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Study of Safety Classification of Components and Parts Used in NPP DCS Electric Cabinet

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Abstract

To achieve the required level of safety and design standards need to provide a criteria and methodology for determining and evaluating changes to the safety and quality classification of components and parts in safety related used in 1E DCS equipment. The process defined by this study is intended to provide a consistent step-by-step approach for classification determinations.

Keywords

Nuclear power plant (NPP); Digital instrument and control system (DCS); Classification.

1. INTRODUCTION

Safety Classification is a process of determining whether a part intended for use in a safety related application should be classified as 1E, safety related, or non-safety related. Classification of structures, systems and components (SSC) acts as part of the defence in depth approach as an essential task in the overall life cycle of a nuclear power plant. The classification of SSCs specifies their importance to safety, according to the consequences of their failure to perform when required [1]. Early identification of safety relevant SSCs contributes in the correct definition of systems requirements, preliminary layout and design integration [2].

During the design and construction phases of NPP, the focus of safety classification was on the system and component level of equipment. During the operation and maintenance phases of NPP, the focus of safety classification is on the detailed evaluation of component and piece-part safety classification [3].

IEEE SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants, and EPRI NP-6895, Guidelines for the Safety Classification of Systems, Components and Parts Used in Nuclear Power Plant Applications, provides a direction needed for establishing a rational and justifiable basis for components and part classification. In combination studying with standard IEEE 323, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations, IEEE 344, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Stations, determining safety and quality classification information can be extended as applicable to all DCS items in accordance with the intent of the use of nuclear power plant projects document. This study emphasizes the safety classification method for 1E DCS cabinets components and parts to give a technical route to engineering implementation.

2. 1E, SAFETY RELATED COMPONENTS

The methodology to ensure the performance of the Seismic Category I components can refer to an assessment of credible failure mechanisms in accordance with the guidelines specified in

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EPRI NP-6895, to identify the critical characteristics of the components that should be verified. This process provides the necessary assurance that the Seismic Category I components will perform their required functions in supporting the safety related 1E components.

Components that were originally supplied as an assembly can have the individual parts evaluated and analyzed to make the following determinations:

a. The intended function(s) of the part;

b. The intended function of the part is relied upon for the accomplishment of the safety related function(s) of the parent component (item is 1E); or

c. The failure of the part to perform an intended function may degrade or impair the safety related function of the parent component or system (item is 1E); or

d. The function of the part is not relied upon for the accomplishment of the parent component's safety related function(s) and its failure, in any mode, would not degrade or impair the safety related function(s) of another safety related component, the parent component or system, i.e., the item is non-safety related (NQ).

3. DCS ELECTRIC CABINETS' COMPONENTS AND PARTS CLASSIFICATION EVALUATION METHOD

Electric cabinet is one of the most popular components in the nuclear industry, which contains many power distribution systems such as electric switchboard, control transformer, or control circuit fuse, etc [4]. NPP DCS electric cabinets include standing cabinets and wall-mount cabinet. The cabinets' components and parts classifications (collectively referred to as 'item') should address the subject matter specified as follows:

Step 1: Item Identification

Description

Manufacturer and/or Supplier

Step 2: Application(s)

Identify the applications evaluated. For generic use items, state the specific bounding applications or evaluate the item for the most severe application and specify the item for general plant use.

Step 3: Items Function

Identify the item's function(s) in the parent component application(s). Document whether the item is required to accomplish any of the parent component's 1E, Safety Related (1E) functions.

Step 4: Credibility of Potential Failures

The credibility of potential failures of the item as well as the effect of such failures on the parent component's function(s) will be evaluated, this evaluation considers:

Potential initiating mechanisms and modes for the failure based on the operating environment (e.g., temperature, pressure, radiation, and humidity);

Operating experience based on plant-specific data, industry data, regulatory notices;

The specific application(s) in which it is used.

If the credible failure of the item would prevent another safety related component, the parent component, or system from accomplishing any of their safety or quality related functions, then the part is classified as 1E, safety related.

Step 5: Assumptions and Reasoning

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Any assumptions made in the development of the classification determination will be documented. This includes:

Assumptions or reasoning used in developing a bounding or worst case application.

Engineering judgment addressing the seismic or environmental sensitivity of the item being evaluated and its impact on the parent component.

Basis for determining that a specific failure mechanism(s) is not credible. This basis may be approved calculations, documented engineering judgment, design basis documents, etc.

Step 6: Item's Classification

Based on the evaluation, identify the safety or quality classification of the item (e.g., 1E, Safety Related, Non-Safety Related (NQ)). Figure 1, which depicts the flow of the above evaluation, it can be considered a model.

