Arc Flash Hazard Calculations in DC systems

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ARC FLASH HAZARD CALCULATIONS IN DC SYSTEMS

IEEE 1584 standard does not discuss arc flash hazard calculations in the DC systems. Standard NFPA-70E- 2000 provides a short calculation method. Therefore, the current literature is lacking calculations of arc flash hazard in DC systems. The necessary calculation steps are very similar to calculations in AC systems, however there are marked differences, particularly with respect to protection, cause of short - circuit currents in the DC electrical systems, and the current interruption devices in DC systems, which function fast to limit the energy let - through. Arc flash hazard calculation process in DC systems can be summarized as follows:

- Calculate the short-circuit currents in the DC systems. Fault currents in DC systems rise at a certain rate, depending upon the DC source.
- Calculate the arcing resistance and the arcing currents.
- Adjust the time–current characteristics of the protective equipment for increasing DC currents.
- Calculate the arc flash arcing time.
- Calculate the arc flash incident energy.

SHORT -CIRCUIT CURRENTS CALCULATIONS IN DC SYSTEMS

The short - circuit currents calculations in DC systems is vital for the design of distribution and protective devices used in DC systems and for arc flash assessment. The DC systems include DC motors, drives, controllers, battery power applications, emergency power supply systems, data - processing equipment, and computer DC power systems and transit systems. Maximum short - circuit currents have to be taken into account when choosing the rating of the electrical devices, like cables, buses, and associated equipment. The high - speed DC protective equipment may break the current before the peak is reached. It is mandatory to consider the current rate of rise and interruption time, in order to find the maximum current that will be actually obtained. Lower - speed DC protective elements may allow the peak to be reached before breaking current. For arc flash assessment, the operation of the protective elements needs to be calculated for the arcing currents.

Even though the simplified methodologies for DC short - circuit current calculation are presented in some documents, calculation procedures are not that transparent. Unfortunately, there is no ANSI/IEEE standard for calculation of short - circuit currents in DC installations. ANSI/IEEE C37.14 standard gives some guidelines. IEC standard 61660-1 is the only detailed document available on the subject. This standard discusses short - circuit currents calculations in DC auxiliary systems in power plants and substations, and does not present calculations in other big DC power systems, such as electrical railway traction and transit installations. The IEC standard discusses quasi-steady-state techniques for DC systems. The time change of the characteristics of major sources of DC short-circuit current from initiation to steady - state are presented, and adequate estimation curves and rules are presented. A dynamic simulation is a possibility, nevertheless, akin to short-circuit current computations in AC systems; the simplified methodologies are easy to use. However, these need to be checked by an actual simulation. Even though some documentation and examples of short - circuit currents in DC systems according to ANSI/IEEE documents are available, this course will use IEC equations and procedures because of the comprehensive nature of the IEC methodology. It is suggested that student gets a copy of IEC standard for complete appreciation of IEC methodology.

DC SHORT -CIRCUIT CURRENT SOURCES

Four types of DC sources have to be considered:

- Lead acid batteries
- DC motors
- Converters in three-phase bridge arrangement
- Smoothing capacitors

Figure 1 presents the normal short- circuit current time profiles of these sources, and Figure 2 presents the standard function used in the IEC standard. The following permissions are applicable:

I_k - quasi steady-state short-circuit current

i_p - peak short-circuit current

T_k - short-circuit duration

t_p - time to peak

τ_1 - rise time constant

τ_2 - decay time constant

The approximate function is expressed as:

$$i_1(t) = i_p \frac{1-e^{-\frac{t}{\tau_1}}}{1-e^{-\frac{t_p}{\tau_1}}} \tag{1}$$

$$i_2(t) = i_p\left[(1-\alpha)e^{-(t-t_p)\tau_2} + \alpha\right] \quad (t \geq t_p) \tag{2}$$

$$\alpha = \frac{I_k}{i_p} \tag{3}$$

The quasi steady-state current I_k is assumed as the value at 1 second after the short – circuit start. If no certain maximum is present, as presented in Figure 1(a) for the converter current, then the value is determined only with Equation (1).

