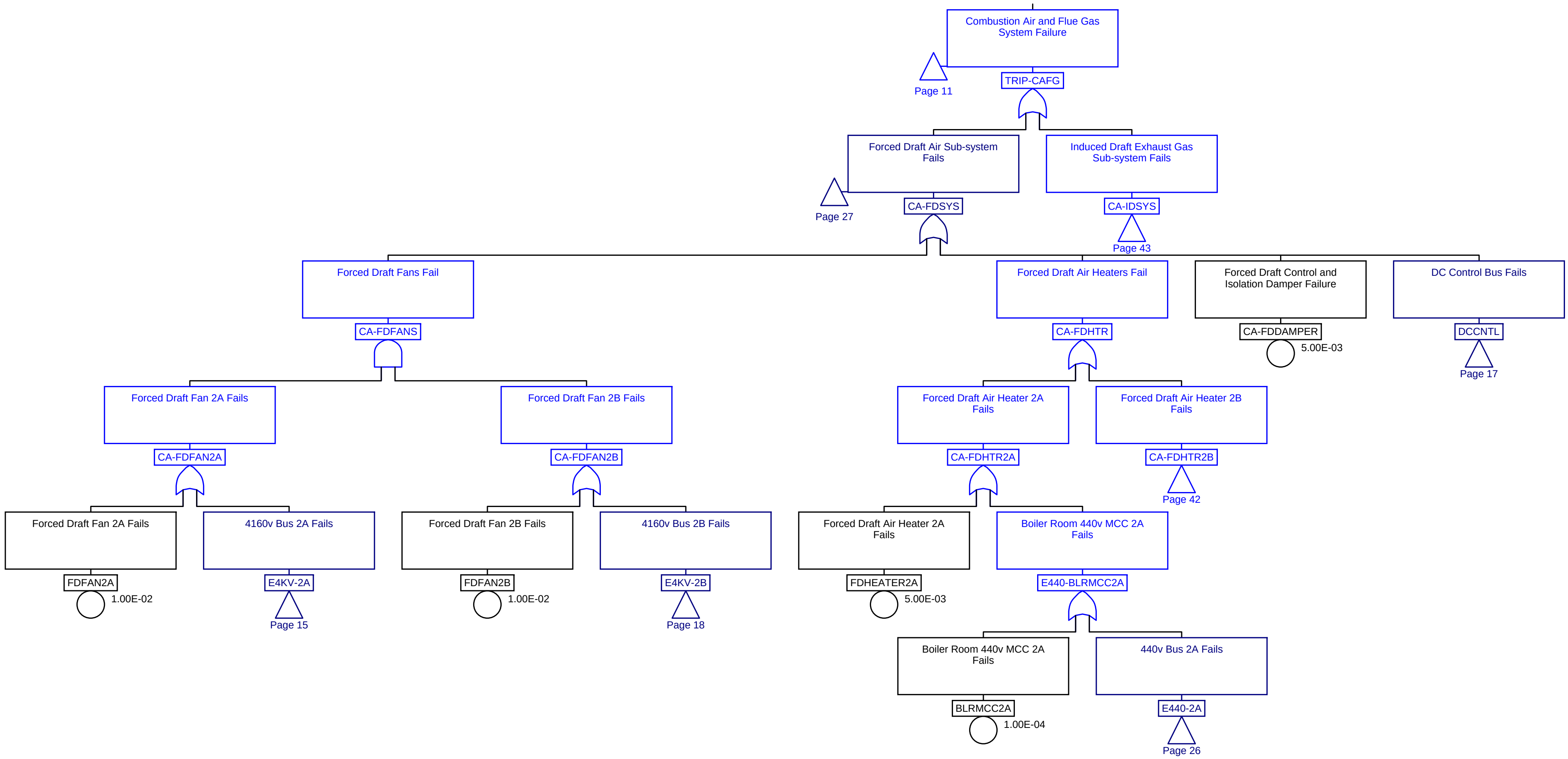
440v Essential Services Bus Fails
E440-ES2BUS
1.00E-05
440v Bus 2A Fails
E440-2A
Page 26
Flame Scanner Blower A Fails
SCANBLOWERA
1.00E-02
Flame Scanner Blower B Fails
SCANBLOWERB
1.00E-02



Combustion Air and Flue Gas System Failure
TRIP-CAFG
Page 11
Forced Draft Air Sub-system Fails
CA-FDSYS
Page 27
Induced Draft Exhaust Gas Sub-system Fails
CA-IDSYS
Page 43
Forced Draft Fans Fail
CA-FDFANS
Forced Draft Air Heaters Fail
CA-FDHTR
Forced Draft Control and Isolation Damper Failure
CA-FDDAMPER
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DC Control Bus Fails
DCCNTL
Page 17
Forced Draft Fan 2A Fails
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Forced Draft Fan 2B Fails
CA-FDFAN2B
Forced Draft Air Heater 2A Fails
CA-FDHTR2A
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Forced Draft Fan 2A Fails
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Forced Draft Fan 2B Fails
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5.00E-03
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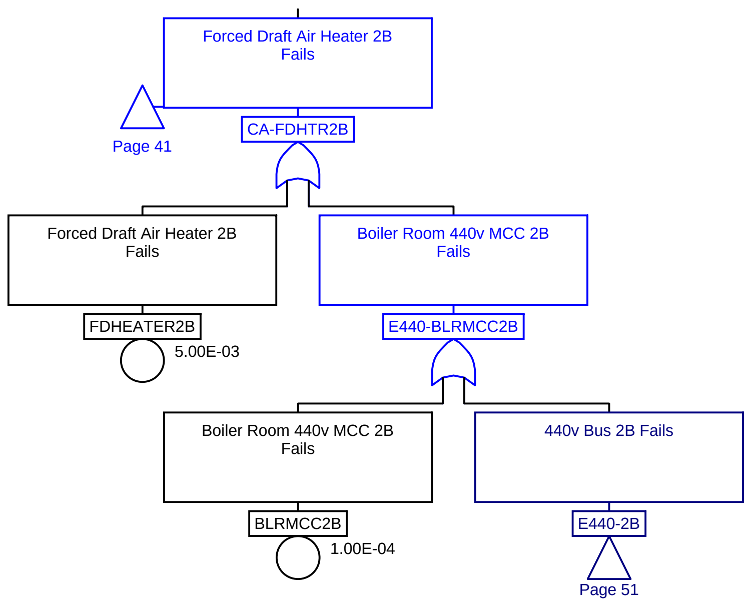
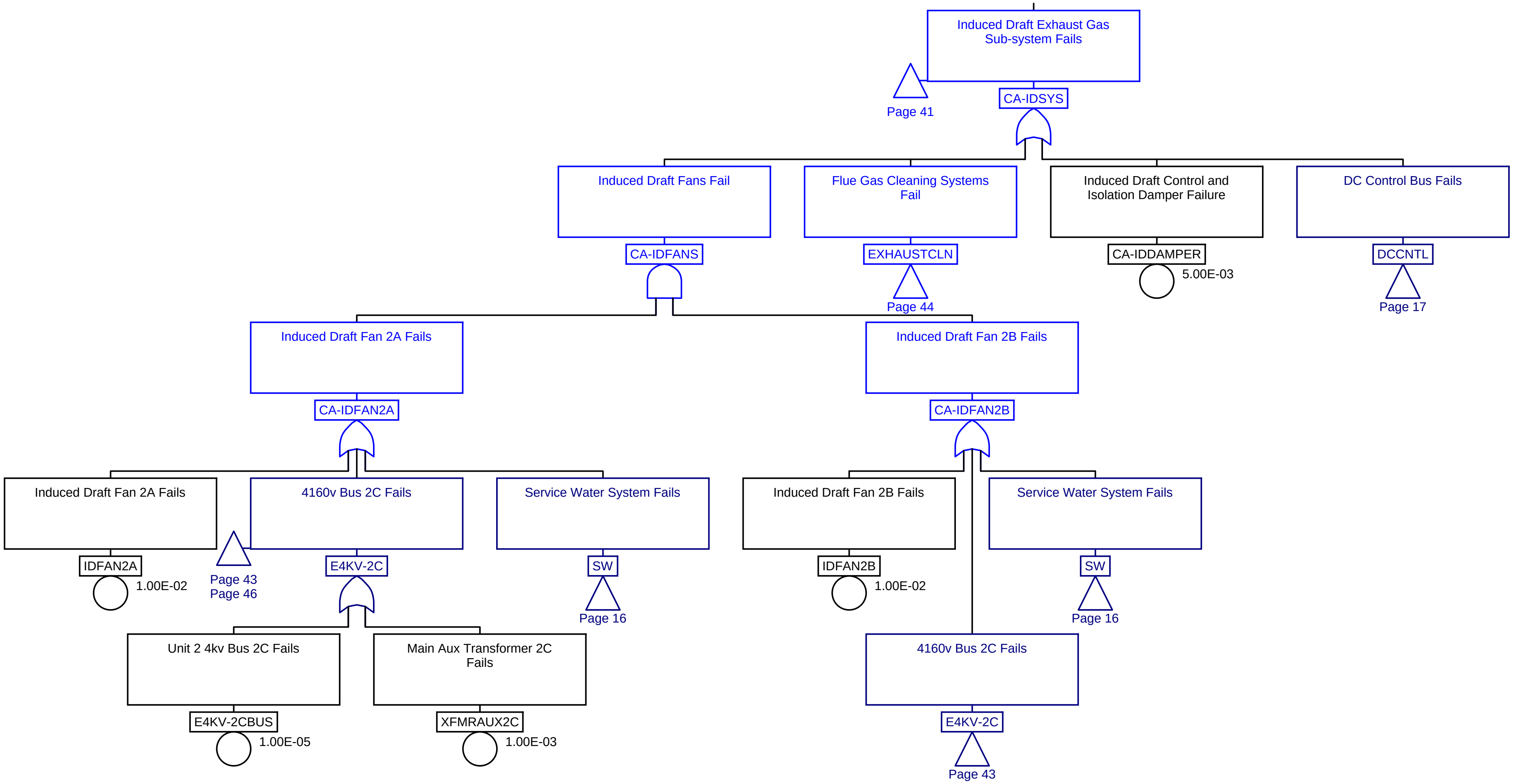
E440-BLRMCC2A
Boiler Room 440v MCC 2A Fails
BLRMCC2A
1.00E-04
440v Bus 2A Fails
E440-2A
Page 26


Forced Draft Air Heater 2B Fails
Page 41
CA-FDHTR2B
Forced Draft Air Heater 2B Fails
FDHEATER2B
5.00E-03
Boiler Room 440v MCC 2B Fails
E440-BLRMCC2B
Boiler Room 440v MCC 2B Fails
BLRMCC2B
1.00E-04
440v Bus 2B Fails
E440-2B
Page 51


Induced Draft Exhaust Gas Sub-system Fails
CA-IDSYS
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Induced Draft Fans Fail
CA-IDFANS
Flue Gas Cleaning Systems Fail
EXHAUSTCLN
Page 44
Induced Draft Control and Isolation Damper Failure
CA-IDDAMPER
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DCCNTL
Page 17
Induced Draft Fan 2A Fails
CA-IDFAN2A
Induced Draft Fan 2B Fails
CA-IDFAN2B
Induced Draft Fan 2A Fails
IDFAN2A
1.00E-02
4160v Bus 2C Fails
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Service Water System Fails
SW
Page 16
Induced Draft Fan 2B Fails
IDFAN2B
1.00E-02
Service Water System Fails
SW
Page 16
Unit 2 4kv Bus 2C Fails
E4KV-2CBUS
1.00E-05
Main Aux Transformer 2C Fails
XFMRAUX2C
1.00E-03
4160v Bus 2C Fails
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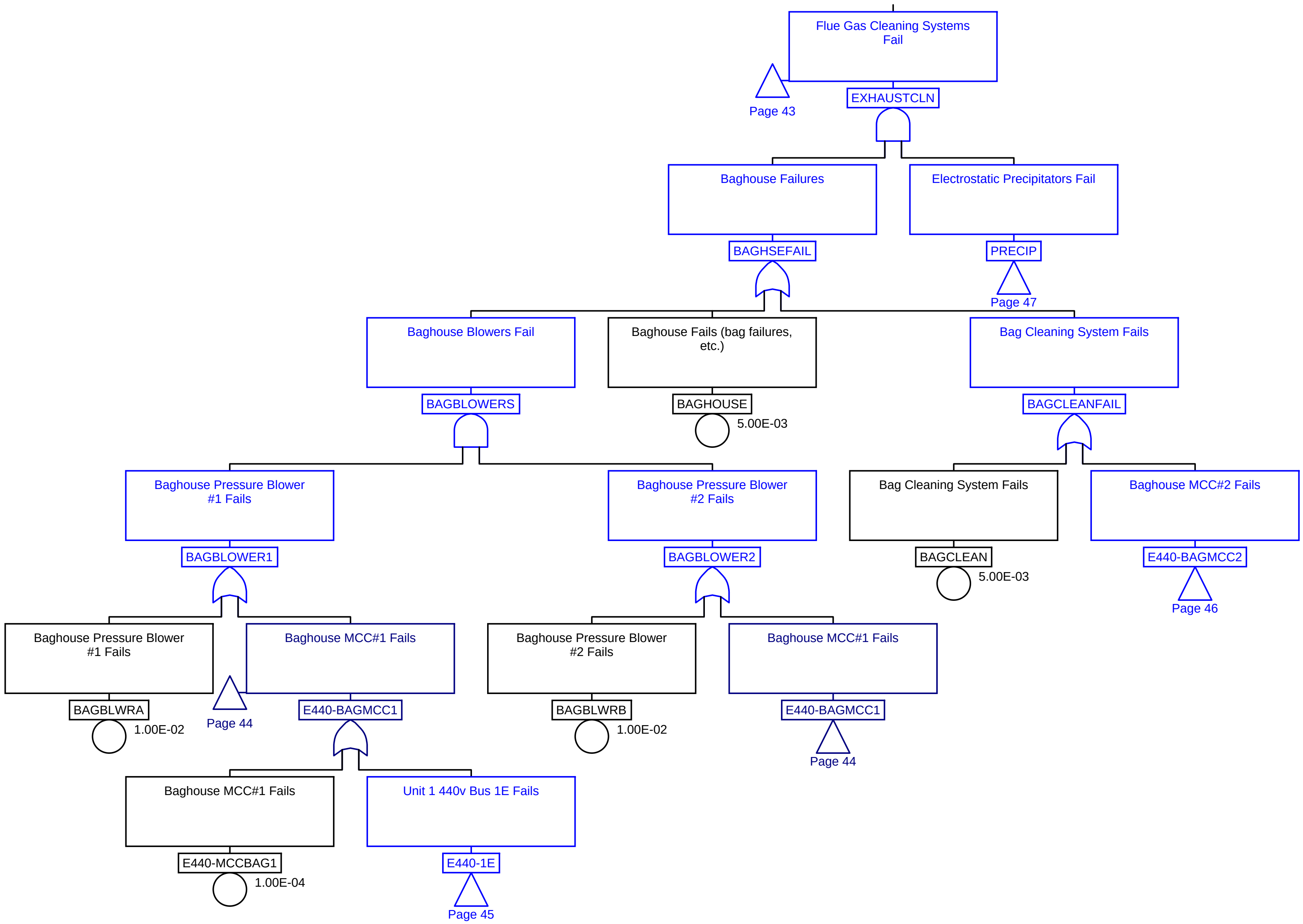
Page 43