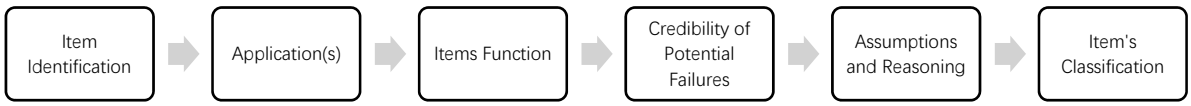

Figure 1. Components and Parts Classification Evaluation Model

4. CLASSIFICATION OF COMMONLY USED NON-SAFETY PARTS IN 1E DCS ELECTRICAL CABINETS

The items that are commonly used to build Electrical Cabinets such as ties, separators, cable organizers, washers for nuts and bolts etc. are evaluated and classified in this study.

4.1. Washers (Flat Washers, Tab Washers and Lock washers)

Step 1: Item Identification

Washers:

a. Flat Washers,

b. Tab Washers

c. Lock washers (External Tooth)

Step 2: Application(s)

a. Flat Washers provide a sacrificial bearing surface for bolting configurations to minimize damage to assembly parts.

b. Tab Washers - are used in bolting configurations similar to lock wire to prevent fastener rotation in the unlikely event that the fastener fails by losing its preload.

c. Lock washers - do not prevent rotation of the fastener. Only proper application of preload is credited with preventing fastener rotation. Furthermore, the lock washer will either fail during the assembly process (at which time it will be replaced) or it will not fail at all. For these reasons lock washers do not serve a critical function in the assemblies where torque values are stated.

Step 3: Items Function

Washers are integral part of a bolting mechanism and are held together by the bolt.

Step 4: Credibility of Potential Failures

There are no credible failure mechanisms that can cause the washers to get loose and interfere with any safety related component and jeopardize the functional ability of those components.

Step 5: Assumptions and Reasoning

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Therefore these components may be classified as non-safety-related and may be procured to industry standards that govern such parts.

4.2. Wraps (Cable Tie Wraps and Spiral Wrap)

Step 1: Item Identification

Wraps

a. Cable Tie Wraps

b. Spiral Wrap

Step 2: Application(s)

The purpose of the cable tie wrap and spiral wrap is to hold bundles of cable in place for routing. They are used to allow the cabinets to be neatly built and to allow ease of maintenance on the other equipment in the panel.

Step 3: Items Function

Keeping the wires restrained allows easier maintenance on the devices mounted in the panel to which the wires are connected. The cabinets will operate properly without the cable ties installed. The cable tie and spiral wrap is non-metallic, light weight material, has no moving parts and simple in design.

Step 4: Credibility of Potential Failures

The credible failure mechanism for the cable tie is becoming damaged or falling off. if the cable ties/spiral wrap fall off they do not weigh enough to damage any other equipment and therefore will not prevent other equipment in the cabinet from performing its safety function. A failed cable tie and spiral wrap cannot affect any equipment as all of the equipment such as relays that have moving parts is enclosed.

Step 5: Assumptions and Reasoning

Therefore a cable tie and spiral wrap, which has fallen off will not prevent the equipment in the panel from performing its safety function. The non-metallic cable tie and spiral wrap are not used to enforce channel to channel or train to train separation.

Step 6: Item's Classification

Therefore non-metallic cable ties and spiral wrap do not perform a safety function and are considered to be on-safety-related.

4.3. Labels (Wiring Labels, Warning Markers, Tag Carriers and Marker Strips)

Step 1: Item Identification

Labels

a. Wiring Labels

b. Warning Markers,

c. Tag Carriers,

d. Marker Strips

Step 2: Application(s)

The wiring labels, warning markers, tag carriers, and marker strips (label) are useful for the personnel installing equipment or maintaining the equipment in the cabinets.

Step 3: Items Function

The label is useful for identifying equipment and items in the cabinet.

Step 4: Credibility of Potential Failures

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They have no function during or after an accident. The cabinets will operate properly without the label, warning markers, tag carriers and marker strips installed. The label is non-metallic, light weight material, has no moving parts and simple in design.

Step 5: Assumptions and Reasoning

The credible failure mechanism for the label is becoming damaged or falling off. If the label falls off it does not weigh enough to damage any other equipment and therefore will not prevent other equipment in the cabinet from performing its safety function. A failed label cannot affect any equipment as all of the equipment such as relays that have moving parts is enclosed. Therefore a label, which has fallen off will not prevent the equipment in the panel from performing its safety function.

Step 6: Item's Classification

There is no impact on the safety function of the cabinets, the labels are non-safety-related.

