Risk analysis and mandatory marking for machines and industrial control panels

Protection against arc flash hazards for the US market

Arc flash incidents and their consequences are major causes of injuries in the electrical industry. An arc flash is an ionized cloud of highly energized plasma composed of heated gas and melted conductors or small particles. Unprotected and unprepared persons who are exposed to an arc flash may suffer life-threatening injuries. These are mainly caused by the intense pressure wave, extreme temperatures, hazardous radiation and toxic gases that are released when metals melt or evaporate. By maintaining appropriate safety distances and wearing appropriate personal protective equipment (PPE), the risks due to these hazards can be significantly reduced.

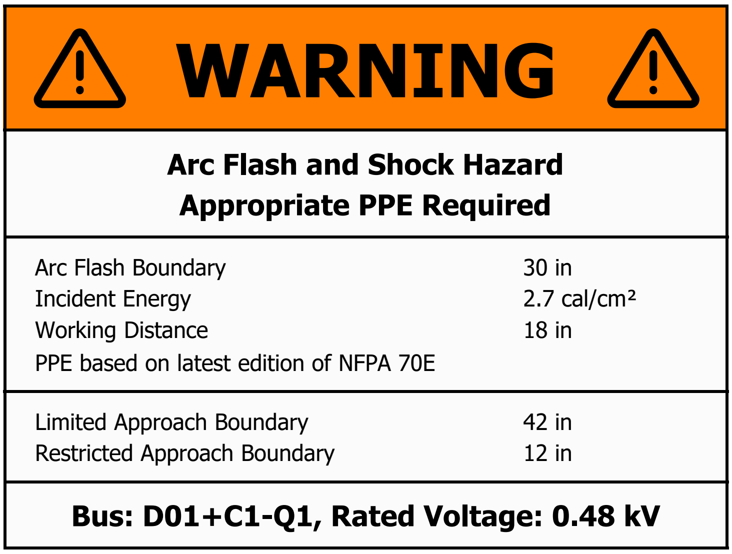

Fig. 1: Example of an arc flash warning label

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Standards relating to the protection of employees in the USA

The topic of »arc flash hazards« plays an important role in the USA. Protection against arc flashes (warning signs, minimum distances and PPE) and the associated required measures are therefore covered by the relevant standards, in particular in the National Electric Code (NEC), NFPA 79 [1] and NFPA 70E [2].

The best protection against an arc flash hazard is to work on a de-energized system.

But for troubleshooting, maintenance or testing purposes, sometimes a it is unavoidable that work must be carried out on live parts. For this reason, the NEC in the USA stipulates in Section 110.16 [3] that, at the very least, a warning must be given about the dangers of a potential arc flash.

The NEC requires that a warning label must be fixed on the enclosure doors of electrical equipment to warn persons who have to work on or close to energized equipment that death or serious injury may result from an arc flash and that suitable protective clothing must be worn. However, these warning labels do not ensure safe work on energized equipment if the necessary protective measures are not determined in more detail.

Marking of industrial control panels

Protection of every employee against arc flash incident energy must be ensured by the employer as stipulated by US legislation. Generally speaking, the NEC allows field marking or factory marking. However, the responsibility for calculating, evaluating and marking is increasingly being delegated to suppliers of control panels and machines so they need to bear an appropriate label when they are shipped.

Fig. 1 shows an example of a typical warning label. Among other things, it shows the type of hazard and the corresponding action to be taken as well as some important indicators for the risk classification.

Information concerning the required protective equipment is set out in the NFPA 70E standard. However, as this regulation is updated on a regular basis and labels have to be continuously modified, the warning label often only makes ref-