Flue Gas Cleaning Systems Fail
EXHAUSTCLN
Page 43
Baghouse Failures
BAGHSEFAIL
Electrostatic Precipitators Fail
PRECIP
Page 47
Baghouse Blowers Fail
BAGBLOWERS
Baghouse Fails (bag failures, etc.)
BAGHOUSE
5.00E-03
Bag Cleaning System Fails
BAGCLEANFAIL
Baghouse Pressure Blower #1 Fails
BAGBLOWER1
Baghouse Pressure Blower #2 Fails
BAGBLOWER2
Bag Cleaning System Fails
BAGCLEAN
5.00E-03
Baghouse MCC#2 Fails
E440-BAGMCC2
Page 46
Baghouse Pressure Blower #1 Fails
BAGBLWRA
1.00E-02
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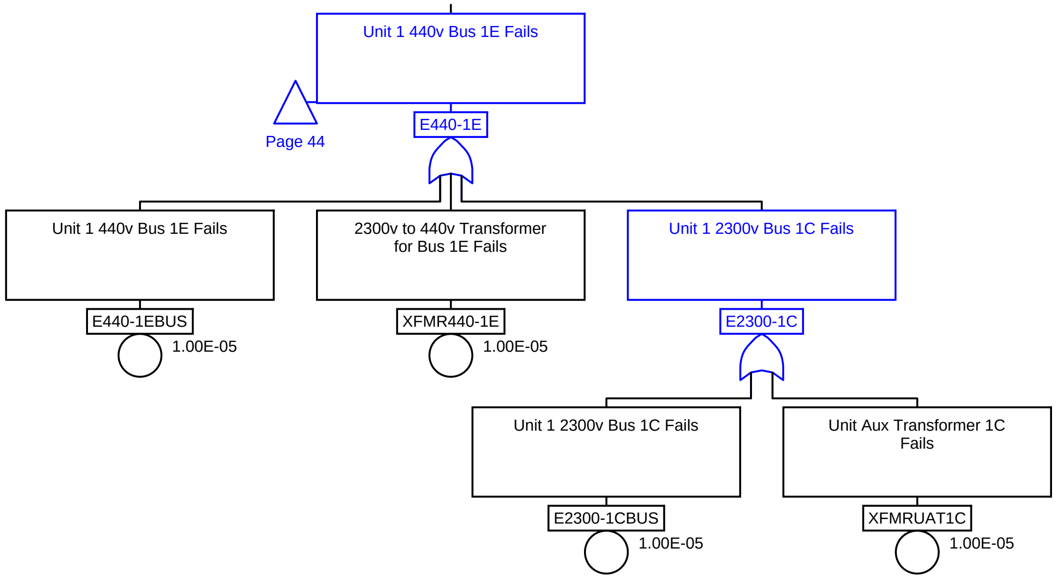
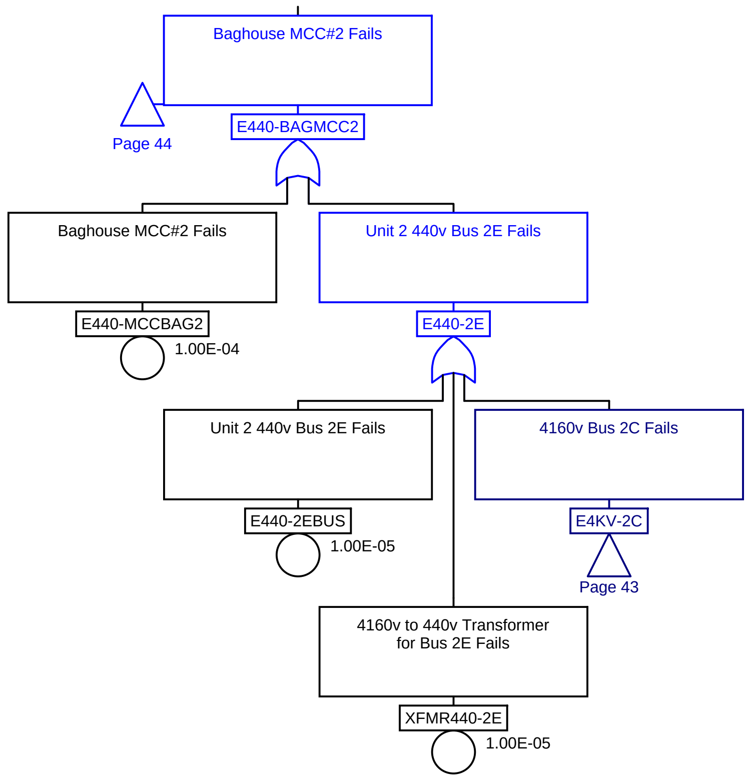
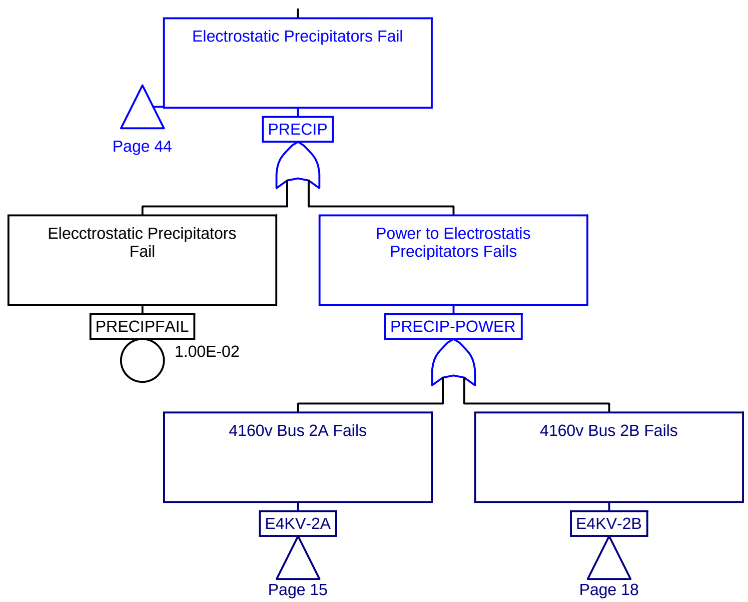
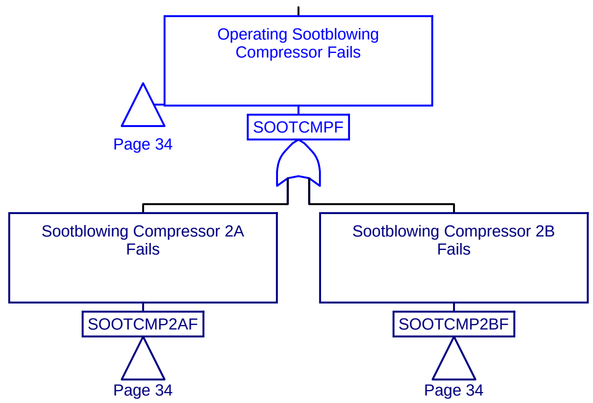
Baghouse MCC#1 Fails
E440-BAGMCC1
Baghouse Pressure Blower #2 Fails
BAGBLWRB
1.00E-02
Baghouse MCC#1 Fails
E440-BAGMCC1
Page 44
Baghouse MCC#1 Fails
E440-MCCBAG1
1.00E-04
Unit 1 440v Bus 1E Fails
E440-1E
Page 45


Unit 1 440v Bus 1E Fails
E440-1E
Page 44
Unit 1 440v Bus 1E Fails
E440-1EBUS
1.00E-05
2300v to 440v Transformer for Bus 1E Fails
XFMR440-1E
1.00E-05
Unit 1 2300v Bus 1C Fails
E2300-1C
Unit 1 2300v Bus 1C Fails
E2300-1CBUS
1.00E-05
Unit Aux Transformer 1C Fails
XFMRUAT1C
1.00E-05



Baghouse MCC#2 Fails
E440-BAGMCC2
Page 44
Baghouse MCC#2 Fails
E440-MCCBAG2
1.00E-04
Unit 2 440v Bus 2E Fails
E440-2E
Unit 2 440v Bus 2E Fails
E440-2EBUS
1.00E-05
4160v Bus 2C Fails
E4KV-2C
Page 43
4160v to 440v Transformer
for Bus 2E Fails
XFMR440-2E
1.00E-05


Electrostatic Precipitators Fail
PRECIP
Page 44
Elecctrostatic Precipitators Fail
PRECIPFAIL
1.00E-02
Power to Electrostatis Precipitators Fails
PRECIP-POWER
4160v Bus 2A Fails
E4KV-2A
Page 15
4160v Bus 2B Fails
E4KV-2B
Page 18


Operating Sootblowing Compressor Fails
SOOTCMPF
Page 34
Sootblowing Compressor 2A Fails
SOOTCMP2AF
Page 34
Sootblowing Compressor 2B Fails
SOOTCMP2BF
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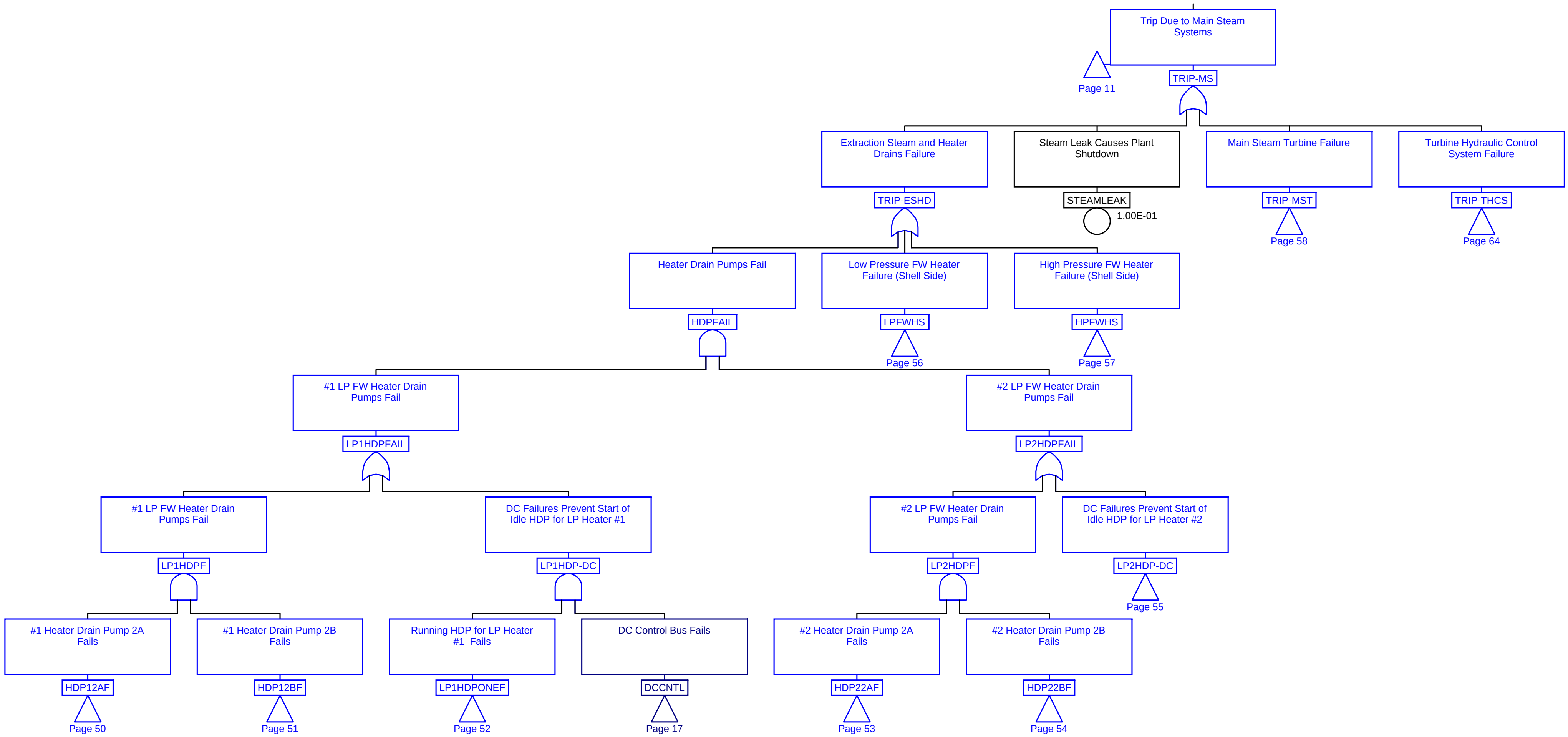
Trip Due to Main Steam Systems
TRIP-MS
Page 11
Extraction Steam and Heater Drains Failure
TRIP-ESHD
Steam Leak Causes Plant Shutdown
STEAMLEAK
1.00E-01
Main Steam Turbine Failure
TRIP-MST
Page 58
Turbine Hydraulic Control System Failure
TRIP-THCS
Page 64
Heater Drain Pumps Fail
HDPFAIL
Low Pressure FW Heater Failure (Shell Side)
LPFWHS
Page 56
High Pressure FW Heater Failure (Shell Side)
HPFWHS
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#1 LP FW Heater Drain Pumps Fail
LP1HDPFAIL
#2 LP FW Heater Drain Pumps Fail
LP2HDPFAIL
#1 LP FW Heater Drain Pumps Fail
LP1HDPF
DC Failures Prevent Start of Idle HDP for LP Heater #1
LP1HDP-DC
#2 LP FW Heater Drain Pumps Fail
LP2HDPF
DC Failures Prevent Start of Idle HDP for LP Heater #2
LP2HDP-DC
Page 55
#1 Heater Drain Pump 2A Fails
HDP12AF
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#1 Heater Drain Pump 2B Fails
HDP12BF
Page 51
Running HDP for LP Heater #1 Fails
LP1HDPONEF
Page 52
DC Control Bus Fails
DCCNTL
Page 17
#2 Heater Drain Pump 2A Fails
HDP22AF
Page 53
#2 Heater Drain Pump 2B Fails
HDP22BF
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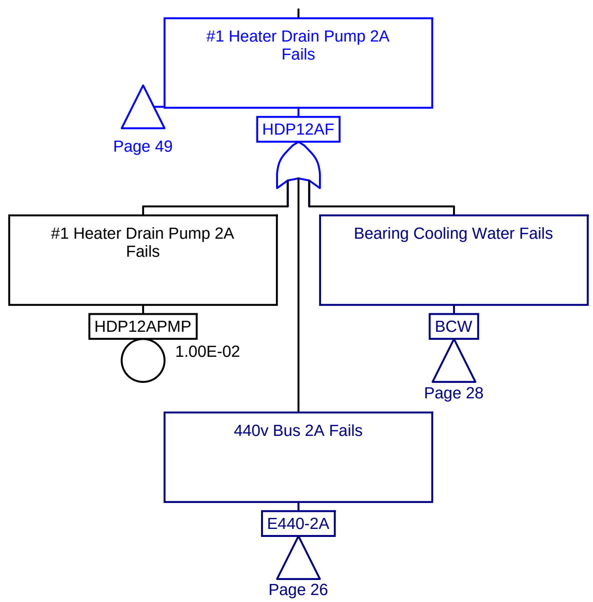
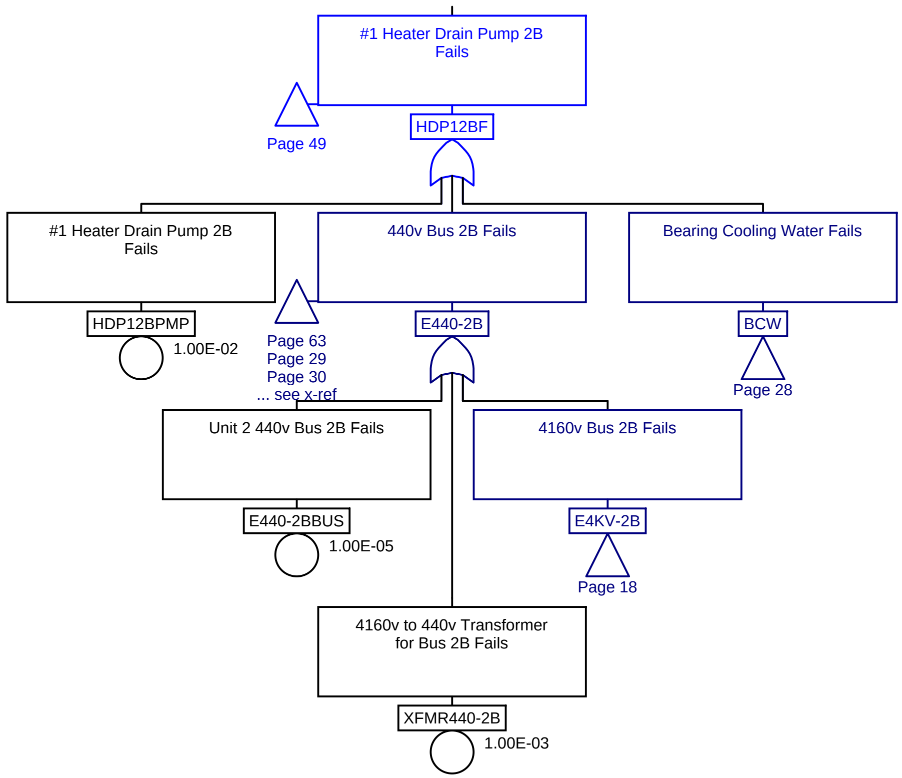