The descriptions above can be generally applied to Bill of Material (BOM) items to electric DCS cabinet. Typical cabinet components and parts, as listed Tab.1. The below listed items do not perform a safety function and therefore are not required to be commercially dedicated and/or bought as 1E parts.

Table 1. Typical Non-safety Classification Components and Parts of Specific IE Cabinet

Components and Parts Description	Classification	Evaluation Note
Eyebolt	Non-safety	X
Cable Tray	Non-safety	X
End Cover	Non-safety	X
End Cap	Non-safety	X
Wire Basket	Non-safety	X
Cable trays	Non-safety	X
Outlet Filter	Non-safety	X
Partition Plate	Non-safety	X
Washer	Non-safety	Section 4.1
Wrap	Non-safety	Section 4.2
Label	Non-safety	Section 4.3

5. EVALUATION AND CLASSIFICATION OF SEISMIC CATEGORY Ⅰ MECHANICAL AND STRUCTURAL COMPONENTS FOR 1E DCS ELECTRICAL CABINETS

5.1. Identification of Design Basis

Functions to be performed by DCS systems shall be assigned to categories according to their importance to safety. The importance to safety of a function shall be identified by means of the consequences in the event of its failure when it is required to be performed and the consequences in the event of a spurious actuation [5].

The IE DCS cabinets' enclosures are structurally designed and analyzed to withstand normal operating conditions and seismic conditions. The seismic conditions are defined by the required response spectra (RRS) for the elevations specific to the locations of the enclosures in the plant. The RRS are provided by customer as design inputs [6].

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Generally speaking, the safety related DCS cabinets' enclosures are fabricated by sub-suppliers to industry approved codes and standards. These companies are recognized in the nuclear industry for providing such components and have a quality program that ensures adherence to the codes and standards to which they manufacture the components. The layout and design of the enclosures follow standard design practices embraced by the industry and comply with the design requirements stipulated by Nuclear power Plant engineering company (customer), the Nuclear Plant's Design Authority.

The structural components of the enclosure include the skin of the enclosure, the framing, the cross bracing, the mounting plates, internal mounting brackets, internal design elements such as cable trays, wire baskets, and fasteners and connectors. All the structural elements of the enclosure are included in the structural model. The weights of each and every component within the enclosure are reflected in the model in a conservative manner, so as to produce the most critical response. The model is analyzed using ANSYS. The seismic analysis qualifies the enclosures for OBE and SSE as delineated in the RRS. The enclosures are located in a mild and non-corrosive environment with low temperature, humidity and radiation. Therefore the material properties of structural steel and metallic components do not experience degradation over time that may result in a lower allowable strength. The design of all structural components is performed to code specified allowable for material strength and to elastic limits. This establishes a safety margin to the elastic limit which ensures that the deformations within the enclosure are small and will not impact the performance of the safety related control system components they support.

5.2. Performance Assurance

The structural components will include all structural and metallic parts that are used to attach and hold the safety related parts in place so they may perform their intended function during normal operations and post a beyond design basis accident. Further assurance can be provided by procuring the components from recognized supply chains that certify their products to industry recognized codes and standards and have verifiable quality programs which ensure adherence to quality.

5.3. Engineering Evaluation of Structural Components

This evaluation applies to mechanical and structural parts of the design of 1E Cabinets as shown on design drawings. The drawings are inputs to the seismic models analyzed to assess the performance of the components in their function to support the components. The DIN rails, structural steel supports, connectors and fasteners are mechanical/structural components that support the 1E safety related components in the 1E enclosures. They do not directly perform any safety related function. However they do need to hold the safety related 1E components in place so they may perform their safety function after a design basis accident. The structural fasteners, DIN rails and mounting plates are required to be designed to prevent their collapse under the safe shutdown earthquake. By virtue of their inherent design they should not have any credible failure modes that could contribute to the failure of the components performing safety functions.

The configuration and attachment of the structural components in the cabinet are seismically analyzed and designed with a safety margin to their corresponding elastic limit. This ensures that the component continues to perform after a beyond design basis accident event and that the failure mode is not catastrophic. The credible failure modes are established by the load paths. The vulnerability of any load path depends on the ability of the component to transfer the forces to the connectors and the ability of the connectors to transmit them to the anchors. Based on an engineering evaluation of the design and a review of the layout of the weights of components in the enclosure, it is evident that there are no load paths that are critically close

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to meeting or exceeding the allowable elastic strength limits of the components. Where over stress and flexibility were encountered in the analysis, the areas were reinforced to ensure that adequate margin to failure was provided.

