Application of the Box-Test Method according to IEC 61482-1-2 - Experiences and Advantages

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***Abstract*—20 years ago, the first standard draft of the box test method for personal protective equipment (PPE) against the thermal hazards of a fault arc was published. Since 2007, when becoming the international standard IEC 61482-1-2, the method has been increasingly used in practice. It has proved its worth, as the accident figures and statistics clearly show. In Germany, the number of serious personal injuries has fallen drastically and is now at a very low level of just a few individual cases per year. Serious burns have generally been avoided when PPE is worn. The box test was developed to provide a test method which, in contrast to the open-arc test method already existing at this time, is primarily tailored to low-voltage applications with small-scale, enclosed systems. The method requires also less testing effort and is therefore more cost-effective. Comparative tests on textiles and clothing samples in different lab institutes have demonstrated the very good repeatability and reproducibility of the method. In recent years, user guides such as DGUV-I 203-077 have been developed for selecting PPE based on the arc protection class APC of the box test. These tools provide selection algorithms for AC and DC systems and also include risk assessments. In risk assessment and selection of PPE, the advantage is utilized that the thermal incident energy is not used as the risk parameter (as e.g. in IEEE 1584), but rather the electrical arc energy, which is easier and mor exact to determine. The box test is now anchored as equal-priority PPE test option in the international product standards for protective clothing and face protection devices as well as in the drafts for protective gloves. Nevertheless, there is partly still uncertainty among users due to a lack of knowledge or accurate information. Open questions even exist among safety experts. In addition, there is no comparability between the box test and the open arc test. In the paper therefore the main features of the box test method, its background and justification are outlined. The pros and cons of the procedure are described. The paper reports on many years of experience in the testing and selection of PPE. It also refers to research work on which the procedures are based and which has been used to improve the method. The paper is aimed to help increase user understanding and safety.**

Keywords—arc flash, personal protective equipment, PPE testing, box test, arc protection class, risk assessment

I. Introduction

The protective effect of personal protective equipment (PPE) against the thermal hazards of an electric arc (hereinafter referred to as PPE against arc flash or briefly PPEaA) must be proven or certified. This requires a standardized test for arc flash resistance and heat transfer. In Europe, PPEaA must fulfil the basic requirements of EU PPE Regulation 2016/425 Section II [1]. The international product standards for PPEaA (e.g. IEC 61482-2 for protective clothing [2]) provide two test methods of equal priority with regard to the verification of arc protection properties, which can be used optionally. These are the open arc test in accordance with IEC 61482-1-1 [3] and the box test in accordance with IEC 61482-1-2 [4]. Although the box test is verifiably reproducible and has proven itself very well in practice, the test and its advantages are not yet sufficiently known by potential users. In addition to a lack of knowledge, there are also uncertainties regarding the differences to the open-arc test, the areas of application, applicability and suitability. Incorrect assessments are also occasionally found in publications. In the technical literature, there is generally an extreme preponderance of publications on the open-arc test and the procedures for hazard analysis, risk assessment and PPEaA selection based on it. In the following, therefore, the fundamental differences between the two methods, the special features and the advantages of the box test will be outlined. The characteristics of risk assessments and selection procedures for PPEaA that were tested in the box test will then be discussed. These assessments are not new. However, they are intended to provide users with a better understanding.

II. Different Perspectives of Arc Flash Protection

A. General Approaches

PPEaA that fulfils current international standards is specified either for its arc rating or its arc protection class, which is related to two fundamentally different procedures and approaches. The risk analyses methods for arc flash assessment and the PPEaA selection are carried out

- on the one hand by means of the thermal incident energy and on the basis of PPEaA testing in the open arc test in accordance with IEC 61482-1-1 or
- on the other side by means of the electrical arc energy and on the basis of PPEaA testing in the box test in accordance with IEC 61482-1-2.

Risk assessment and PPEaA selection are therefore directly linked to the test procedure. The result of the open arc test is the arc rating of the PPEaA, which is characterized by the arc thermal performance value (ATPV), arc breakopen threshold energy (EBT) or incident energy limit (ELIM). The arc protection class (APC) as a result of the box test is characterized by the value of the set electrical arc energy test level.