#1 Heater Drain Pump 2A Fails
HDP12AF
Page 49
#1 Heater Drain Pump 2A Fails
HDP12APMP
1.00E-02
Bearing Cooling Water Fails
BCW
Page 28
440v Bus 2A Fails
E440-2A
Page 26



#1 Heater Drain Pump 2B Fails
HDP12BF
Page 49
#1 Heater Drain Pump 2B Fails
HDP12BPMP
1.00E-02
440v Bus 2B Fails
E440-2B
Page 63
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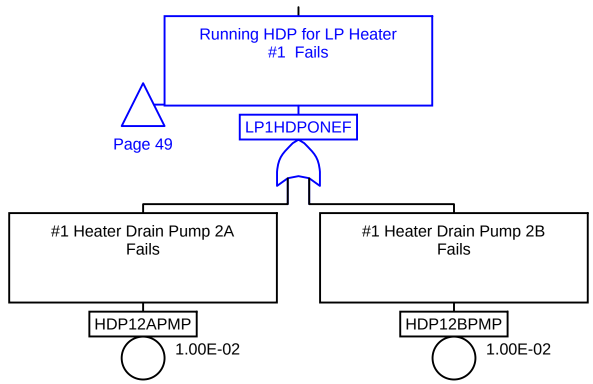
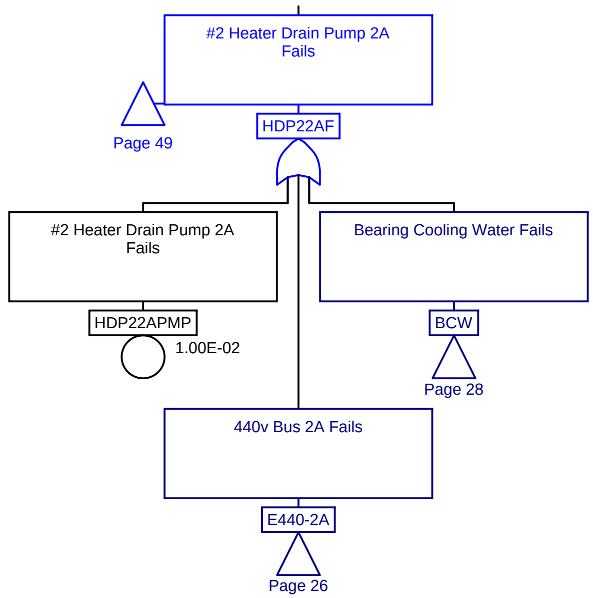
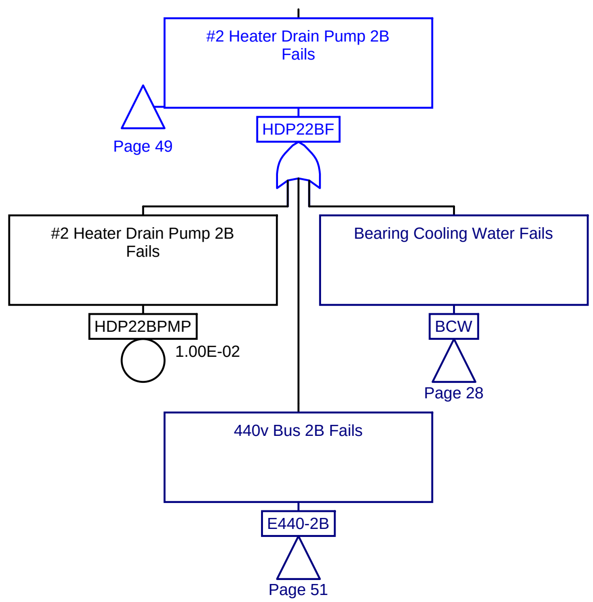
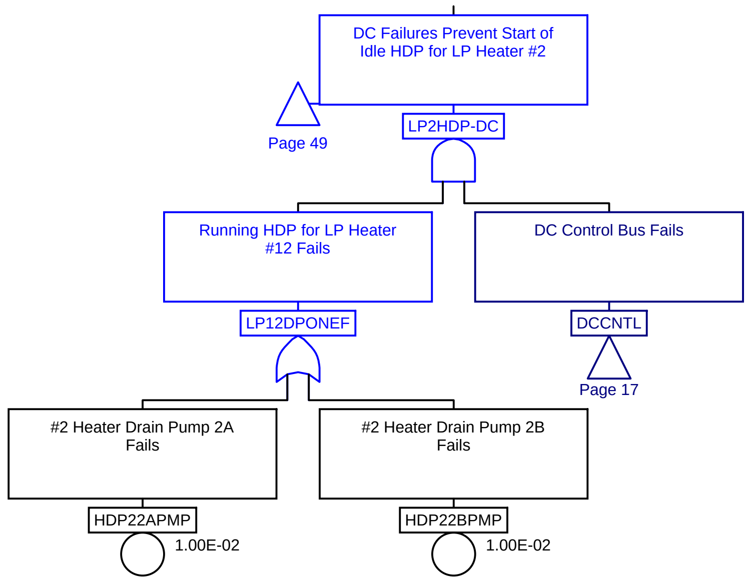
... see x-ref
Bearing Cooling Water Fails
BCW
Page 28
Unit 2 440v Bus 2B Fails
E440-2BBUS
1.00E-05
4160v Bus 2B Fails
E4KV-2B
Page 18
4160v to 440v Transformer for Bus 2B Fails
XFMR440-2B
1.00E-03

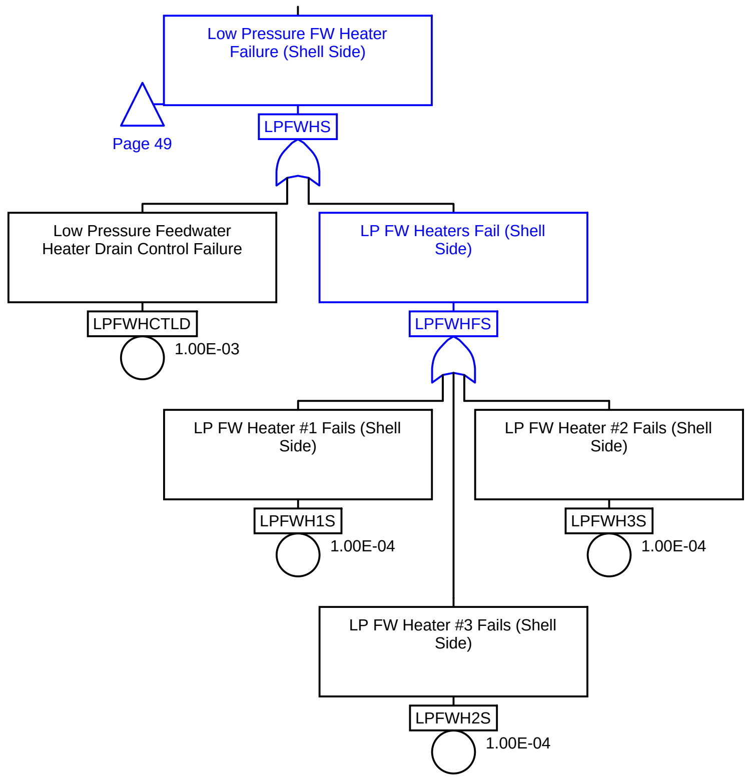

Running HDP for LP Heater #1 Fails
LP1HDPONEF
Page 49
#1 Heater Drain Pump 2A Fails
HDP12APMP
1.00E-02
#1 Heater Drain Pump 2B Fails
HDP12BPMP
1.00E-02

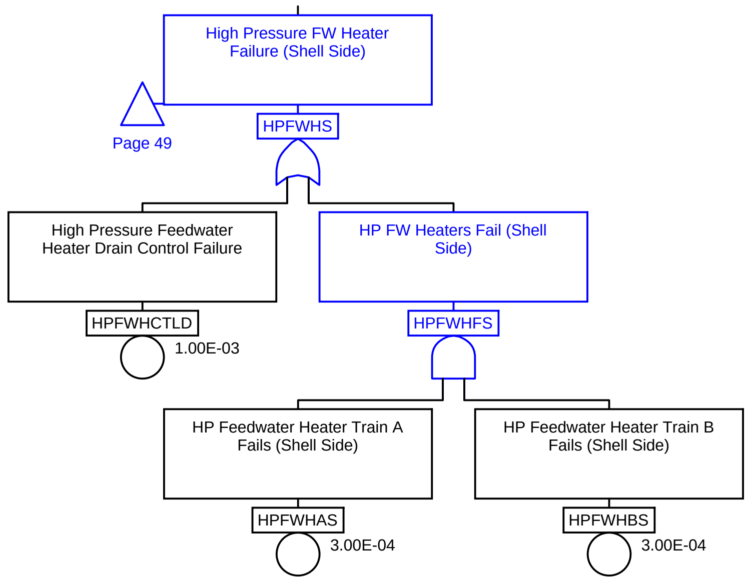

#2 Heater Drain Pump 2A Fails
HDP22AF
Page 49
#2 Heater Drain Pump 2A Fails
HDP22APMP
1.00E-02
Bearing Cooling Water Fails
BCW
Page 28
440v Bus 2A Fails
E440-2A
Page 26

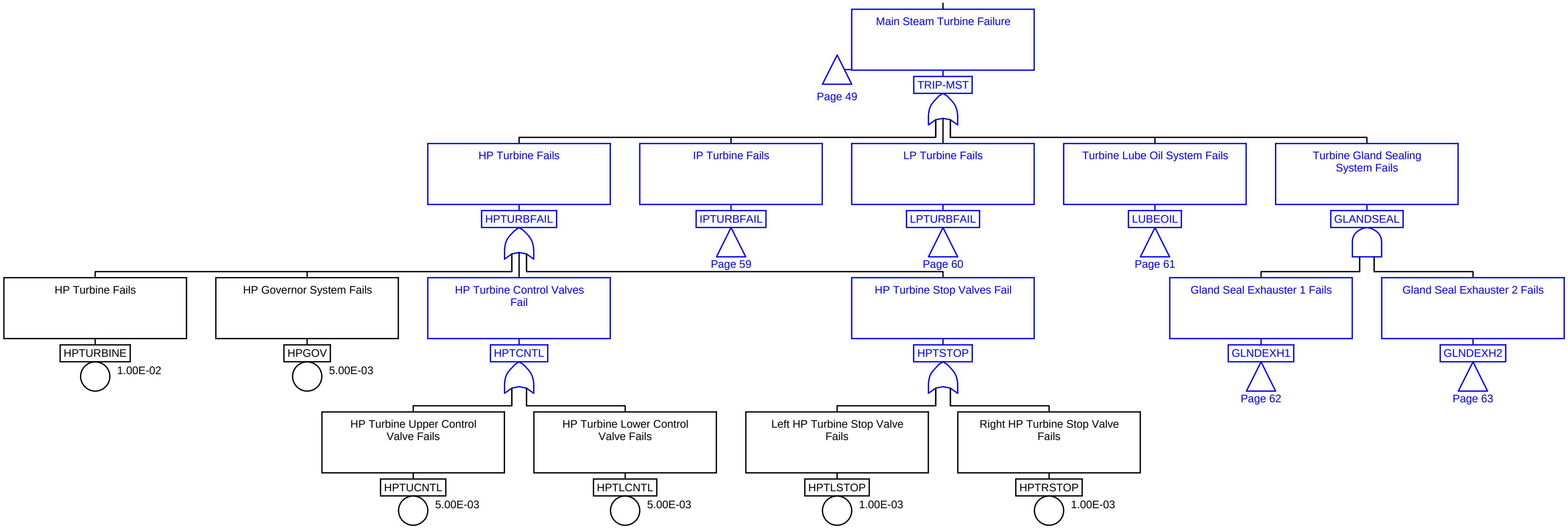

#2 Heater Drain Pump 2B Fails
HDP22BF
Page 49
#2 Heater Drain Pump 2B Fails
HDP22BPMP
1.00E-02
Bearing Cooling Water Fails
BCW
Page 28
440v Bus 2B Fails
E440-2B
Page 51



DC Failures Prevent Start of
Idle HDP for LP Heater #2
LP2HDP-DC
Page 49
Running HDP for LP Heater
#12 Fails
LP12DPONEF
DC Control Bus Fails
DCCNTL
Page 17
#2 Heater Drain Pump 2A
Fails
HDP22APMP
1.00E-02
#2 Heater Drain Pump 2B
Fails
HDP22BPMP
1.00E-02


Low Pressure FW Heater Failure (Shell Side)
LPFWHS
Page 49
Low Pressure Feedwater Heater Drain Control Failure
LPFWHCTLD
1.00E-03
LP FW Heaters Fail (Shell Side)
LPFWHFS
LP FW Heater #1 Fails (Shell Side)
LPFWH1S
1.00E-04
LP FW Heater #2 Fails (Shell Side)
LPFWH3S
1.00E-04
LP FW Heater #3 Fails (Shell Side)
LPFWH2S
1.00E-04