5.4. Component Classification and Procurement Position

Based on the Engineering Evaluation above that identifies the technical issues associated with the parts in question and based on experience and sound engineering judgment, the mechanical and structural components identified in Tab.2 will be classified as safety-related, Seismic Category 1. Commensurate with their importance to safety, these components will be subject to the procurement and quality assurance documentation requirements described below.

Table 2. Typical Safety-Related Seismic Category 1 Structural Components (SC1)

Component Description	Qualification Method	Critical Characteristics
Captive Nut, M6	Analysis	Spec. Conformance
Torx screw, M6x16	Seismic Test	Spec. Conformance
Bolt, M6 x 12mm	Seismic Test	Spec. Conformance
Standoff	Seismic Test	Spec. Conformance
Cable Clamp	Seismic Test	Spec. Conformance
DIN Rail	Analysis	Spec. Conformance
Mounting Panel	Analysis	Spec. Conformance
System Chassis Bar Support Bracket	Analysis	Spec. Conformance
T-Handle with Lock	Analysis	Spec. Conformance
Adapter Bracket	Analysis	Spec. Conformance
M10 Nut	Analysis	Spec. Conformance

The components of Table 2 fall into two categories:

a. Structural fasteners whose strength and integrity are assumed in the seismic analysis

Table 3 provides a typical list of critical characteristics (component strength) considered in its analysis of the different styles of cabinets. These characteristics are essential to the qualification of the structural components [7]. The primary means of verification for these critical characteristics is assurance that the component is manufactured to the corresponding ASME or ASTM standard yield strength specified in the analysis [8]. Additional dedication testing or verification may be required commensurate with the complexity of the critical characteristics and the quality assurance program of the vendor.

b. Fasteners and supporting components that attach 1E components to structural assemblies

Fasteners, brackets, and other supporting components that attach safety related components to structural assemblies are not explicitly modeled by in its analysis. These components are selected during the design process by evaluating the results of component shake table tests and selection of fasteners and mounting components that meet or exceed the yield strength of the tested items. The corresponding manufacturer's catalog for the parts shall be used to identify the limiting strength characteristics for these parts and the applicable Industry Codes and Standards. The purchase order provides verification of the purchase of the specified fasteners with a certificate of conformance supported by a verifiable quality process that ensures adherence to the Industry Codes and Standards. Ancillary items such as spacers, clips and

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components added as part of Industry standard design practices shall be procured to conform to the Manufacturer's Catalog from known suppliers to the Industry.

Table 3. Typical Structural Characteristics Considered in Seismic Analysis Models (Will be Unique for Each Cabinet Type)

Component Description	Specification	ASME ASTM Equivalent Material or Specification	Min.Yield Stress in ksi, Fy	Min. Tensile Strength in ksi, Fu
ETA Screw	5.5×13 TORX Pan HD Tap Screw	SAE 1022	58.0(400 Mpa) (Min.Spec.)	69.6(480 Mpa) (Min. Spec.)
Bracket Screw	5.5×13 TORX Pan HD Tap Screw	SAE 1022	58.0(400 Mpa) (Min.Spec.)	69.6(480 Mpa) (Min. Spec.)
Bullet Fixing Screw	TORX T30	ASTM F568M-07 (Property Class 8.8)	92.8(640 Mpa) (Min.Spec.)	116.0(800 Mpa) (Min.Spec.)
Diagonal Stiffener Screw	M10 x 20 Soc HD Cap Screw	ASTM F568M-07 (Property Class 12.9)	159.5 (1100 MPa) (Min.Spec.)	174.0(1200 Mpa) (Min.Spec.)
Plinth Cover Screw	M6 x 12 TORX Flanged Button HD	SAE 1022 - zinc plated	58.0 (400 MPa) (Min.Spec.)	69.6 (480 MPa) (Min. Spec.)
ETA Rails	---	ASTM Al 008/Al 008M-10 (CRS, CS Type B)	23.6 (Min. Test) 20.0 (Min. Spec.)	44.4 (Min. Test)
Rear Panel	---	ASTM A1008 (Cold Rolled Steel - CS Type B)	20.0 (Min. Spec.)	55.5(Test)
Front Panel		ASTM A1008 (Cold Rolled Steel - CS Type B	20.0 (Min. Spec.)	55.5(Test)
Anchor Bolts	---	---	---	150.0 (Min. Spec.)
Punched Rail	---	(Assumed minimum values)	20.0 (140 Mpa) (Min.Spec.)	39.2 (270 Mpa)(Min.Spac.)

6. CONCLUSIONS

The safety classification of a part is based on its function and any specific licensing commitments and is independent of the quality assurance or quality controls that govern its manufacture, installation, maintenance or operation. Through the method route discussed in this paper was developed 'bridges' between codes and standards for NPP DCS components and parts safety classification.

7. DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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