# REVIEW OF SHORT-CIRCUIT ANALYSES

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## Purpose

This Plan Review Guideline (PRG) informs plan submitters about our process for reviewing submittals for compliance with the short-circuit analysis requirements of 46 CFR 111.52, and other regulations that require the results of this analysis.

## Contact Information

If you have any questions or comments concerning this document, please contact the Marine Safety Center (MSC) by e-mail or phone. Please refer to Procedure Number E2-19.

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## 1. Applicability

This Plan Review Guideline (PRG) is applicable to all vessels to which 46 CFR Subchapter J applies. Per 46 CFR 111.52-1, short-circuit current must be computed from the largest possible generator and motor loads. Note that for systems below 1500 kW, 46 CFR 111.52-3 allows for the use of certain simplifying assumptions. A short-circuit analysis is submitted in support of a one-line diagram; for guidance on these plans, see reference (a).

## 2. Background

At the instant of a fault, significant current levels occur from all operating ship's service generators. For a vessel electrical system with synchronous motors, a short circuit causes these motors to lose power and slow down. However, the mechanical inertia and stored energy of a synchronous motor will cause the motor to act as a generator, delivering fault current for many cycles. The same thing happens with induction motors, where the initial value of short circuit current is approximately equal to the locked-rotor current of the motor. After a short circuit occurs, AC fault current is asymmetrical during the first few cycles, and is at a maximum during the first of these cycles. It is this first cycle of generated mechanical force that electrical system components must withstand. Fault current calculations are necessary to properly select the type, interrupting rating, and tripping characteristics of power and lighting system circuit breakers and fuses. Results of the fault current calculations are also used to determine the required short-circuit ratings of power distribution system components, including bus transfer switches, variable speed drives, switchboards, and panelboards.

## 3. References

(a) MSC Plan Review Guideline E2-07, Electrical One-Line Diagram
(b) UL 489—Molded-Case Circuit Breaker, Molded-Case Switches, and Circuit Breakers, Ninth Edition (Revisions through and including March 22, 2000), October 31, 1996
(c) Naval Sea Systems Command (NAVSEA) Design Data Sheet DDS 300-2, "A.C. Fault Current Calculations," 1988
(d) IEC 61363-1, "Procedures for Calculation Short Circuit Currents in Three-Phase AC"
(e) MIL-HDBK-299 Military Handbook Cable Comparison Handbook, 2 April 1989
(f) Engineering Handbook-Engineering Data for Copper and Aluminum Conductor Electrical Cables, 2010

## 4. Review (Systems below 1500 kW)

The following items are needed to comply with 46 CFR 110.25-1 for all short-circuit analyses using the assumptions for systems below 1500 kW:

a. Sufficient information about components must be provided in the short-circuit analysis inputs and on the one-line diagram, as listed below. The information must be consistent between the short-circuit analysis and the one-line diagram. If all required information is provided on the one-line diagram, no manufacturer's information or specification sheets are needed. If component information is not provided, but manufacturer and model number are listed, then specification sheets may be provided in lieu of listing the information on the one-line diagram. Specification sheets alone, with no manufacturer's information on the one-line diagram, are not sufficient to demonstrate compliance.

(1) For generators, the power rating (in kW or hp), power factor, frequency, voltage, rated current, and number of phases.

(2) For motors, the power rating (in kW or hp), frequency, voltage, current, number of phases, and (for variable speed drives) short-circuit current rating.

(3) For busbars, the rating for their bracing (in kAIC).

(4) For bus transfer switches, their rating (in kAIC).

(5) For circuit breakers, the specification (UL 489 or IEC 60947-2), trip current, interrupting current (in kAIC), and number of poles. DC generator circuit breakers, and AC generator circuit breakers when three or more generators can be paralleled, should also have their instantaneous trip current listed.

b. The following equipment and systems must have interrupting capacities higher than any maximum asymmetrical fault current they could be exposed to:

(1) Switchboard and distribution panel bus bracing (IEEE 45-1998 section 7.10, via 46 CFR 111.30-19(a)(1));

(2) All circuit breakers and fuses, including for individual feeders (46 CFR 111.53(a)(2) and 46 CFR 111.54(a)(3));
*Note: Per NEC Article 240.83(C), all circuit breakers listed to reference (b) have interrupting capacities of at least 5 kAIC.*

(3) Bus transfer switches (IEEE 45-1998 section 7.10, via 46 CFR 111.30-19(a)(1)); and

(4) Variable speed drives (46 CFR 111.01-1(a)(2)) (short-circuit current rating below overcurrent protection kAIC).

c. For DC generators, or if three or more AC generators can be paralleled, the instantaneous trip for the generator circuit breakers must be set above, but as close as practicable to, ten times the current from a single generator (46 CFR 111.12-11(e)).

## 5. Review (Systems 1500 kW or Above)

For systems of 1500 kW or above, 46 CFR 111.52-5 requires that detailed calculations are performed to find short-circuit currents. This is typically done using specialized software, such as SKM, EASYPOWER, or ETAP, which automatically calculate the exact values based on a model generated from the system's components. Please note that as 46 CFR 111.52-3 allows detailed calculations as an alternative to assumptions, analyses using these software packages will be reviewed in accordance with this section even if the system is under 1500 kW. The following items will be reviewed for all short circuit analyses based on detailed calculations:

a. Asymmetrical currents must be calculated, not just symmetrical currents, mirroring the approach in 111.52-3(c) for systems below 1500 kW. Per 46 CFR 111.52-1(c), only three-phase faults need to be calculated. For ungrounded systems, three-phase faults will yield the highest fault currents, but note that for grounded systems, single line-to-ground faults may be higher.

b. Sufficient information about components must be provided in the short-circuit analysis inputs and on the one-line diagram to comply with 46 CFR 110.25-1, as listed below. The information must be consistent between the short-circuit analysis and the one-line diagram. If all required information is provided on the one-line diagram, no manufacturer's information or specification sheets are needed. If component information is not provided, but manufacturer and model number are listed, then specification sheets may be provided in lieu of listing the information on the one-line diagram. Specification sheets by themselves, with no manufacturer's information and incomplete component information on the one-line diagram, are not sufficient to demonstrate compliance.