High Pressure FW Heater Failure (Shell Side)
HPFWHS
Page 49
High Pressure Feedwater Heater Drain Control Failure
HPFWHCTLD
1.00E-03
HP FW Heaters Fail (Shell Side)
HPFWHFS
HP Feedwater Heater Train A Fails (Shell Side)
HPFWHAS
3.00E-04
HP Feedwater Heater Train B Fails (Shell Side)
HPFWHBS
3.00E-04


Main Steam Turbine Failure
TRIP-MST
Page 49
HP Turbine Fails
HPTURBFAIL
IP Turbine Fails
IPTURBFAIL
Page 59
LP Turbine Fails
LPTURBFAIL
Page 60
Turbine Lube Oil System Fails
LUBEOIL
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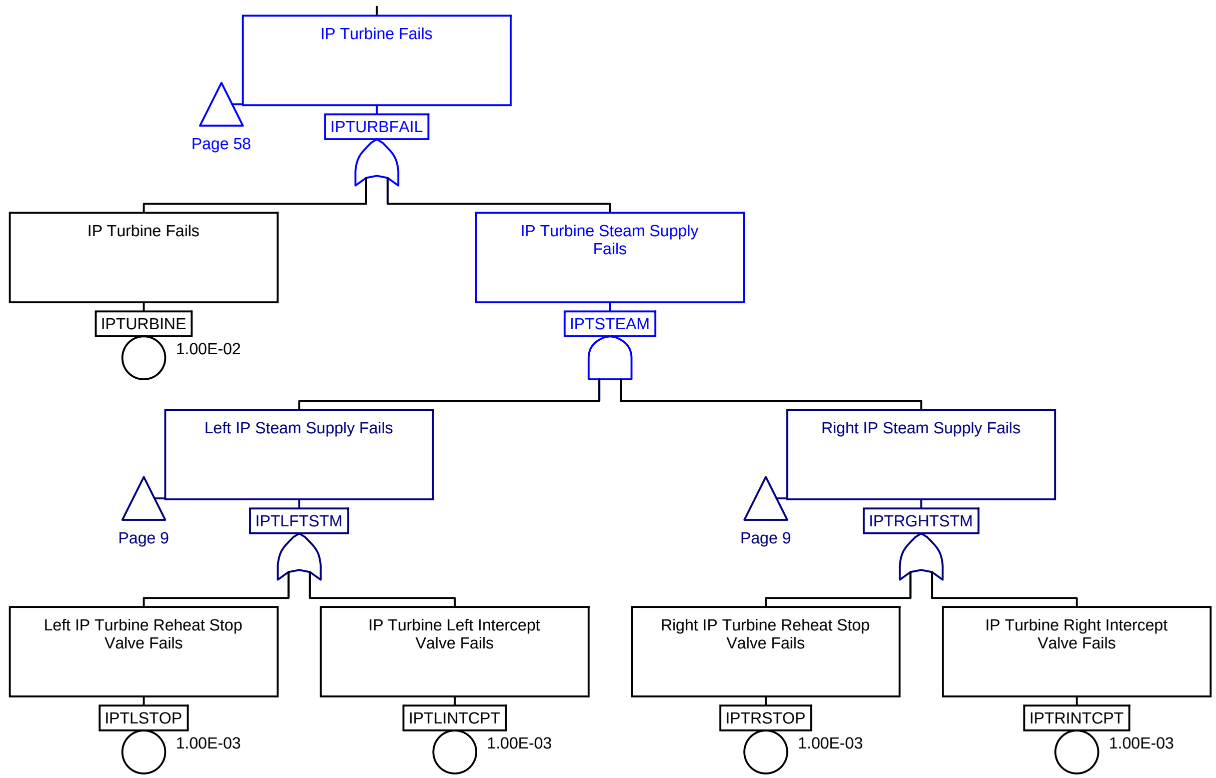
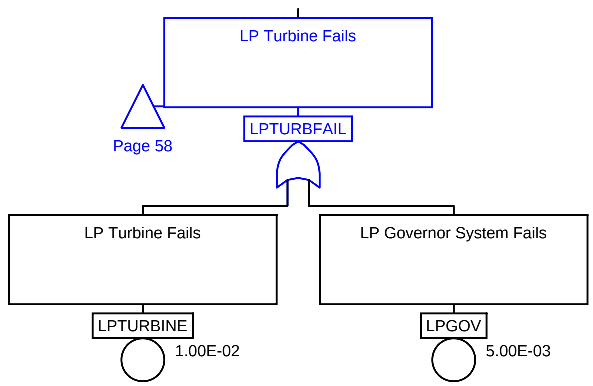
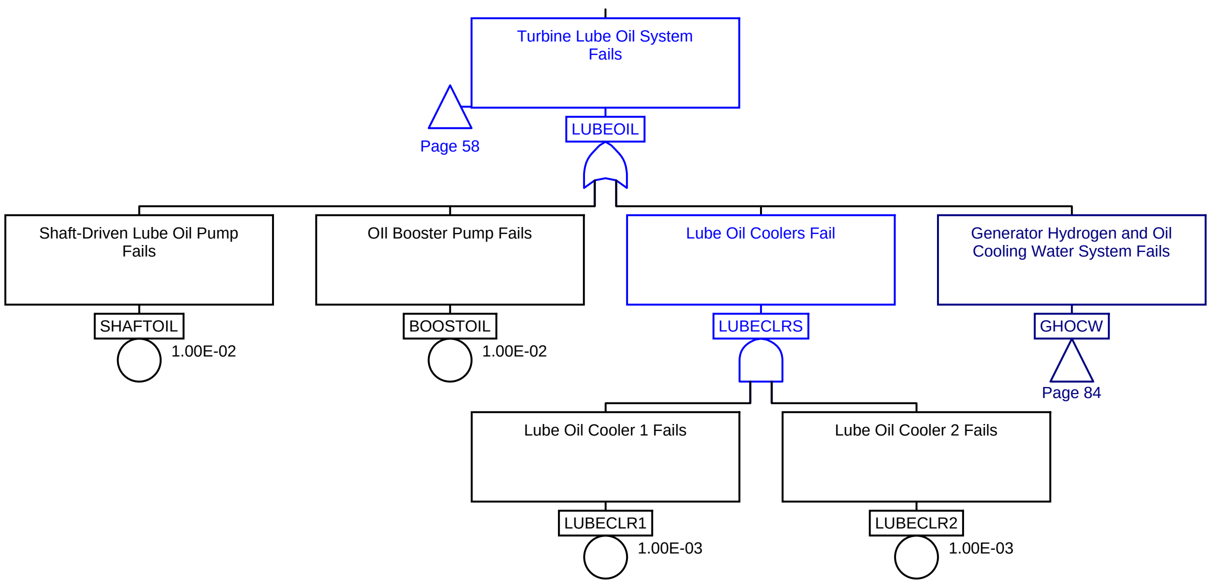
Turbine Gland Sealing System Fails
GLANDSEAL
HP Turbine Fails
HPTURBINE
1.00E-02
HP Governor System Fails
HPGOV
5.00E-03
HP Turbine Control Valves Fail
HPTCNTL
HP Turbine Stop Valves Fail
HPTSTOP
Gland Seal Exhauster 1 Fails
GLNDEXH1
Page 62
Gland Seal Exhauster 2 Fails
GLNDEXH2
Page 63
HP Turbine Upper Control Valve Fails
HPTUCNTL
5.00E-03
HP Turbine Lower Control Valve Fails
HPTLCNTL
5.00E-03
Left HP Turbine Stop Valve Fails
HPTLSTOP
1.00E-03
Right HP Turbine Stop Valve Fails
HPTRSTOP
1.00E-03


IP Turbine Fails
Page 58
IPTURBFAIL
IP Turbine Fails
IPTURBINE
1.00E-02
IP Turbine Steam Supply Fails
IPTSTEAM
Left IP Steam Supply Fails
Page 9
IPTLFTSTM
Right IP Steam Supply Fails
Page 9
IPTRGHTSTM
Left IP Turbine Reheat Stop Valve Fails
IPTLSTOP
1.00E-03
IP Turbine Left Intercept Valve Fails
IPTLINTCPT
1.00E-03
Right IP Turbine Reheat Stop Valve Fails
IPTRSTOP
1.00E-03
IP Turbine Right Intercept Valve Fails
IPTRINTCPT
1.00E-03


LP Turbine Fails
Page 58
LPTURBFAIL
LP Turbine Fails
LP Governor System Fails
LPTURBINE
1.00E-02
LPGOV
5.00E-03



Turbine Lube Oil System Fails
LUBEOIL
Page 58
Shaft-Driven Lube Oil Pump Fails
SHAFTOIL
1.00E-02
OIl Booster Pump Fails
BOOSTOIL
1.00E-02
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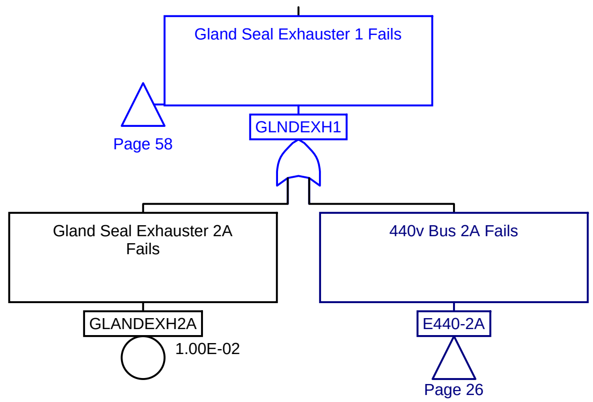
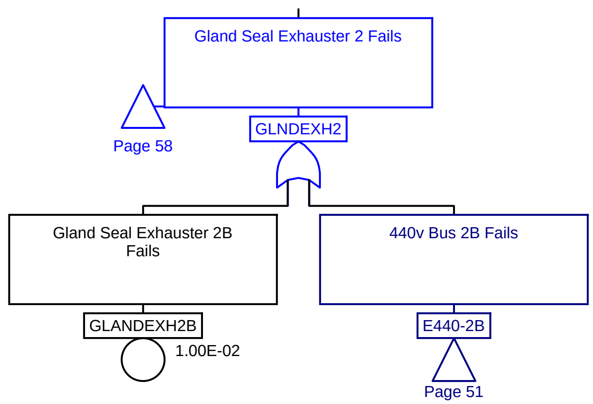
LUBECLRS
Generator Hydrogen and Oil Cooling Water System Fails
GHOCW
Page 84
Lube Oil Cooler 1 Fails
LUBECLR1
1.00E-03
Lube Oil Cooler 2 Fails
LUBECLR2
1.00E-03


Gland Seal Exhauster 1 Fails
Page 58
GLNDEXH1
Gland Seal Exhauster 2A Fails
440v Bus 2A Fails
GLANDEXH2A
1.00E-02
E440-2A
Page 26


Gland Seal Exhauster 2 Fails
Page 58
GLNDEXH2
Gland Seal Exhauster 2B
Fails
440v Bus 2B Fails
GLANDEXH2B
1.00E-02
E440-2B
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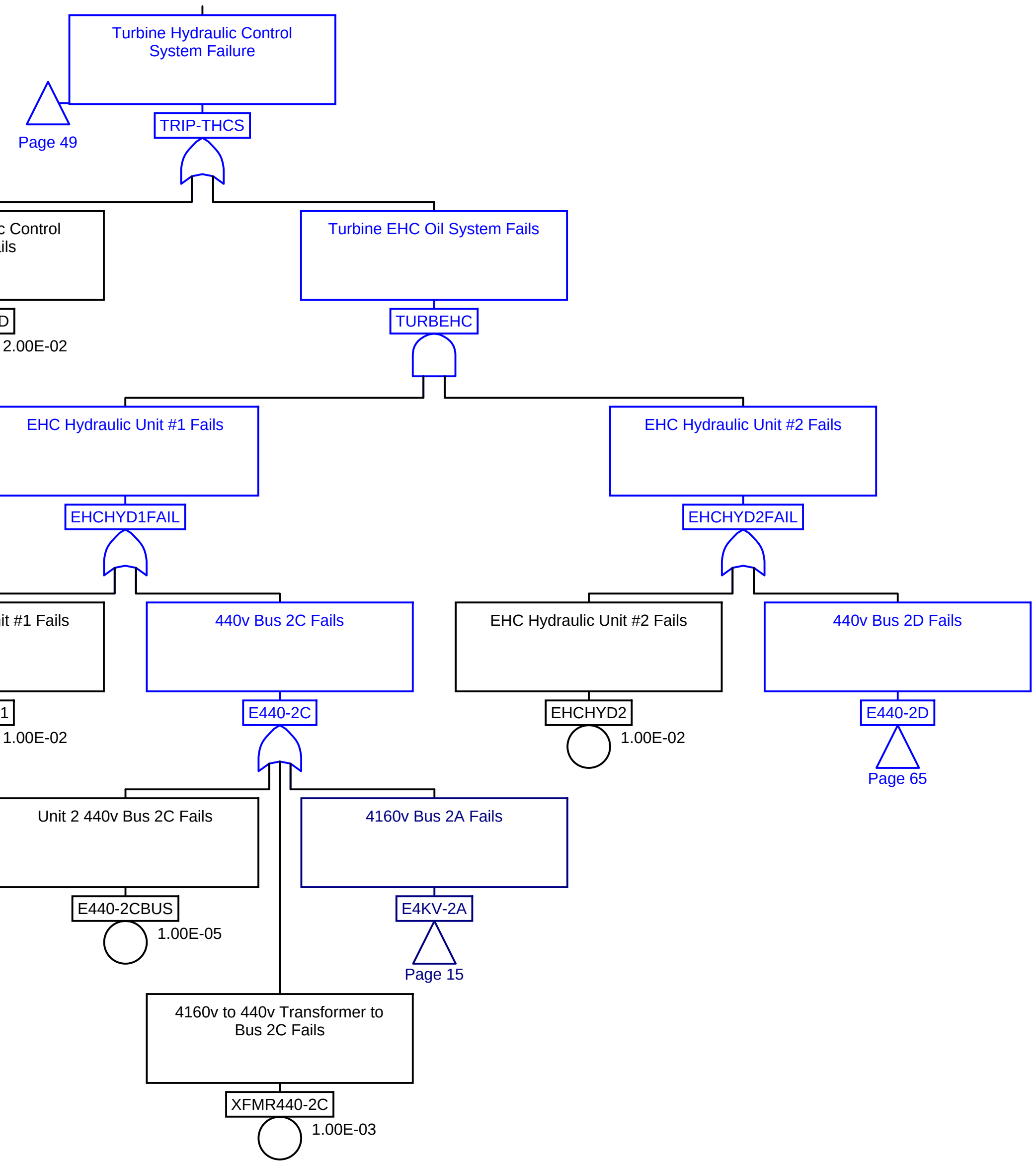
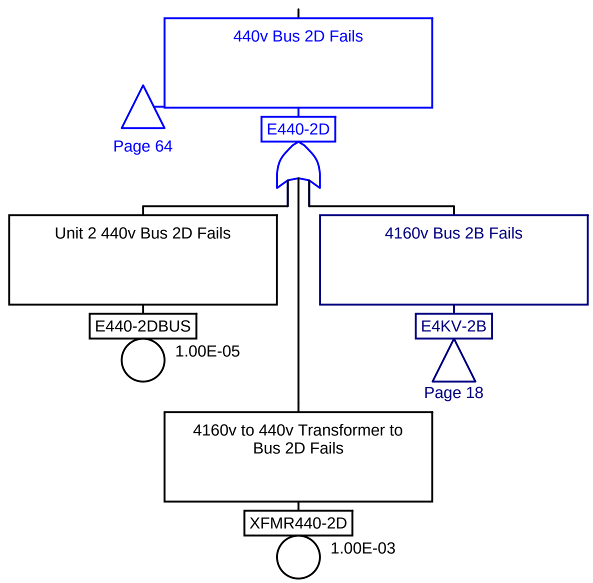
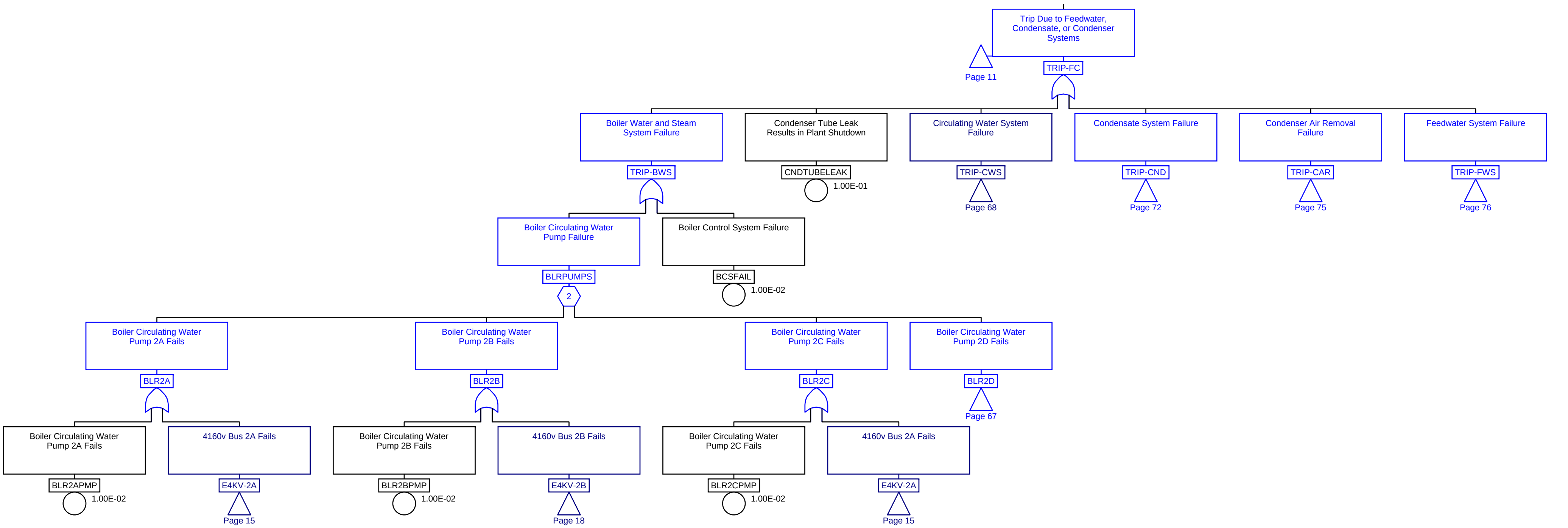