B. Different Methods of PPEaA Testing and Selection

Historically, considerations on risk assessment and PPEaA selection were first made in North America and incorporated into national standards such as IEEE 1584 [5] and NFPA 70E [6]. These refer to arc rating parameters that are assigned to the PPEaA as a result of an open arc test in accordance with IEC 61482-1-1. In the risk assessments, the required arc rating (usually ATPV) is determined as the prospective incident energy, which can be obtained from empirical equations for the workplace under study (e.g. from IEEE 1584 for various exposure scenarios in the AC range). The open-arc test [3] is based on an open test arc that is fed in a test circuit by a source of several kV and an exposure scenario that is typical for open, air-insulated medium-voltage systems. On the basis of such testing and considerations based on it, however, PPEaA are also and above all selected for use in LV installations, which is practically the main area of application. This testing and selection procedure is nevertheless used worldwide today and is generally accepted, partly because the alternatives are not known or are not known in sufficient detail.

Starting just over 20 years ago, there were alternative considerations in Europe that were more focused on applications for PPEaA which are predominantly located in the low-voltage range (work on enclosed switchgear and distribution systems). In this context, initially the box test was developed as the international test standard IEC 61482-1-2 (first edition 2007) and has been stepwise improved. The box test proves that the PSAaA meets the requirements of defined arc protection classes APC. The required APC is determined by the prospective electrical arc energy, which is calculated as the protection level of the PPEaA (in kJ) at the workplace under study and can be determined using guidelines. The basis for this can be found in the literature [7] and is confirmed by extensive research [8, 9]. The box test is carried out in a 400 V test circuit with directed arc exposure to the PPEaA sample [4], which is typical for the exposure conditions in low-voltage distribution systems. The test is good reproducible [12] and simpler than the open-arc test. In addition to the test standard, there are now also guidelines and user tools for the risk assessment and PPEaA selection, which are based on the arc protection class such as DGUV-I 203-077 [10] and ISSA guide [13]. In DGUV-I 203-077, procedures are described for both AC and DC systems [10]. In addition to the calculations, the PPEaA selection process can be extended by risk assessments in order to find protective solutions by defining additional measures (technical, organizational, etc.) [11].

The IEC product standards [2,14] and drafts for PPEaA application (IEC TR 63375 [15] and IEC TR63491 [16]) give equal priority to the two basic test methods as options for the verification of arc protection properties. The procedures and results of both tests are not comparable. It is not possible to specify generally valid equivalents or make conversions.

C. *Fundamental Differences in the Test Methods and Transferability of the Test Results*

The two approaches to arc flash protection differ fundamentally in terms of the setup, procedure and result of the tests and the various hazard parameters (incident energy or electrical arc energy) for the risk assessment and PPEaA selection. The test results and hazard parameters cannot be converted into each other. This has a number of reasons.

The test arc forms and has a completely different effect in the two test methods. In the long, open arc of the open-arc test with an all-round effect, the radiation component dominates. In the small-scale arrangement of the box test, in addition to the radiation, the heat transfer results in an intensive convective heat component due to a directed gas and plasma flow ('gas lobe'). Even if the resulting thermal incident energies in both methods have the physically equivalent unit of measurement (cal/cm^2 or kWs/m^2), they cannot be converted into each other. The same direct incident energy is generated by very different electrical arc energies due to the very different heat transfer ratios in the two test methods. The correlating levels of the electrical arc energy are not determined in the open arc test and the risk assessment procedures based on it, and are therefore not known. Furthermore, in the open arc test, the result parameters ATPV or ELIM are determined in a test series by varying the test duration (at least 7 individual tests) and a complicated logistical evaluation as the incident energy limit for the onset of 2nd degree skin burns. In the box test, on the other hand, the arc protection class is characterized by the electrical arc energy, which is set as a fixed test energy. It therefore corresponds to the minimum energy level at which the PPEaA provides protection. The box test therefore does not test the energy limit up to which the PPEaA provides protection, but only whether protection is guaranteed at the set energy level. The actual protective range of the PPEaA is therefore usually greater; the energy limit can also be higher if the working distance when using PPEaA is greater than the box test distance of 300 mm or if the volume of the installation at the fault location is greater than the small-scale box of the test setup. This is another reason why there can be no universally valid correspondence between the arc rating (ATPV) and the arc protection class (APC) of the box test.