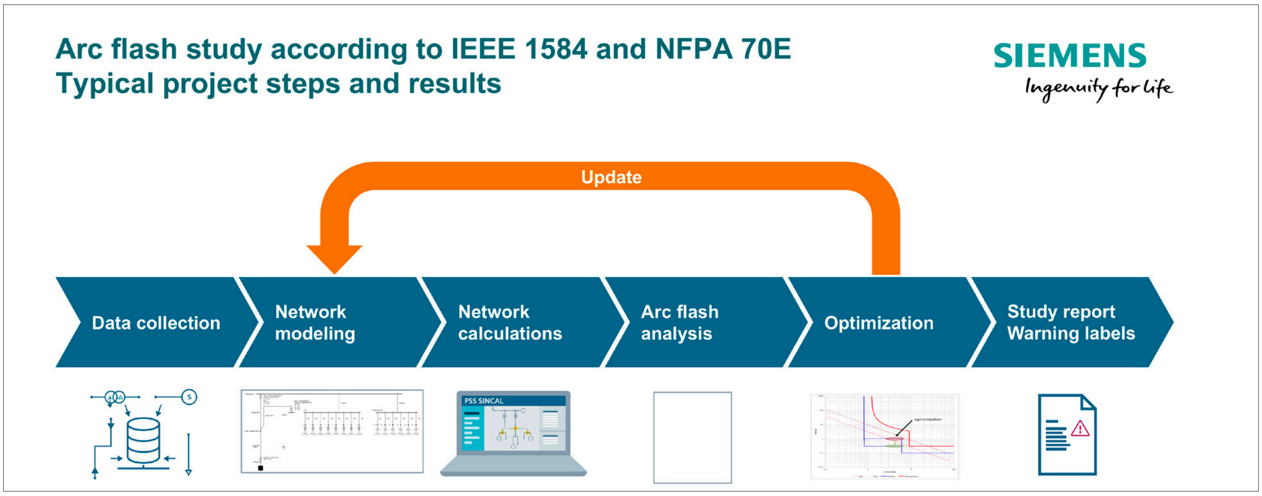

Fig. 2 – Steps in the arc flash assessment process

erence to NFPA 70 (PPE based on latest edition of NFPA 70E).

In addition to NFPA 70E, IEEE Std. 1584 [4] is a further important standard in the USA. It includes a method of calculating arc flash incident energy, which is of major importance for risk classification. The standard was completely revised in 2018, and the new method is significantly more complex than its predecessor. Special simulation software is now necessary for the calculation.

Arc flash incident energy, the required PPE and the necessary safety distances can vary considerably. The relevant information for the warning label is therefore determined in an arc flash study.

Steps in an arc flash study

Fig. 2 shows typical components of an arc flash analysis. They are based on the guide described in the IEEE 1584 standard:

- Step 1: Collect all system and installation data
- Step 2: Determine the system modes of operation
- Step 3: Determine the bolted short-circuit current
- Step 4: Determine the bus gap as well as the enclosure size in relation to system voltage
- Step 5: Determine the dominant conductor configuration
- Step 6: Determine the working distances
- Step 7: Determine the arcing current
- Step 8: Determine the arc duration
- Step 9: Calculate the incident energy [cal/cm²]
- Step 10: Determine the arc flash-protection boundaries for all equipment

Collecting the information needed to conduct the study requires significant efforts. Much of this data is often unknown to manufacturers and suppliers of industrial control panels and mechanical equipment. In this case, they need to ask the system operator for this information or make appropriate assumptions.

The next step is to create a digital model of the electrical system that includes the short-circuit conditions and protection concept as well as the electrical data relating to the plant and equipment. The arc flash calculation according to IEEE 1584 can then be carried out using suitable simulation software such as PSS®SINCAL. This calculation delivers all important characteristic key values for the hazard assessment. These include, in particular, the incident energy required for selecting the PPE and the arc flash boundary, which determines the distance within which PPE must be worn.

In many cases, there is a wish to further reduce the arc flash risk by means of optimization measures in various places. In some cases, specifications demand compliance with an upper limit for incident energy, e.g. 8 cal/cm². One possible measure the manufacturer can take in such cases is to adapt the panel design, for example by appropriate positioning and alignment of the components. Furthermore, suitable protective equipment and its parameter set can shorten the duration of a fault. This not only reduces the risk of an arc flash but also makes working conditions for operating staff considerably easier, for example if a lower category of PPE

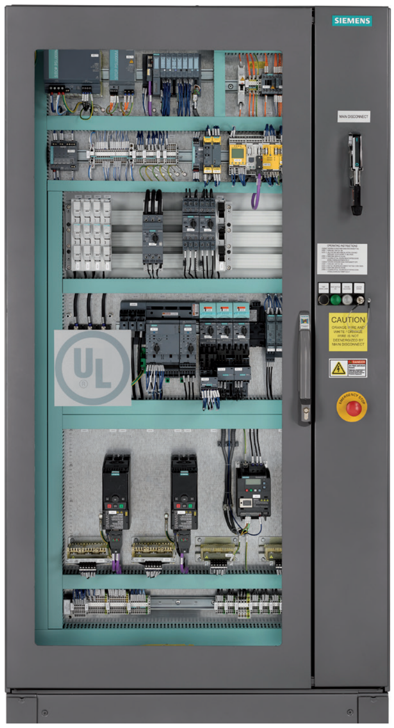

Fig. 3 – Industrial control panel

is sufficient. The calculations are then repeated with adjusted values until the ideal solution is found. Finally, a detailed report is created and the labels are produced.

Assessing extreme scenarios in the event of insufficient data

In an arc flash calculation for electrical equipment like industrial control panels (*Fig. 3*) according to IEEE 1584-2018 and NFPA 70E-2018, two scenarios were evaluated on the basis of the operator possessing insufficient data: minimum and maximum short-circuit current conditions. A model was created for the calculations in PSS®SINCAL based on the layout, circuit diagram and protection concept.