Turbine Hydraulic Control System Failure
Page 49
TRIP-THCS
Turbine Hydraulic Control System Fails
TURBHYD
2.00E-02
Turbine EHC Oil System Fails
TURBEHC
EHC Hydraulic Unit #1 Fails
EHCHYD1FAIL
EHC Hydraulic Unit #2 Fails
EHCHYD2FAIL
EHC Hydraulic Unit #1 Fails
EHCHYD1
1.00E-02
440v Bus 2C Fails
E440-2C
EHC Hydraulic Unit #2 Fails
EHCHYD2
1.00E-02
440v Bus 2D Fails
E440-2D
Page 65
Unit 2 440v Bus 2C Fails
E440-2CBUS
1.00E-05
4160v Bus 2A Fails
E4KV-2A
Page 15
4160v to 440v Transformer to Bus 2C Fails
XFMR440-2C
1.00E-03


440v Bus 2D Fails
Page 64
E440-2D
Unit 2 440v Bus 2D Fails
4160v Bus 2B Fails
E440-2DBUS
1.00E-05
E4KV-2B
Page 18
4160v to 440v Transformer to Bus 2D Fails
XFMR440-2D
1.00E-03



Trip Due to Feedwater, Condensate, or Condenser Systems
TRIP-FC
Page 11
Boiler Water and Steam System Failure
TRIP-BWS
Condenser Tube Leak Results in Plant Shutdown
CNDTUBELEAK
1.00E-01
Circulating Water System Failure
TRIP-CWS
Page 68
Condensate System Failure
TRIP-CND
Page 72
Condenser Air Removal Failure
TRIP-CAR
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Feedwater System Failure
TRIP-FWS
Page 76
Boiler Circulating Water Pump Failure
BLRPUMPS
2
Boiler Control System Failure
BCSFAIL
1.00E-02
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BLR2A
Boiler Circulating Water Pump 2B Fails
BLR2B
Boiler Circulating Water Pump 2C Fails
BLR2C
Boiler Circulating Water Pump 2D Fails
BLR2D
Page 67
Boiler Circulating Water Pump 2A Fails
BLR2APMP
1.00E-02
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E4KV-2A
Page 15
Boiler Circulating Water Pump 2B Fails
BLR2BPMP
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18
Boiler Circulating Water Pump 2C Fails
BLR2CPMP
1.00E-02
4160v Bus 2A Fails
E4KV-2A
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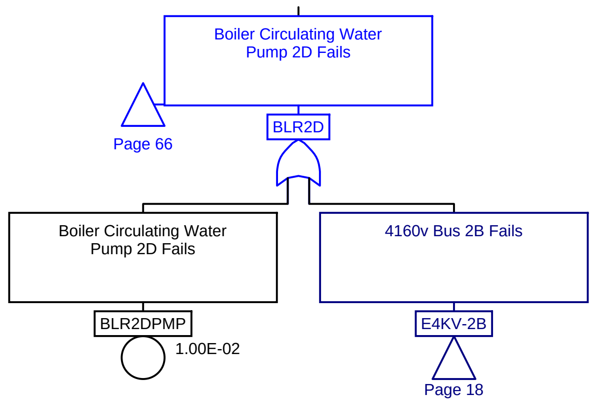
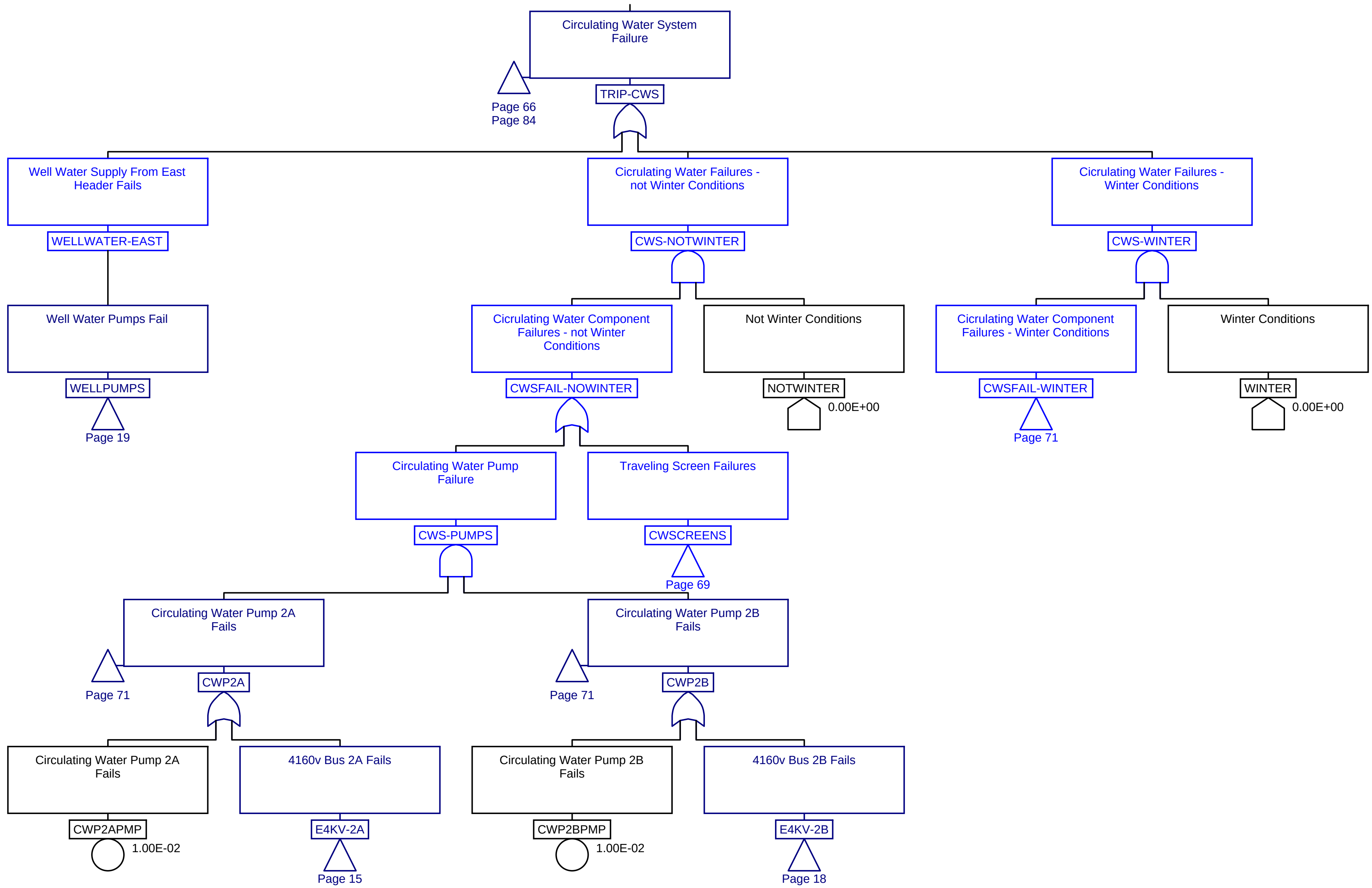

Boiler Circulating Water
Pump 2D Fails
BLR2D
Page 66
Boiler Circulating Water
Pump 2D Fails
BLR2DPMP
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18


Circulating Water System Failure
TRIP-CWS
Page 66
Page 84
Well Water Supply From East Header Fails
WELLWATER-EAST
Well Water Pumps Fail
WELLPUMPS
Page 19
Cicrulating Water Failures - not Winter Conditions
CWS-NOTWINTER
Cicrulating Water Component Failures - not Winter Conditions
CWSFAIL-NOWINTER
Not Winter Conditions
NOTWINTER
0.00E+00
Cicrulating Water Failures - Winter Conditions
CWS-WINTER
Cicrulating Water Component Failures - Winter Conditions
CWSFAIL-WINTER
Page 71
Winter Conditions
WINTER
0.00E+00
Circulating Water Pump Failure
CWS-PUMPS
Traveling Screen Failures
CWSCREENS
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Circulating Water Pump 2A Fails
CWP2A
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Circulating Water Pump 2B Fails
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Circulating Water Pump 2A Fails
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1.00E-02
4160v Bus 2A Fails
E4KV-2A
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Circulating Water Pump 2B Fails
CWP2BPMP
1.00E-02
4160v Bus 2B Fails
E4KV-2B
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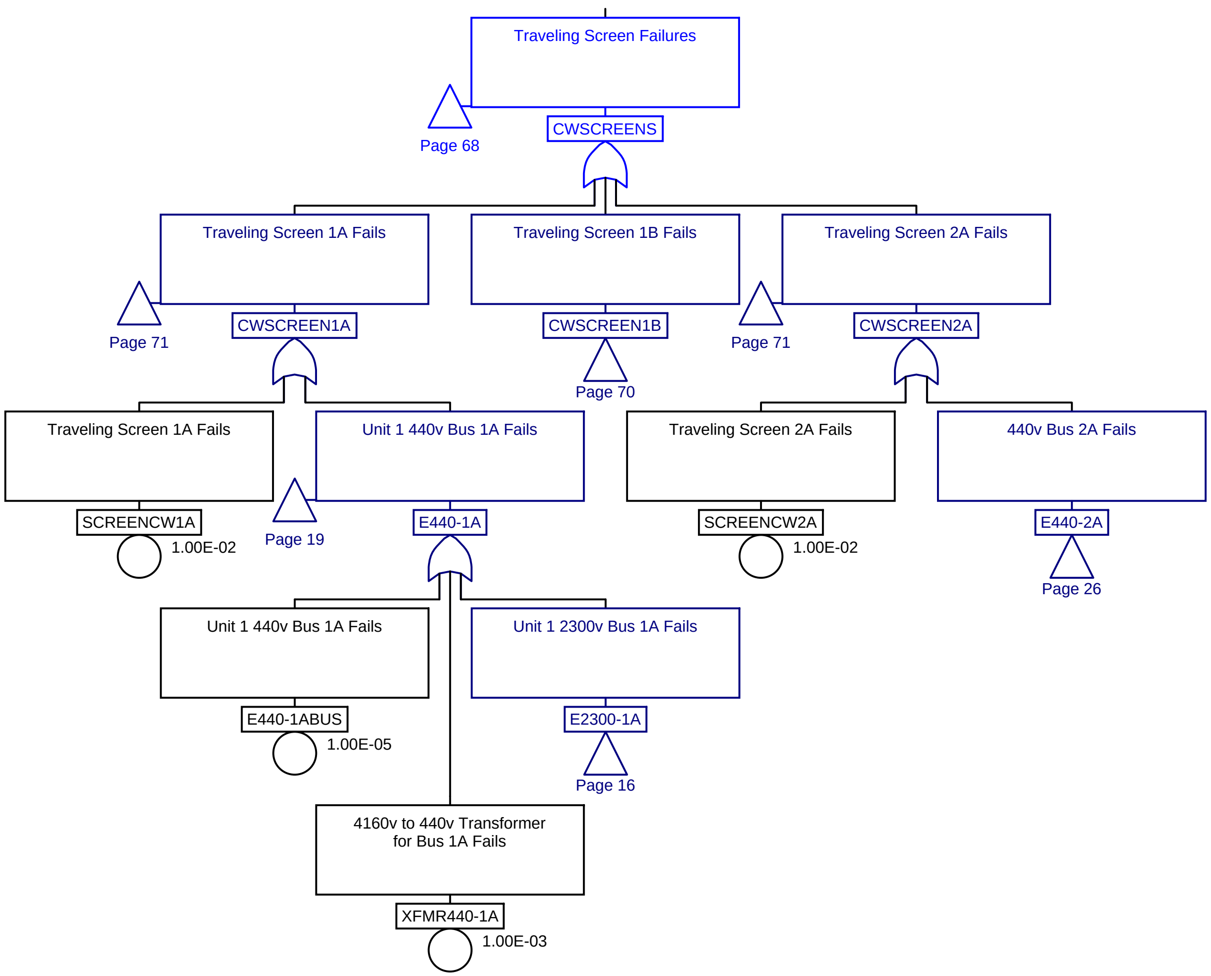
Traveling Screen Failures
CWSCREENS
Page 68
Traveling Screen 1A Fails
CWSCREEN1A
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Traveling Screen 1B Fails
CWSCREEN1B
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Traveling Screen 2A Fails
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1.00E-02
Unit 1 440v Bus 1A Fails
E440-1A
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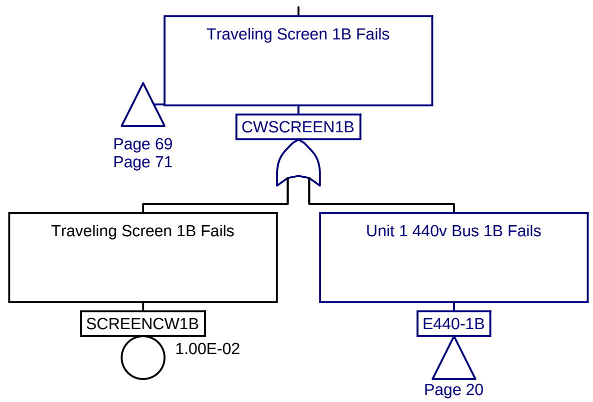
SCREENCW2A
1.00E-02
440v Bus 2A Fails
E440-2A
Page 26
Unit 1 440v Bus 1A Fails
E440-1ABUS
1.00E-05
Unit 1 2300v Bus 1A Fails
E2300-1A
Page 16
4160v to 440v Transformer
for Bus 1A Fails
XFMR440-1A
1.00E-03