The Open Arc Test does not determine or consider any values for electrical arc energy. Even the empirical equations specified in the standards for risk assessment (e.g. IEEE 1584 for AC systems) do not allow to calculate the electrical arc energy. Therefore, no correlations can be found. The main problem, however, is that there is no generally valid function or approximation for the relationship between incident energy and electrical arc energy. As can be seen from comparative measurements, the calculation equations given in the literature (e.g. in [17]) have proved to be not very suitable or very limited in their areas of validity. This applies to the direct incident energies and even more so to the transmitted energies with the additional influence of different materials and products of PPEaA. The lack of comparability and transferability of the test results makes comparative observations on the selection of PPEaA difficult and rules out generalizations. Even comparative theoretical analyses and calculations are only imaginable for individual cases. Generalized comparisons are particularly problematic if they use questionable approaches for converting electrical arc energy into resulting incident energy (e.g. in [18]).

D. *Incident Energy vs. Electrical Arc Energy*

The two perspectives are based on different hazard parameters. The thermal incident energy is the density of thermal energy that impacts on a surface (measured in kJ/m^2). The electrical arc energy (in kJ), on the other hand, corresponds to the electrical active power converted in the arc during the arc duration, which is almost completely transformed into heat.

Arc fault processes are stochastic in nature. The relationships between characteristic values are non-linear and are determined by a large number of influencing variables. The thermal incident energy depends in a very complex way on the electrical arc energy and many factors of heat transfer. In addition to the exposure distance, these influences include the ambient conditions, the distance, the orientation, the material and the shape of the electrodes. With regard to the effect of PPEaA, the material and heat exposure conditions also play a role. The electrical arc energy is determined by arc voltage, arc current and arc duration and is therefore essentially dependent on the system voltage, the prospective short-circuit current, the electrode gap and the clearing time. For physical and practical reasons, it therefore seems appropriate to consider the expected value of the electrical arc energy as a hazard parameter (rather than incident energy), since the heat transfer during arc exposure depends on the many additional, complicated influences and cannot be described by generally valid transfer functions. The electrical arc energy can be predicted with better accuracy from models and also shows less statistical variance in practice [12].

E. Accident Statistics

The box test and selection of PPEaA based on the arc protection class APC are not only used in Europe and have proven their worth. The availability and use of suitable and appropriately tested PPEaA has had a significant impact on accident figures, as can be seen from the statistics on accidents at work. In Germany, both the number of reportable electrical accidents and the number of fatalities caused by electricity when working on electrical installations have fallen significantly [19]. Reportable accidents occur when a sick leave or absence of more than 3 days is required. As can be seen in Fig. 1, the number of fatal accidents at work in the electrical sector (German Social Accident Insurance) has been declining since the early 2000s and is now at a relatively low level. The share of arcing accidents and arc-flash-related burns in the total number of electrical accidents has also fallen steadily, in the low-voltage range from around 25 % to about 10 % today. Reportable electrical accidents at work have generally dropped to a low level in recent years, as can be seen from the figures in Table 1. At the beginning of the millennium, there were still around 1000 accidents per year. These developments are due to constantly improving prevention work, but also to the better protection of workers through PPE, which has prevented the most serious burns in particular.

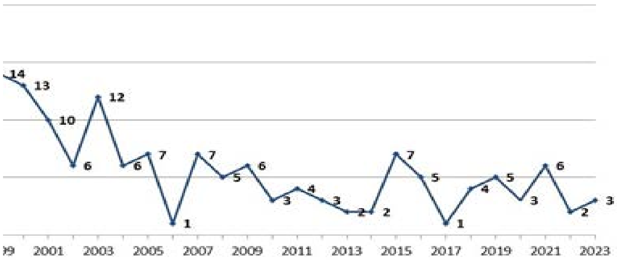

Fig. 1. Annual number of fatal electrical accidents in the electrical work sector since 2000 (source [19])