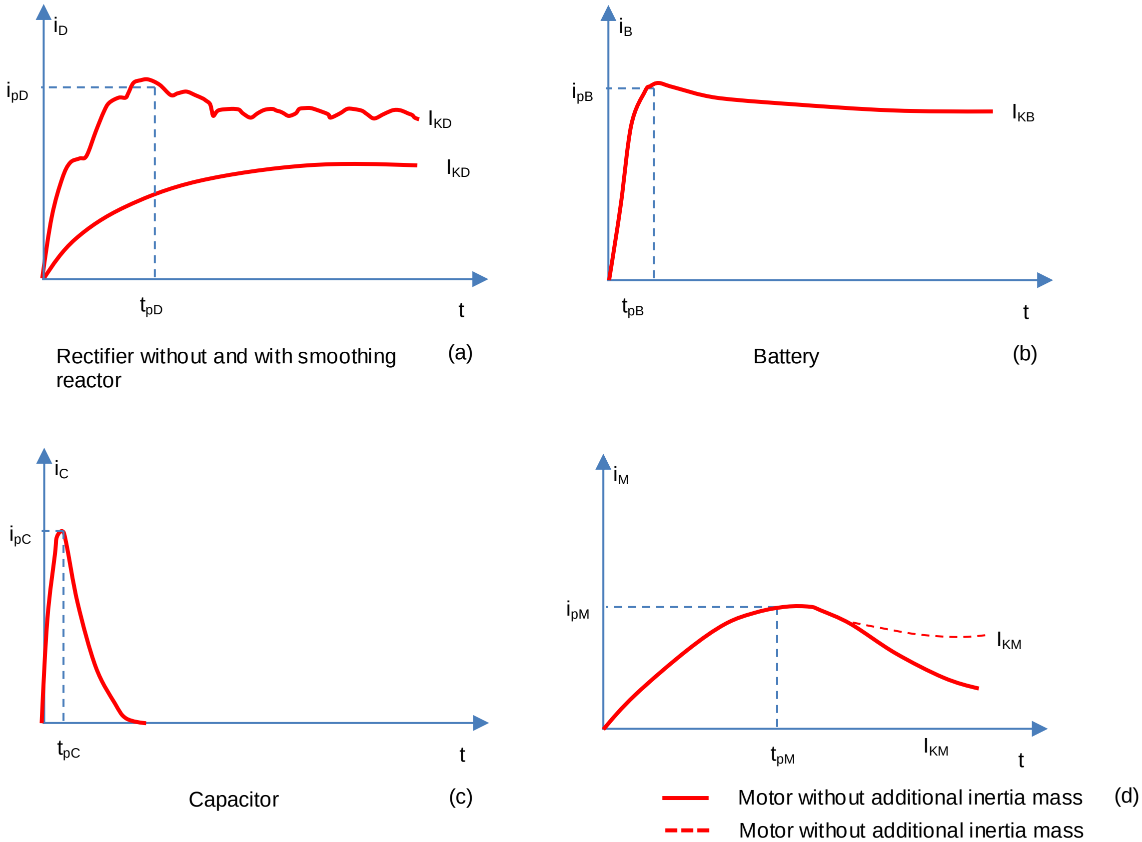

Figure 1. Short circuit profile of different DC sources: (a) rectifier with and without smoothing reactor, (b) Lead acid battery, (c) capacitor, and (d) DC motor with and without initial inertia mass.

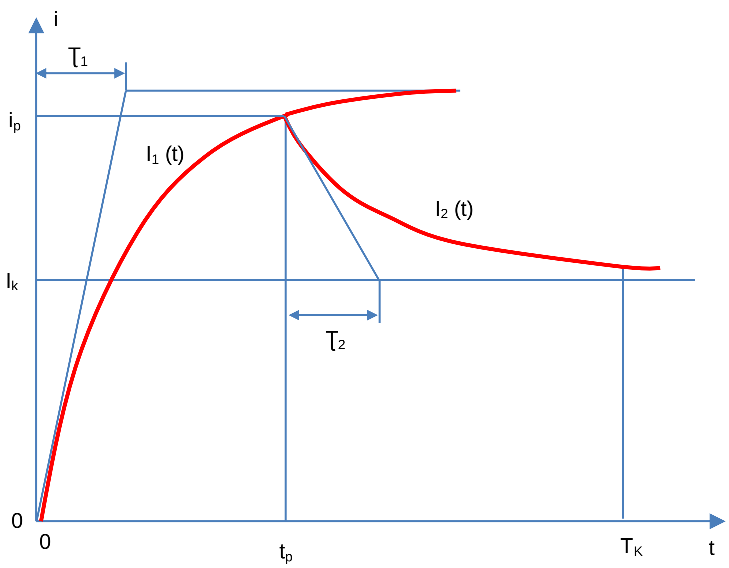

Figure 2. Standard short circuit function curve

IEC CALCULATION TECHNIQUES

Figure 3 presents a DC distribution system that has all four DC short - circuit currents. Two short-circuit positions are presented:

(1) F_1, without a common branch,

(2) F_2, through resistance and inductance, R_y and Ly of the common branch.

The short - circuit current at location F_1 is the short - circuit current summation of the four sources, as if these were acting alone through the series resistances and inductances. For short-circuit current computation at F_2, the short-circuit currents are calculated same as for F_1, but including R_y and L_y to the series circuit in each of the sources. Correction factors are applied, and the different time functions are added to the overall current time function. Whether it is the maximum or minimum short - circuit current calculation, the loads are neglected and the fault impedance is considered to be zero. For the peak short-circuit current, the following conditions can be applied:

- The conductor resistance is expressed at 20°C.
- The contact resistance is neglected