Traveling Screen 1B Fails
CWSCREEN1B
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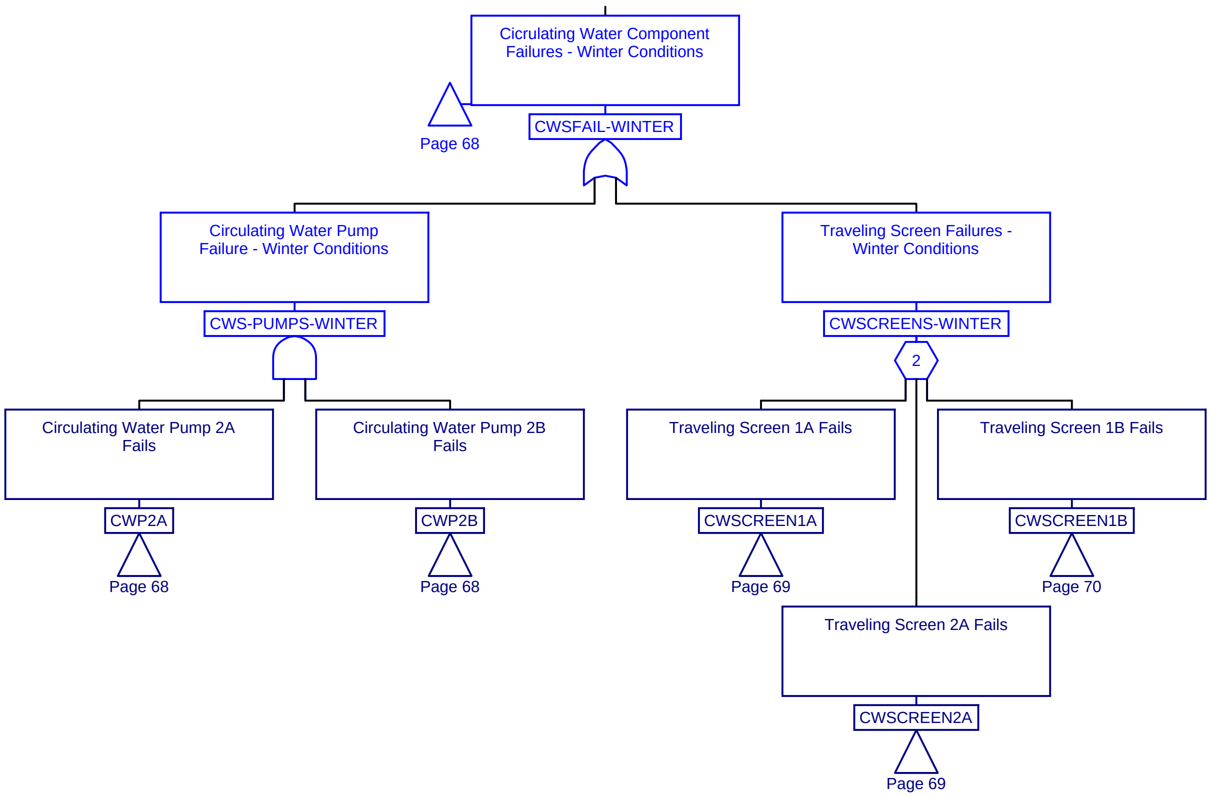
Page 71
Traveling Screen 1B Fails
SCREENCW1B
1.00E-02
Unit 1 440v Bus 1B Fails
E440-1B
Page 20


Circulating Water Component Failures - Winter Conditions
CWSFAIL-WINTER
Page 68
Circulating Water Pump Failure - Winter Conditions
CWS-PUMPS-WINTER
Traveling Screen Failures - Winter Conditions
CWSCREENS-WINTER
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Circulating Water Pump 2A Fails
CWP2A
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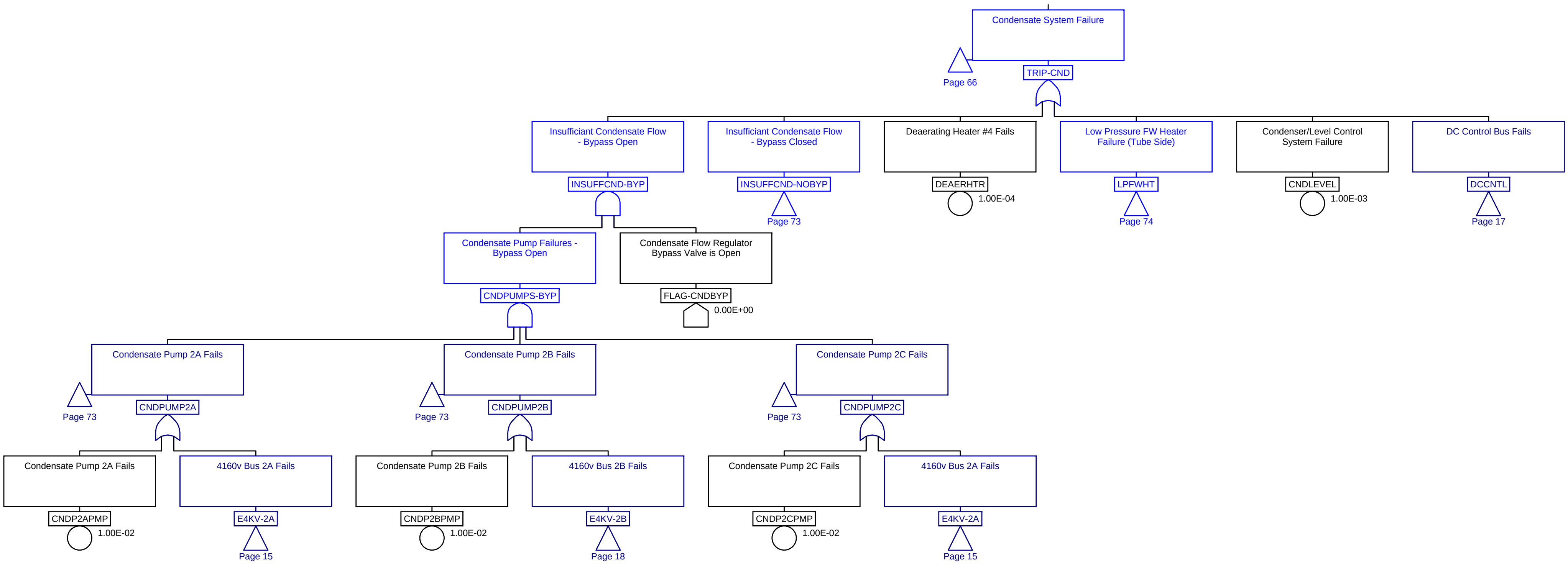
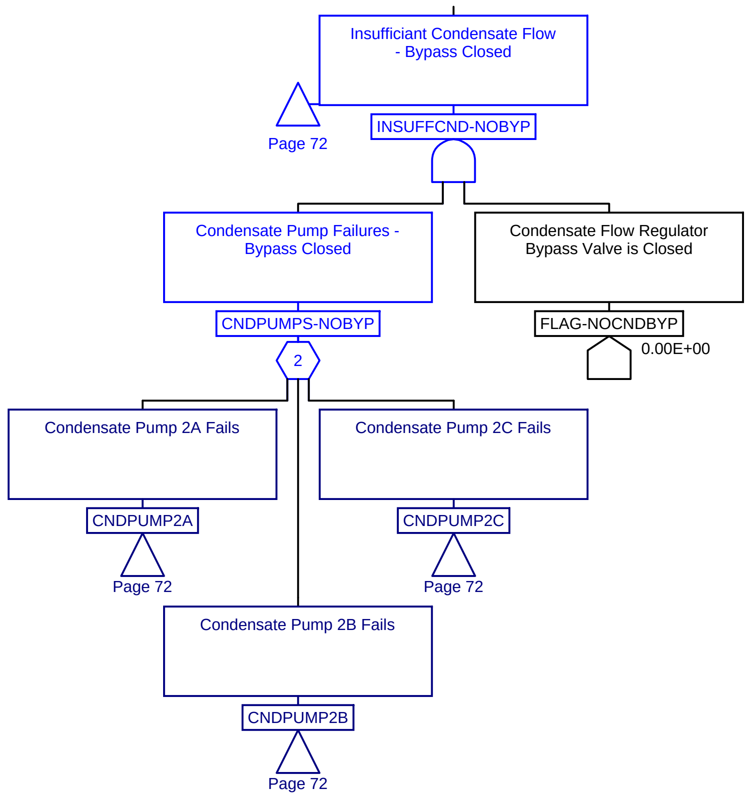
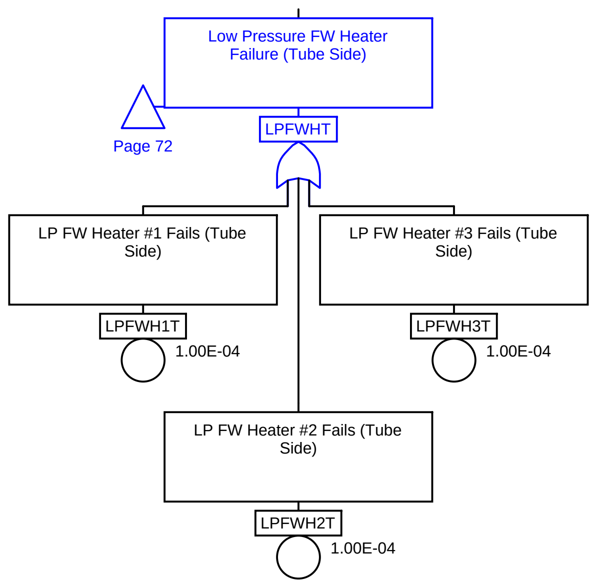
Circulating Water Pump 2B Fails
CWP2B
Page 68
Traveling Screen 1A Fails
CWSCREEN1A
Page 69
Traveling Screen 1B Fails
CWSCREEN1B
Page 70
Traveling Screen 2A Fails
CWSCREEN2A
Page 69

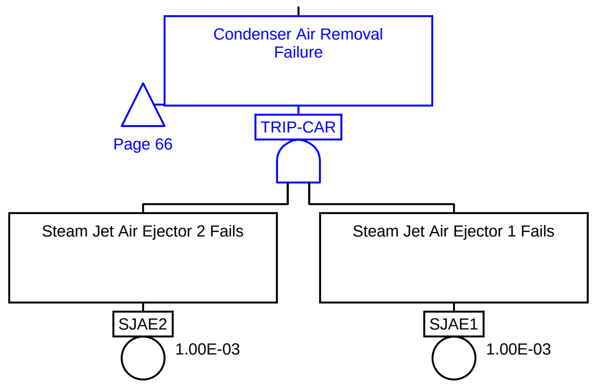


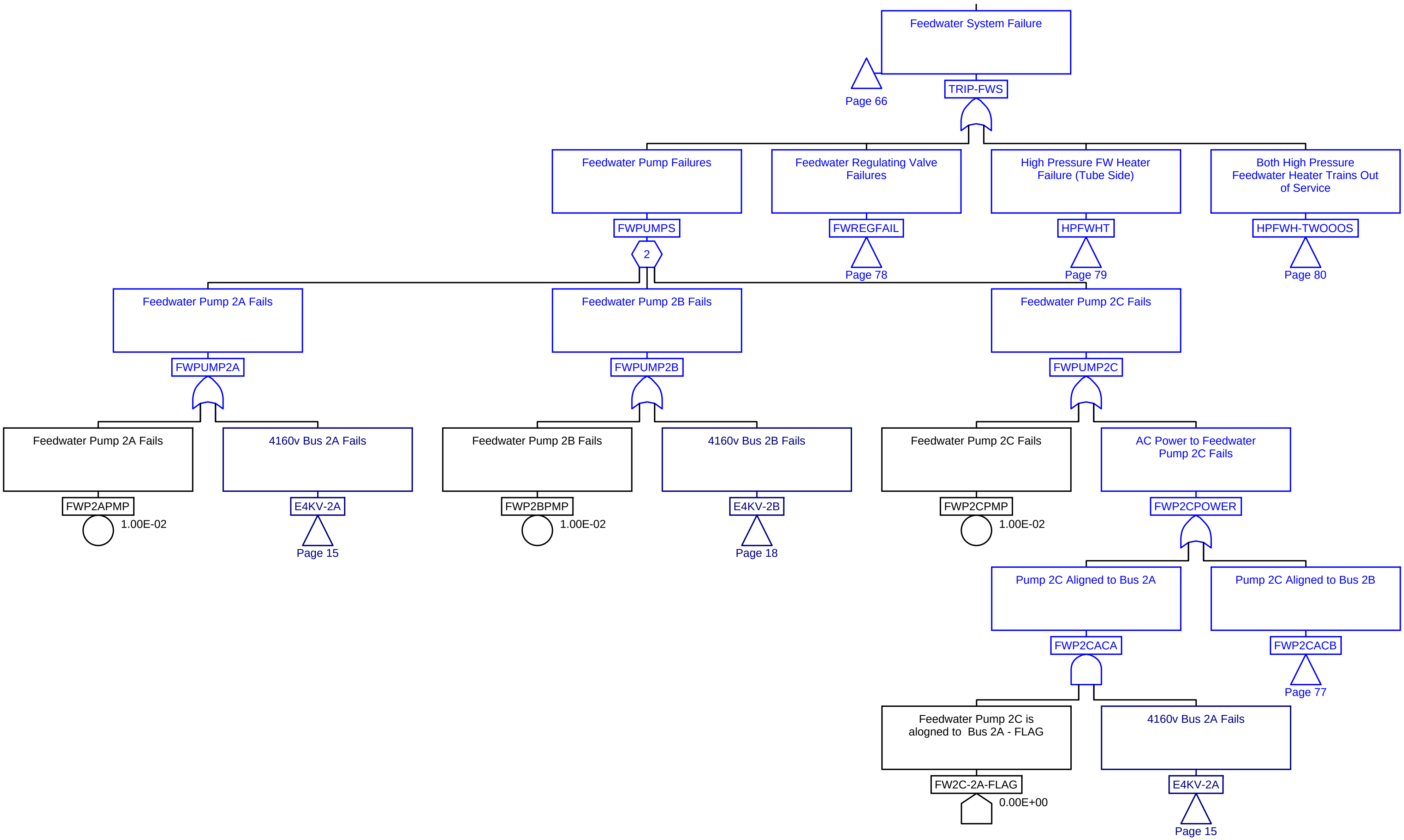
Condensate System Failure
TRIP-CND
Page 66
Insufficiant Condensate Flow - Bypass Open
INSUFFCND-BYP
Insufficiant Condensate Flow - Bypass Closed
INSUFFCND-NOBYP
Page 73
Deaerating Heater #4 Fails
DEAERHTR
1.00E-04
Low Pressure FW Heater Failure (Tube Side)
LPFWHT
Page 74
Condenser/Level Control System Failure
CNDLEVEL
1.00E-03
DC Control Bus Fails
DCCNTL
Page 17
Condensate Pump Failures - Bypass Open
CNDPUMPS-BYP
Condensate Flow Regulator Bypass Valve is Open
FLAG-CNDBYP
0.00E+00
Condensate Pump 2A Fails
CNDPUMP2A
Page 73
Condensate Pump 2B Fails
CNDPUMP2B
Page 73
Condensate Pump 2C Fails
CNDPUMP2C
Page 73
Condensate Pump 2A Fails
CNDP2APMP
1.00E-02
4160v Bus 2A Fails
E4KV-2A
Page 15
Condensate Pump 2B Fails
CNDP2BPMP
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18
Condensate Pump 2C Fails
CNDP2CPMP
1.00E-02
4160v Bus 2A Fails
E4KV-2A
Page 15