TABLE I. REPORTABLE ELECTRICAL ACCIDENTS WHEN WORKING IN THE ELECTRICAL INDUSTRY (SOURCE [19])

year	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***
accidents	793	802	773	682	737	655
fatal accidents	3	2	2	7	5	1
year	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***
accidents	636	706	605	548	515	563
fatal accidents	4	5	3	6	2	3

III. BASICS AND PROS OF THE BOX TEST METHOD

A. Application Fields and Test Principle

The box test was initially developed as an international test standard for protective clothing (materials and products). As a result of adaptations, which mainly concern modifications to the test specimen holders, it is now also used for arc testing of eye and face protection equipment (IEC 62819 [14]) and protective gloves (draft IEC 63232-1-2 [20]). Recent research results also confirm that PPEaA intended for use in low-voltage DC systems can also be tested in this AC test. Being similar in all those tests, in the basic test method standardized in IEC 61482-1-2 the PPEaA samples are exposed by a directed test arc with calorimetric measurement of the incident energy through the PPEaA. The sample is placed in a distance of 300 mm to the arc.

B. Test Set-up

The test arc is fired between two opposing electrodes made of aluminum and copper, and surrounded by a small-scale box. The electrode gap is 30 mm. The circuit no-load voltage is 400 V, 50 Hz. There is a directed heat transfer by radiation as well as convective heat flux and thermal electrode effects (hot metal splash, metal oxide vapor and burning heat of electrode material) to the samples exposed. This also may be seen from the high-speed video frame and scheme in Fig. 2. As already mentioned above, these conditions are typical for enclosed LV power equipment (enclosed load centers, distribution boards and switchgear, such as panel boards, control panels, MCC, switchgear assemblies). The basic setup of the box test is shown in Fig 3.

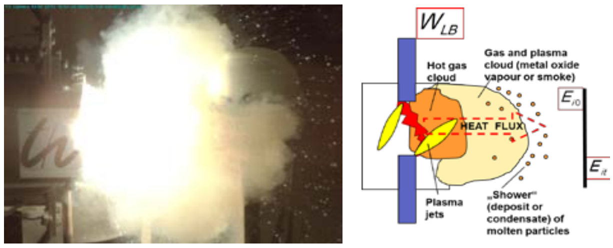

Fig. 2. Typical arc heat exposure scenario in LV equipment

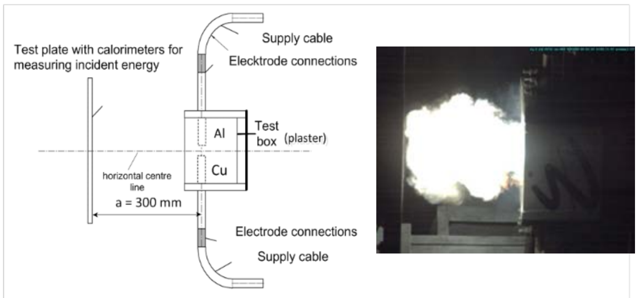

Fig. 3. Box test set-up

There are clear differences between the box test and the open-arc test, both in terms of the test set-up and the procedure. Table 2 summarizes important features in this respect. The comparatively small electrode gap of 30 mm (compared to 300 mm in the open-arc test) means that the test arc and the heat output are subject to fewer changes or fluctuations, which is further supported by the box. There is a stable thermal source. The box generally leads to a significantly more intensive heat effect, as a very intensive gas flow is caused in addition to the radiation. In general, a very high amount of the electrical arc energy is converted into thermal energy. The test setup and the directional effect of the box lead to the maximum possible direct incident energy for a set test energy (electrical arc energy) and mean a 'worst-case' scenario. The stabilized heat source and intensive thermal effect also make arc testing in the box test to have proven very good reproducibility [12].

No monitor sensors are used in the test setup of the box test because they would influence or not fully measure the directed heat flux. Instead, to check the test conditions, an additional test shot without a material or PPEaA sample is performed before the test, in which the direct incident energy is measured. The electrical arc energy is also determined in each test shot with sample. These values are used to check whether the test settings are within the validity range, which is limited by the standard deviation from the mean value from an existing long-term statistic with a very large data base for the respective arc protection class. This ensures the validity of the test and the very good reproducibility of the box test.