For scenario 1 (minimum short-circuit current conditions), a short-circuit power of 4.2 MVA with a maximum short-circuit current of 5 kA was assumed, and no contributions from motor loads. In this case, the calculated arc flash incident energy was less than 1.2 cal/cm². According to the limit values specified in NFPA 70E-2018, no personal protective equipment is required in this case with regard to arc flash.

In the calculations for scenario 2 (maximum short-circuit current conditions), a short-circuit power of 54.0 MVA with a maximum short-circuit current of 65 kA and a motor contribution of 52 kW were considered. The calculations showed that under maximum short-circuit current conditions, the PPE must provide protection against both electric shock and arc flashes. Appropriate protective equipment must be selected according to the current version of NFPA 70E. The specific warning label for scenario 2 is depicted in *Fig. 1*.

Optimization measures for reducing risk

In a further example, a section (typical) of a 4.16 kV industrial network with a medium-voltage(MV) board, two transformer feeders as well as two low-voltage (LV) boards was considered. Plant design and working environment were already determined but parameterization of the DMT protection devices was yet to be optimized. *Fig. 4* shows the results of calculations for a variety of selected tripping currents (Board 1: 27 kA, Board 2: 25 kA). According to the calculation method, the first step is to determine the arc flash current, the incident energy and the hazard limit. Then, in a second step, the arc flash current is reduced and the other characteristic key values are recalculated. In our example, the arc flash current is approx. 28.6 kA or 2514 kA following application of the reduction factor. Due to the tripping limits, this leads to a fault duration of 350 ms (LV board 1) or 90 ms (LV board 2). With regard to LV board 1 this results in a higher incident energy and hazard limit while the arc flash current is reduced.

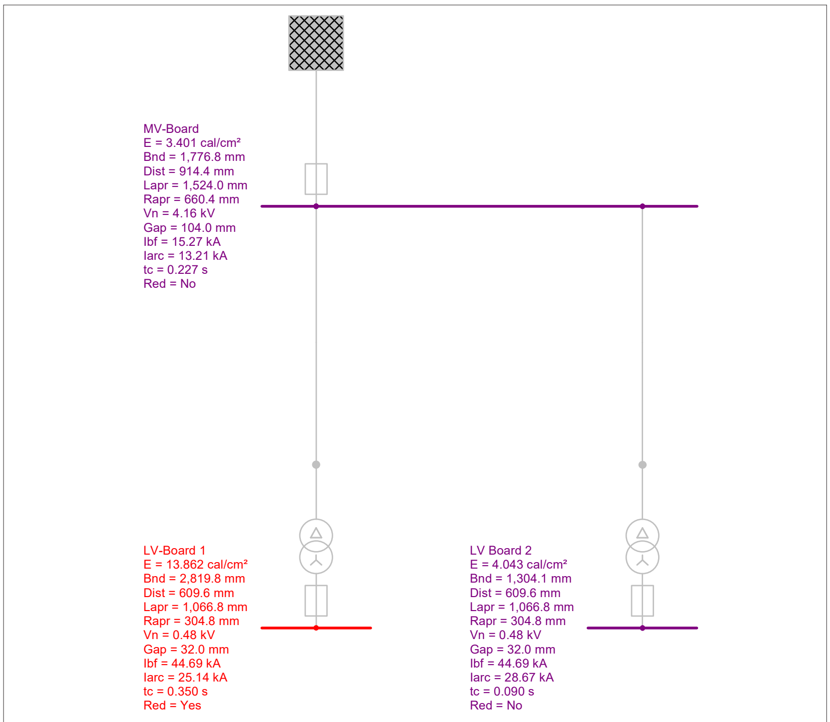

Fig. 4: Example of the results of calculations for different tripping currents as a basis for optimization.

Summary

The US market demands mandatory marking for control panels to warn of arc flash hazards and thus prevent ensuing accidents. Customers frequently demand that arc flash warning labels are already attached to equipment upon shipment. An arc flash assessment in accordance with the standards applicable to the US market can help manufacturers determine the required characteristic key values and produce appropriate warning labels for the equipment. Furthermore, optimization of the layout or selection of the components to be used can reduce the risk of arc flashes thus achieving a lower risk category and improving working conditions for service technicians.

Sources

[1] NFPA 79-2018: Electrical Standard for Industrial Machinery.
[2] NFPA 70E-2018: Standard for the Electrical Safety in the Workplace.
[3] NEC (National Electric Code) Article 110.16: Arc-Flash Hazard Warning.
[4] IEEE Std 1584-2018: Guide for Performing Arc-Flash Hazard Calculations.

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