Insufficiant Condensate Flow - Bypass Closed
INSUFFCND-NOBYP
Page 72
Condensate Pump Failures - Bypass Closed
CNDPUMPS-NOBYP
2
Condensate Flow Regulator Bypass Valve is Closed
FLAG-NOCNDBYP
0.00E+00
Condensate Pump 2A Fails
CNDPUMP2A
Page 72
Condensate Pump 2C Fails
CNDPUMP2C
Page 72
Condensate Pump 2B Fails
CNDPUMP2B
Page 72


Low Pressure FW Heater Failure (Tube Side)
Page 72
LPFWHT
LP FW Heater #1 Fails (Tube Side)
LPFWH1T
1.00E-04
LP FW Heater #3 Fails (Tube Side)
LPFWH3T
1.00E-04
LP FW Heater #2 Fails (Tube Side)
LPFWH2T
1.00E-04


Condenser Air Removal Failure
Page 66
TRIP-CAR
Steam Jet Air Ejector 2 Fails
Steam Jet Air Ejector 1 Fails
SJAE2
1.00E-03
SJAE1
1.00E-03



Feedwater System Failure
TRIP-FWS
Page 66
Feedwater Pump Failures
FWPUMPS
2
Feedwater Regulating Valve Failures
FWREGFAIL
Page 78
High Pressure FW Heater Failure (Tube Side)
HPFWHT
Page 79
Both High Pressure Feedwater Heater Trains Out of Service
HPFWH-TWOOOS
Page 80
Feedwater Pump 2A Fails
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Feedwater Pump 2B Fails
FWPUMP2B
Feedwater Pump 2C Fails
FWPUMP2C
Feedwater Pump 2A Fails
FWP2APMP
1.00E-02
4160v Bus 2A Fails
E4KV-2A
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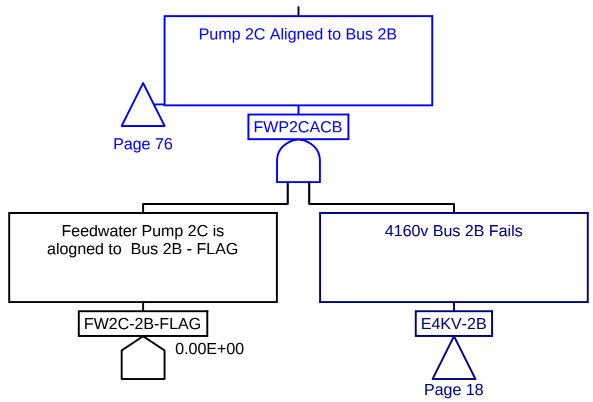
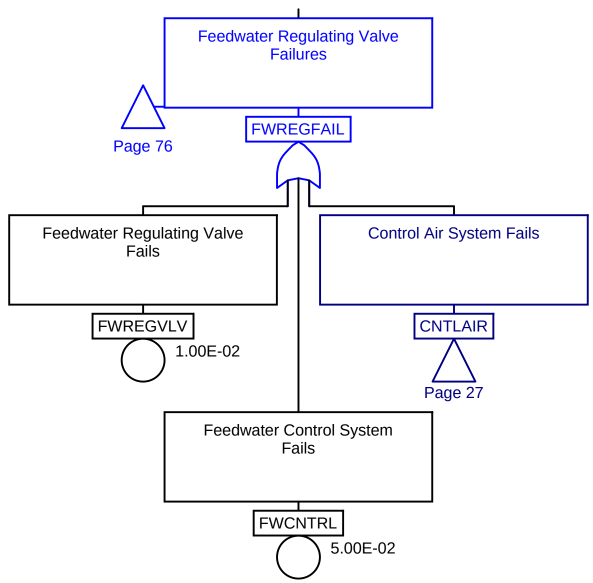
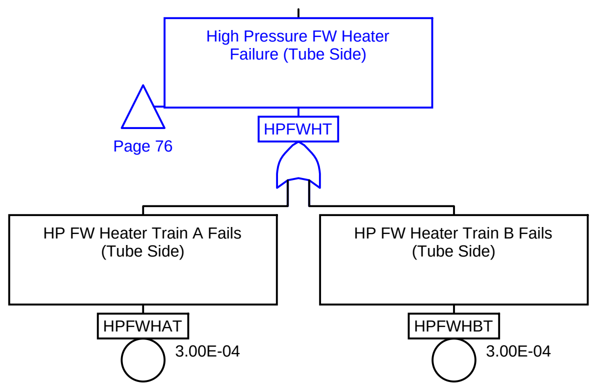
Feedwater Pump 2B Fails
FWP2BPMP
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18
Feedwater Pump 2C Fails
FWP2CPMP
1.00E-02
AC Power to Feedwater Pump 2C Fails
FWP2CPOWER
Pump 2C Aligned to Bus 2A
FWP2CACA
Pump 2C Aligned to Bus 2B
FWP2CACB
Page 77
Feedwater Pump 2C is alogned to Bus 2A - FLAG
FW2C-2A-FLAG
0.00E+00
4160v Bus 2A Fails
E4KV-2A
Page 15

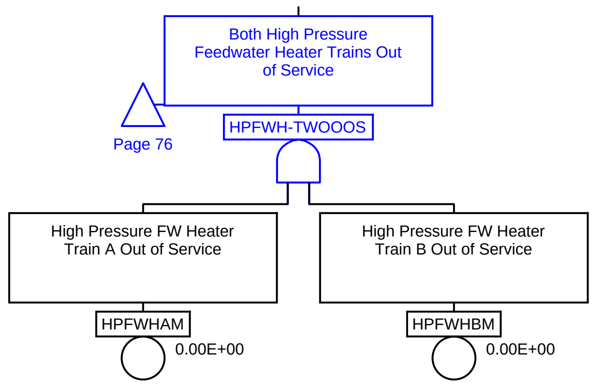


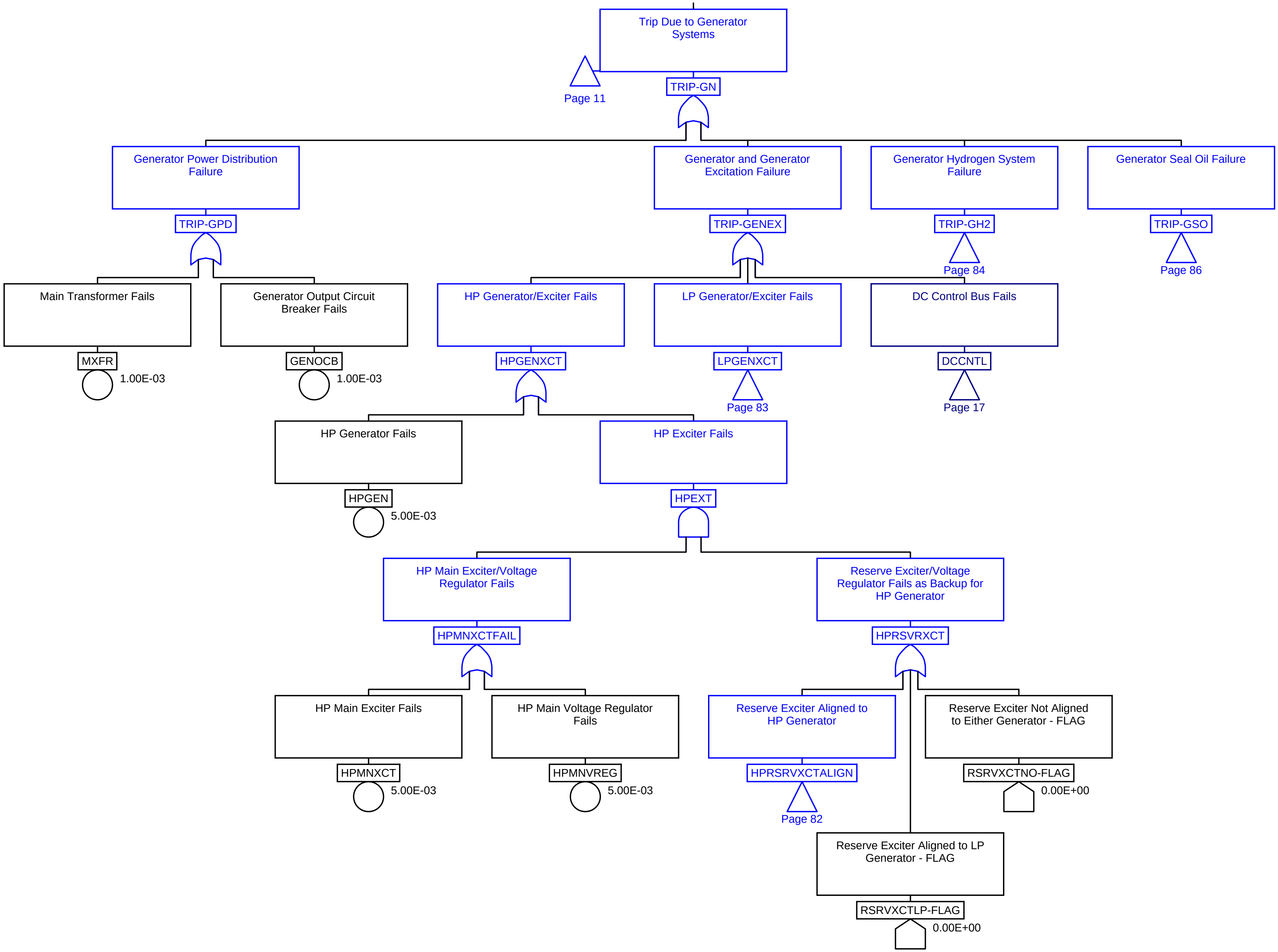
Pump 2C Aligned to Bus 2B
Page 76
FWP2CACB
Feedwater Pump 2C is
alogned to Bus 2B - FLAG
4160v Bus 2B Fails
FW2C-2B-FLAG
0.00E+00
E4KV-2B
Page 18


Feedwater Regulating Valve Failures
FWREGFAIL
Page 76
Feedwater Regulating Valve Fails
FWREGVLV
1.00E-02
Control Air System Fails
CNTLAIR
Page 27
Feedwater Control System Fails
FWCNTRL
5.00E-02



High Pressure FW Heater Failure (Tube Side)
HPFWHT
Page 76
HP FW Heater Train A Fails (Tube Side)
HPFWHAT
3.00E-04
HP FW Heater Train B Fails (Tube Side)
HPFWHBT
3.00E-04


Both High Pressure Feedwater Heater Trains Out of Service
HPFWH-TWOOOS
Page 76
High Pressure FW Heater Train A Out of Service
HPFWHAM
0.00E+00
High Pressure FW Heater Train B Out of Service
HPFWHBM
0.00E+00