TABLE II. DIFFERENCES BETWEEN BOX TEST AND OPEN ARC TEST

	Box test	**Open Arc Test**
Electrode gap	30 mm	300 mm
Electr. material	aluminium and copper	steel
Electr.surrounding	small-scale box	open
Heat transfer	directed	All sides (all-round)
Heat transfer mechanisms	radiation + convection + metal splash + burn.heat	mainly radiataion
Test voltage	400 V	> 3000 V
Test current	4 kA and 7 kA	8 kA
Test duration	500 ms	Varied in test series
Test parameter	Electrical arc energy	Incident energy
Test prcedure	Fix set test level	Test series
Test energy	Arc protection classes, APC 1 and APC 2	Incident energy, range not limited
Test assessment	yes/no decision	Logistical evaluation
Test result	Arc protection class APC	Arc rating parameter ATPV, ELIM or EBT
Validity check	standard deviation from long-term statistics	
Measuring incident energy	Extra test shot without sample	Monitor sensors

With the copper and aluminium electrodes, which dominate as conductor materials in real low-voltage systems, the possible influences of the arc root effects are taken into account in the box test. In contrast, steel electrodes are used in the open-arc test in order to achieve low electrode burn-up and a more stable test arc. However, this means that mechanical-chemical material effects and the thermal energy components that occur under real practical conditions are not included in the exposure of the test specimens. As our own laboratory measurements have shown, the impact energies are highly dependent on the electrode materials. In three-phase AC conductor arrangements, they can be approx. 30...50 % greater with aluminium electrodes than with steel ones.

C. Procedure and Result Parameters

The arc protection classes are characterized by the level of the set electrical arc energy (test level). The definition of arc protection classes, generally entails a limitation of the test energies. This is in contrast to open arc test, which - except for the performance limits of the test laboratory - has no upper energy limit. However, this open-ended system does not take into account the fact that working at very high energy levels may be severely restricted, hindered or impracticable by PPEaA or should be ruled out due to non-thermal hazards. PPEaA alone cannot protect against any amount of energy. The energy limitation through the defined APCs of the box test is in line with considerations regarding the practical feasibility of work, ergonomic requirements for PPEaA and wearer acceptance. What initially appears to be a restriction here is, however, beneficial because the focus is on achieving arc flash protection not only through the use of PPEaA but also primarily through technical and organizational measures (greater working distances, faster clearing times of the protection, etc.). In addition, although not defined, in the standard for the box test it is also permitted to carry out tests with a higher test energy level. Testing in the box test is comparatively simple. The test energy of the arc protection class APC is fixed. Based on the thermal resistance and heat transfer, a yes/no decision is made as to whether the PPEaA fulfils the arc protection class. This means that the protective effect of the PPEaA exists at least up to a prospective arc energy at the work location that corresponds to the test level.[1] The protection level of PPEaA tested in the box test can also cover even higher arc energies under conditions at the workplace that differ from the test setup in terms of working distance and electrode ambient conditions [10].

Testing PPEaA with a very high ATPV value in the open-arc test may be problematic if relatively long test times (several seconds) have to be set due to the test current of 8 kA. The relationship between incident energy and current is not linear over the entire value range. The required ATPV value therefore depends on the current and time. The open arc test procedure requires a test series of at least 7 arc shots and a complicated logistical evaluation to determine the arc rating parameters. The procedure for the box test is simpler and generally requires less testing effort. Testing in a 400 V test circuit also means lower demands on the facilities of a test laboratory. The box test is therefore generally more cost-effective.

The advantages of the box test consist in the simulation of conditions in LV systems, a simple procedure, less testing effort and good reproducibility.