(1) For generators, the power rating (in kW or hp), power factor, frequency, voltage, rated current, per-unit subtransient reactance (written as a percentage, usually as "X"d," and can be obtained from the generator datasheet) and number of phases.

(2) For motors, the power rating (in kW or hp), frequency, voltage, current, number of phases, and (for variable speed drives) short-circuit current rating.

(3) For busbars, the rating for their bracing (in kAIC).

(4) For bus transfer switches, their rating (in kAIC).

(5) For transformers, the power rating (in kVA), voltage, rated current, frequency, number of phases, per-unit impedance, and power factor.

(6) For circuit breakers, the specification (UL 489 or IEC 60947-2), trip current, interrupting current (in kAIC), and number of poles. DC generator circuit breakers, and AC generator circuit breakers when three or more generators can be paralleled, should also have their instantaneous trip current listed.

(7) For cables, their size, type, length, and impedance. Note that cable lengths do not need to be listed on the one-line diagram. Impedance also does not need to be listed on the one-line diagram, as it will be constant between manufacturers for a given type and size.

c. If the cables used are not of a type that can be selected in the software package used, cable datasheets, if available, can be used for the reactance and resistance values (references (e) and (f) can be used if datasheets are not available), using the following steps. Here cable impedance is Z=R+jX, where R=resistance, X=reactance:

(1) Reactance: Reactance range changes very little with cable sizes, use the cable datasheet (or MIL-HDBK-299 reference (e), Table XXVII on page 141 to find a comparable cable size for reactance at 60 Hz).

(2) Resistance: Use the cable datasheet (or reference (f), Table 1-3 for stranded copper, Table 1-4 for temperature correction, and Table 1-5 AC/DC ratio).

(3) Multiply (Resistance in ohms/1000 ft)(Temp Correction)(AC/DC Ratio). The software may represent the input data in ohms/1000 ft before the distance consideration, but the final calculation shown may be in Per Unit. Note: The insulation type and the temperature used must match the cable library.

d. The following equipment and systems must have interrupting capacities higher than any maximum asymmetrical fault current they could be exposed to. Note that circuit breakers that meet UL 489 must have an interrupting current rating of at least 5 kAIC, so if the fault currents are below 5 kAIC, UL 489 circuit breakers are assumed to be compliant.

(1) Switchboard and distribution panel bus bracing (IEEE 45-1998 section 7.10, via 46 CFR 111.30-19(a)(1));

(2) All circuit breakers and fuses, including for individual feeders (46 CFR 111.53(a)(2) and 46 CFR 111.54(a)(3));
*Note: Per NEC Article 240.83(C), all circuit breakers listed to reference (b) have interrupting capacities of at least 5 kAIC.*

(3) Bus transfer switches (IEEE 45-1998 section 7.10, via 46 CFR 111.30-19(a)(1)); and

(4) Variable speed drives (46 CFR 111.01-1(a)(2)) (short-circuit current rating below overcurrent protection kAIC).

e. The fault current calculations must be performed for faults on the load side terminals of each distribution system protection device, not at the loads themselves, where it will be significantly lower (46 CFR 111.52-1(c)).

f. For offshore installations or large industrial loads, the short circuit analysis will be incomplete if it does not include analysis of the low voltage distribution systems that powers vital equipment. For example, if the main switchboard is 6.9kV, then low voltage systems (e.g. 480V or 208/120V) cannot be assumed to be compliant if the high voltage arrangements are compliant, as short circuits are higher when the voltage is stepped down. Additionally, if the installation has any high voltage DC systems, they must also be included in the report.

g. For DC generators, or if three or more AC generators can be paralleled, the instantaneous trip for the generator circuit breaker must be set above, but as close as practicable to, the maximum asymmetrical short circuit current available from a single generator (46 CFR 111.12-11(e)).

## 6. Other Review Methods (Systems 1500 kW or Above)

The method described in section 5 is for compliance with 46 CFR 111.52-5(d), which is by far the most common method chosen by submitters for systems of this size. If a submitter elects to perform short-circuit analysis in accordance with 46 CFR 111.52-5(a), (b), or (c), the submission must meet the following criteria:

a. Sufficient information about components must be provided, as discussed in section 5b.

b. Equipment and systems have interrupting capacities higher than any fault current they could be exposed to, as discussed in section 5d.

c. The guidance in 5c, 5e, 5f, and 5g also applies.

d. Calculations must be performed as follows:

(1) For submissions complying with 46 CFR 111.52-5(a), using Ohm's Law to solve for the current across each load in listed in section 5c.

(2) For submissions complying with 46 CFR 111.52-5(b), reference (c).

(3) For submissions complying with 46 CFR 111.52-5(c), reference (d).

## 7. Disclaimer

This guidance is not a substitute for applicable legal requirements, nor is it itself a rule. It is not intended to nor does it impose legally-binding requirements on any party. It represents the Coast Guard's current thinking on this topic and may assist industry, mariners, the general public, and the Coast Guard, as well as other federal and state regulators, in applying statutory and regulatory requirements. You can use an alternative approach for complying with these requirements if the approach satisfies the requirements of the applicable statutes and regulations. If you want to discuss an alternative, you may contact MSC, the unit responsible for implementing this guidance.