Trip Due to Generator Systems
TRIP-GN
Page 11
Generator Power Distribution Failure
TRIP-GPD
Generator and Generator Excitation Failure
TRIP-GENEX
Generator Hydrogen System Failure
TRIP-GH2
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TRIP-GSO
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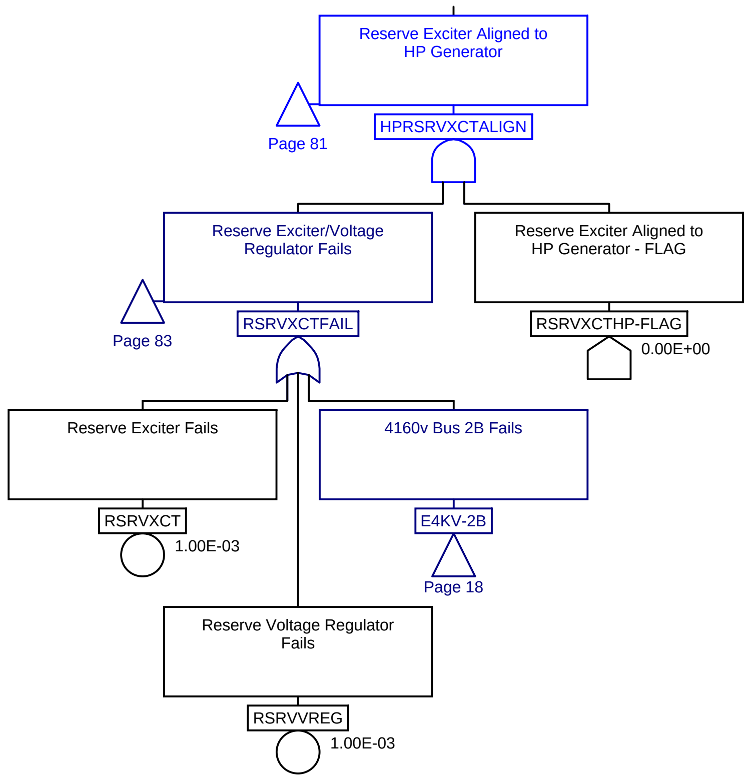
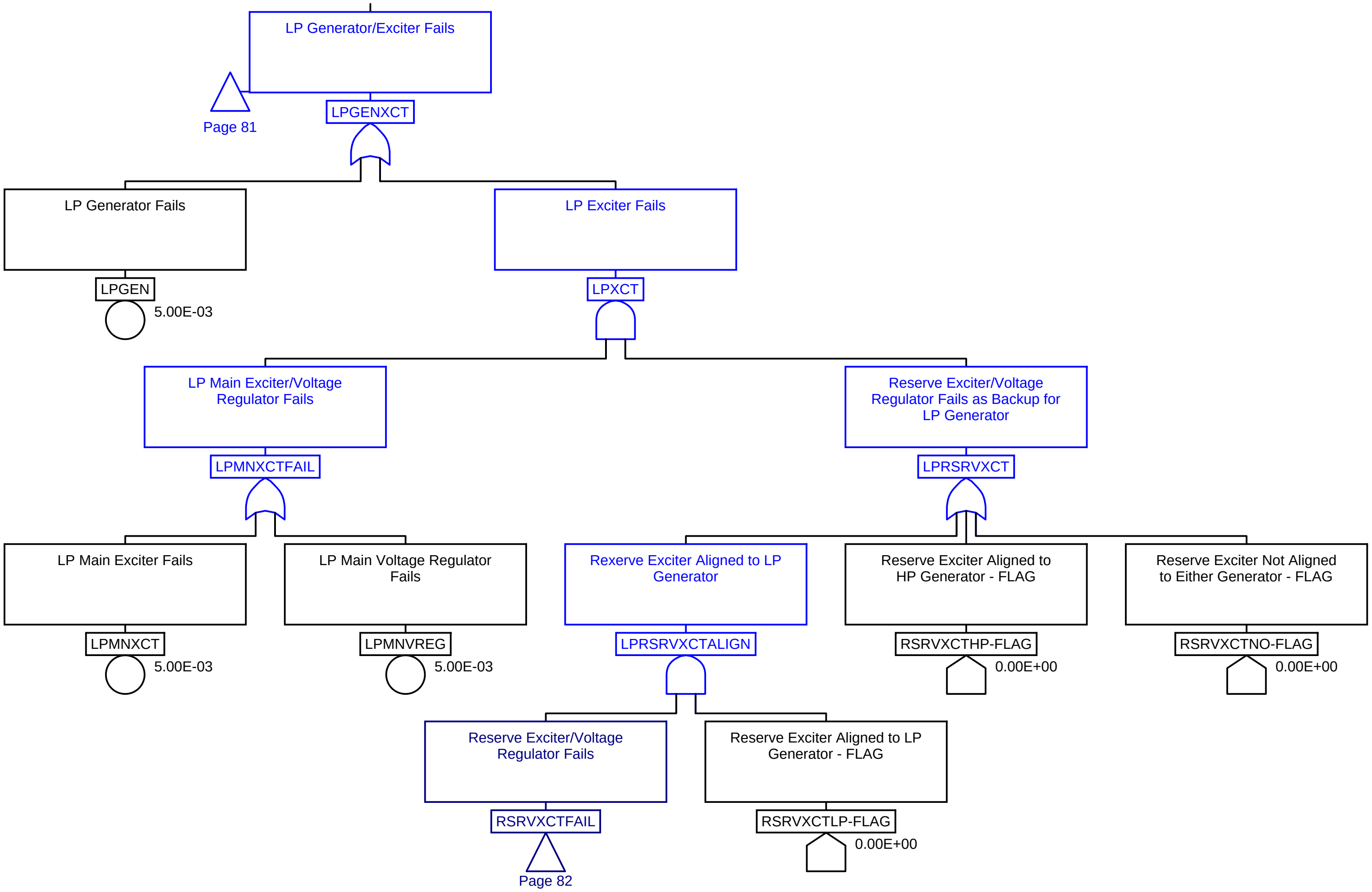
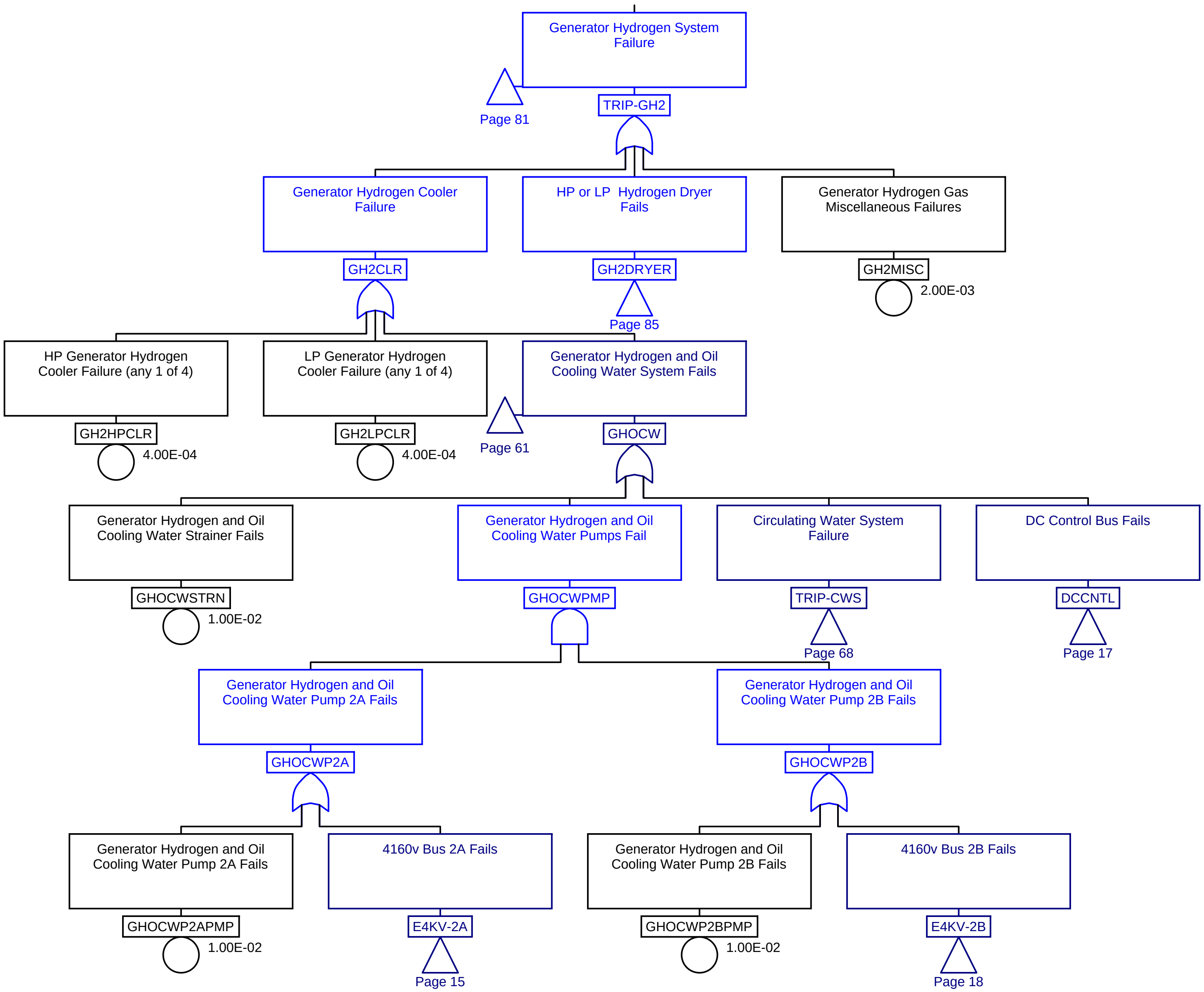
MXFR
1.00E-03
Generator Output Circuit Breaker Fails
GENOCB
1.00E-03
HP Generator/Exciter Fails
HPGENXCT
LP Generator/Exciter Fails
LPGENXCT
Page 83
DC Control Bus Fails
DCCNTL
Page 17
HP Generator Fails
HPGEN
5.00E-03
HP Exciter Fails
HPEXT
HP Main Exciter/Voltage Regulator Fails
HPMNXCTFAIL
Reserve Exciter/Voltage Regulator Fails as Backup for HP Generator
HPRSVRXCT
HP Main Exciter Fails
HPMNXCT
5.00E-03
HP Main Voltage Regulator Fails
HPMNVREG
5.00E-03
Reserve Exciter Aligned to HP Generator
HPRSRVXCTALIGN
Page 82
Reserve Exciter Not Aligned to Either Generator - FLAG
RSRVXCTNO-FLAG
0.00E+00
Reserve Exciter Aligned to LP Generator - FLAG
RSRVXCTLP-FLAG
0.00E+00



Reserve Exciter Aligned to HP Generator
Page 81
HPRSRVXCTALIGN
Reserve Exciter/Voltage Regulator Fails
Reserve Exciter Aligned to HP Generator - FLAG
Page 83
RSRVXCTFAIL
RSRVXCTHP-FLAG
0.00E+00
Reserve Exciter Fails
4160v Bus 2B Fails
RSRVXCT
1.00E-03
E4KV-2B
Page 18
Reserve Voltage Regulator Fails
RSRVVREG
1.00E-03



LP Generator/Exciter Fails
Page 81
LPGENXCT
LP Generator Fails
LPGEN
5.00E-03
LP Exciter Fails
LPXCT
LP Main Exciter/Voltage Regulator Fails
LPMNXCTFAIL
Reserve Exciter/Voltage Regulator Fails as Backup for LP Generator
LPRSRVXCT
LP Main Exciter Fails
LPMNXCT
5.00E-03
LP Main Voltage Regulator Fails
LPMNVREG
5.00E-03
Rexerve Exciter Aligned to LP Generator
LPRSRVXCTALIGN
Reserve Exciter Aligned to HP Generator - FLAG
RSRVXCTHP-FLAG
0.00E+00
Reserve Exciter Not Aligned to Either Generator - FLAG
RSRVXCTNO-FLAG
0.00E+00
Reserve Exciter/Voltage Regulator Fails
RSRVXCTFAIL
Page 82
Reserve Exciter Aligned to LP Generator - FLAG
RSRVXCTLP-FLAG
0.00E+00



Generator Hydrogen System Failure
TRIP-GH2
Page 81
Generator Hydrogen Cooler Failure
GH2CLR
HP or LP Hydrogen Dryer Fails
GH2DRYER
Page 85
Generator Hydrogen Gas Miscellaneous Failures
GH2MISC
2.00E-03
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GH2HPCLR
4.00E-04
LP Generator Hydrogen Cooler Failure (any 1 of 4)
GH2LPCLR
4.00E-04
Page 61
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GHOCW
Generator Hydrogen and Oil Cooling Water Strainer Fails
GHOCWSTRN
1.00E-02
Generator Hydrogen and Oil Cooling Water Pumps Fail
GHOCWPMP
Circulating Water System Failure
TRIP-CWS
Page 68
DC Control Bus Fails
DCCNTL
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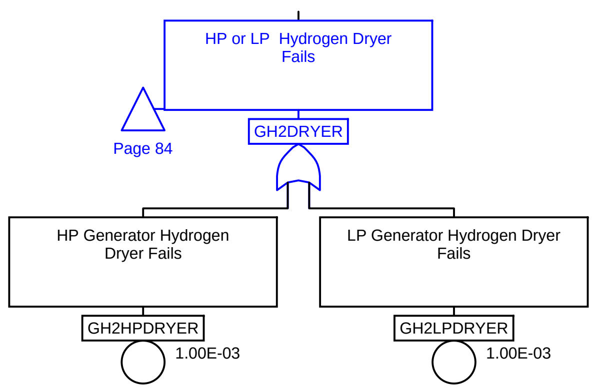
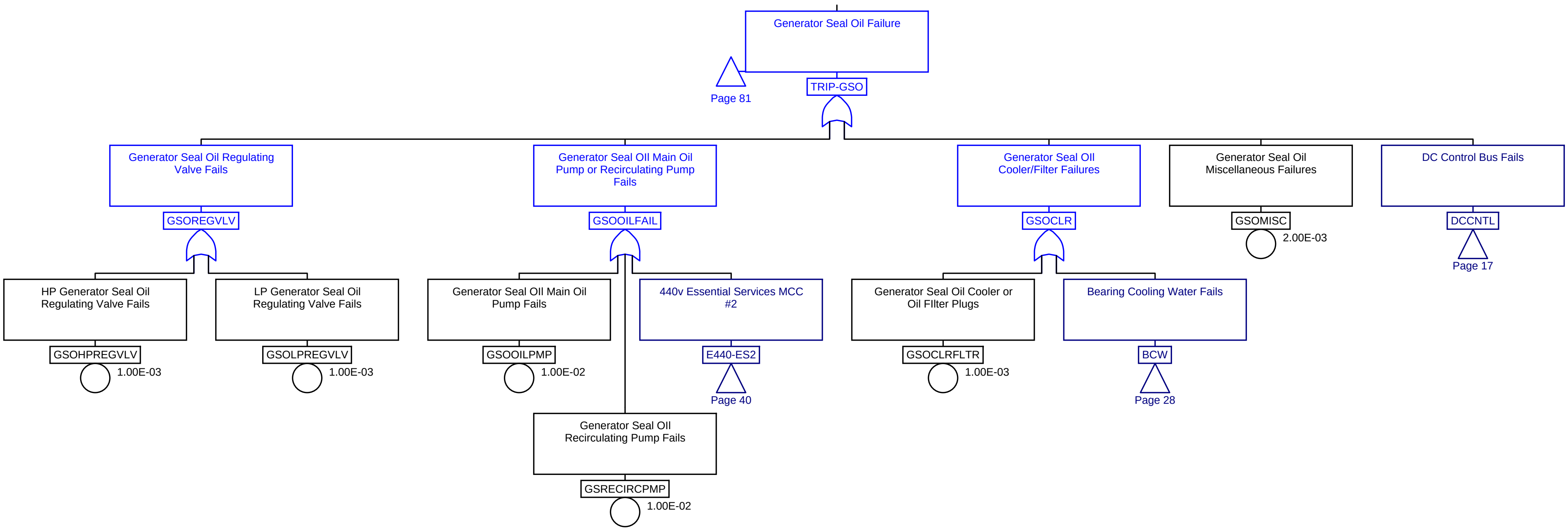
GHOCWP2A
Generator Hydrogen and Oil Cooling Water Pump 2B Fails
GHOCWP2B
Generator Hydrogen and Oil Cooling Water Pump 2A Fails
GHOCWP2APMP
1.00E-02
4160v Bus 2A Fails
E4KV-2A
Page 15
Generator Hydrogen and Oil Cooling Water Pump 2B Fails
GHOCWP2BPMP
1.00E-02
4160v Bus 2B Fails
E4KV-2B
Page 18


HP or LP Hydrogen Dryer Fails
GH2DRYER
Page 84
HP Generator Hydrogen Dryer Fails
LP Generator Hydrogen Dryer Fails
GH2HPDRYER
1.00E-03
GH2LPDRYER
1.00E-03


Generator Seal Oil Failure
Page 81
TRIP-GSO
Generator Seal Oil Regulating Valve Fails
GSOREGVLV
Generator Seal OIl Main Oil Pump or Recirculating Pump Fails
GSOOILFAIL
Generator Seal OIl Cooler/Filter Failures
GSOCLR
Generator Seal Oil Miscellaneous Failures
GSOMISC
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DC Control Bus Fails
DCCNTL
Page 17
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GSOHPREGVLV
1.00E-03
LP Generator Seal Oil Regulating Valve Fails
GSOLPREGVLV
1.00E-03
Generator Seal OIl Main Oil Pump Fails
GSOOILPMP
1.00E-02
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1.00E-03
Bearing Cooling Water Fails
BCW
Page 28
Generator Seal OIl Recirculating Pump Fails
GSRECIRCPMP
1.00E-02

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