IV. RISK ASSESSMENT AND PPEAA SELECTION BASED ON DGUV-I 203-077

A. Goals and scope of DGUV-I 203-077

As the basic relationships in Chapter I and also practical experience show, it is important for users not to address testing, risk analysis and assessment and selection of PPEaA separately, but as a package. This objective has been pursued in DGUV-I 203-077, where the single aspects are considered in context and coordinated with each other. It is not purposeful if arc flash protection for any level of energy is aimed to achieve exclusively by means of PPEaA and corresponding tests. Technical and organizational measures to reduce energy and hazards should always be included, as well as risk considerations if necessary. DGUV-I 203-077 is a practical guide to analyzing hazards and selecting PPEaA based on their protection level, which is derived from the arc protection class of the box test. The basis for all considerations is the electrical arc energy. The scope of DGUV-I 203-077 mainly covers the low-voltage level (up to 1000 V AC and 1500 V DC), which was the original focus. However, it also includes the medium voltage (MV) range. In MV systems, live work or

[1] It should be noted that the relevant characteristic value of the box test is the test level of the arc energy. The validity and application range of the arc protection classes is not given by the test currents of 4 kA (APC 1) or 7 kA (APC 2) - just as the values of the arc rating (ATPV etc.) determined in the open arc test do not only apply to the set test current of 8 kA.

work in the vicinity of live system components is now also carried out more frequently, resulting in a corresponding need for PPEaA protection. With regard to MV considerations, it should be noted that the calculation algorithm for the worst-case assessment may provide unrealistically high values for the prospective arc energy and thus huge safety reserves. For this reason, a method has been developed specifically for MV applications up to 30 kV, which is presented in [21].

B. *Calculation of Electrical Arc Energy*

The algorithm of the deterministic PPEaA selection procedure determines the prospective electrical arc energy to be expected at a work location under study. The protection level of the PPEaA results from the test level of the arc protection class APC, the working distance and the system conditions (transmission factor). It must be selected so that it is greater than or at least equal to the expected arc energy value. The working or exposure distance to the arc is not taken into account when determining the prospective arc energy, but with regard to the protection level of the PPEaA, as the protective effect depends on the exposure distance. DGUV-I 203-077 describes procedures for both AC and DC systems. The arc energy is the product of arc power and arc duration. As generally known, arc power cannot be calculated precisely. The user guideline describes approximation and estimation methods for determining the arc power from a few practically available grid and system parameters (grid voltage, prospective short-circuit current, R/X ratio in the AC system, time constant L/R in the DC system, electrode distance), which are based on empirical determination equations [7]. In addition, there are also approximation options for the user in the form of guide values or 'worst-case' considerations. These options allow very rough estimations, but do not require precise input data. For procedural reasons, the algorithms use different approximation strategies for AC and DC arcing faults. For DC systems, the electrical arc power is determined iteratively from an empirical approach for the arc characteristic [9]. For AC systems, typical characteristic values and reference ones are provided, based on modelling and empirical approximations for three-phase AC systems [7]. The basic principles were derived from theoretical considerations, statistical evaluations and very extensive laboratory measurements. It is a major issue of DGUV-I 203-077 that the very complex and non-linear relationships of the arc characteristics can be handled. For this reason, the deterministic calculations use related auxiliary variables for non-linear relationships, the values of which are assigned a certain statistical probability. The current attenuation factor k_B, which is used to determine the actual fault current, and the power transfer factor k_P to determine the arc energy from the short-circuit capacity of the electrical system describe the non-linear relationships between arc voltage, arc current, electrode gap and R/X ratio or L/R ratio of the circuit for different statistical probabilities [7]. Under these conditions, linear systems can be considered in the calculations. It should be noted that the R/X or X/R ratio is an important influence. A non-consideration of this ratio in the calculation equations means a significant shortcoming of the IEEE 1584 method or other similar ones. An important aspect in the risk analyses according to IEEE 1584 is that the PPEaA selection for AC systems, in which five different scenarios of arc exposure are differentiated, is only made on the basis of the thermal incident energy, without considering the electrical arc energy. However, it is interesting to note that, in contrast, methods for the DC range first determine the electrical arc energy and then convert it into a thermal incident energy [22, 23] in order to be able to select the PPEaA based on this parameter. However, these conversions, which are also used in software packages, must be evaluated very critically, as the equations used for this purpose have proven to be not generally valid or only very inaccurate according to our own laboratory measurements.

C. *Characteristic Values of the Short-Circuit Current*

The prospective arc energy must be determined in the procedures as an upper limit from the maximum values for arc power and arc duration. In the DGUV-I 203-077 procedure for determining the electrical arc energy in AC systems, it is important to correctly take into account the influence and level of the short-circuit or fault current. Due to a number of practical influences, the short-circuit current always lies within a certain value range, which requires a differentiated use of the current values. In order to find the maximum possible arc power and arc energy - as intended - the maximum three-phase short-circuit current has to be used to determine the short-circuit power of the system. For this current value, all influences specified in the relevant standards for short-circuit current calculation must be taken into account: the maximum possible short-circuit capacity of the upstream and feeding systems, the most critical grid switching states, upper limits of the grid voltage, conductor temperatures of 20°C, motor regeneration, additional feed-in from generator, inverter and battery branches (in particular also regenerative sources such as PV and wind energy systems). The arcing or short-circuit duration, on the other hand, is determined as the clearing time from the characteristic curves of the switching and protective devices upstream of the fault location on the basis of the smallest possible fault current, as the switch-off time is longer with a smaller current. The actual fault current that flows in the event of an arc flash is the arcing fault current, which takes into account the fault arc influence and can be calculated by using the current attenuation factor from the minimum three-phase short-circuit current. For the minimum short-circuit current, feeds and grid switching states with the lowest short-circuit capacity, lower limits of the mains voltage, increased conductor temperatures (80°C) and the neglection of all additional supply sources must be assumed.

D. *Risk Assessments*

DGUV-I 203-077 provides for an extended selection of PPEgS, if necessary, by risk considerations in order to find protective solutions with determining additional measures (technical, organizational, etc.), particularly for high arc energies. The deterministic part of the procedure with the calculation of the prospective electrical arc energy can be followed by a probabilistic part. In the case of very high expected values for the arc energy, there is the approach of estimating the severity and probability of occurrence of personal injury in a risk assessment and defining suitable additional measures (for system conditions and technical means, work organization, personal requirements of the workers, consideration of statistical and ergonomic influencing factors) that justify the use of PPEaA of arc protection class APC 2 [11]. There are detailed explanations and assessment schemes for the supplementary risk assessments in [10].

With the help of Excel tools, users can carry out the necessary calculations based on the network and system data usually available.

V. SUMMARY

It is important to effectively protect people working on electrical installations from the thermal hazards of an arc flash. PPEaA can make a significant contribution to this, but must be tested to an international test standard and selected on the basis of a correct risk assessment. Over the last two decades, great progress has been made in the development of PPEaA, its testing and selection procedures. Last but not least, such progress is always linked to the knowledge and acceptance of users. There are two fundamentally different approaches worldwide: the arc rating-based approach with testing of the PPEaA in the open arc test, and the arc protection class-based approach with testing in the box test. Both test methods are optional. However, the box test has a whole range of advantages. Although the box test has proven its worth for more than 20 years and has, e.g. in Germany, contributed to a significant reduction in arc flash accidents and serious burns when working on electrical systems, there are still some misjudgments about its applicability and benefits resulting from a lack of knowledge. The box test is a simple, cost-effective and easily reproducible test method that is tailored to the conditions in low-voltage systems. It is not only used for testing textile materials and protective clothing, for which it was originally developed, but also for face protection equipment and protective gloves. DGUV-I 203-077 is a user guideline that provides procedures for determining the electrical arc energy for the risk assessment and selection of PPEgS based on the arc protection class of the box test for both AC and DC systems. The basic considerations relate to a deterministic view of the risks based on the severity of damage (severity of an injury based on the level of arc energy). In addition, probabilistic considerations of the probability of damage (probability of occurrence of an injury) can be made in risk assessments. Together with considerations on technical and organizational measures to prevent arc hazards, effective solutions for personal protection against arc flash hazards can be found for almost all practical applications. Tools are available for users in the form of Excel calculation sheets for simple and convenient use of the guideline.

These developments have produced a solid base for achieving arc flash protection for persons. It is important that users are aware of and familiar with the relevant information.

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