Arc Hazard

The European approach

Introduction

This technical brochure provides information concerning the danger of an electric arc in an electrical power installation. The available options on how to deal with this danger in an installation are explained. In order to understand this danger, a detailed knowledge of electrical installations is necessary.
A risk analysis can provide insights into the hazard; for Europe, the result of the risk analysis must comply with European regulations.

If the result of the risk analysis is applied to a choice in suitable protective clothing and PPE, the possibilities are limited due to the requirements of European regulations.

PPE in electrical engineering, including protective clothing, must have a CE certificate. The information in this brochure is intended to enable the selection of suitable CE certified PPE.

The main hazards of working on electrical installations

The main hazards of working with electricity are:

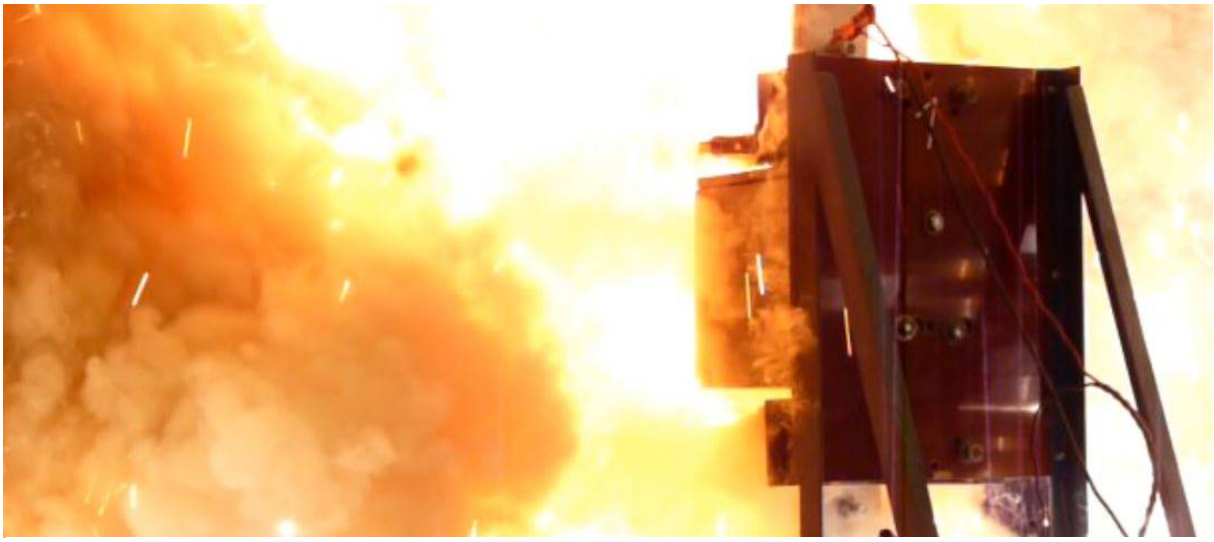
- Electric shock and burns from contact with live parts;
- Injury from exposure to arcing; injury from fire from faulty electrical equipment or installations; injury due to improper handling of installations and equipment;
- Fire caused by overload or short circuit;
- Explosion caused by unsuitable electrical equipment or static electricity igniting flammable vapors or dust;
- Electric shocks can also lead to other types of injury, for example by causing a fall from ladders or scaffolds etc.

A fire at a waste processing plant in Hengelo, the Netherlands, is probably due to a short circuit (2018).

Hazards due to an electric arc fault

An electric arc fault generates a very large amount of energy in a short period of time. The temperature can rise to well over 10 000 °C.
The direct impact of an electric arc are:

- enormous heat radiation;
- high visual light optical radiation;
- intense UV radiation;
- splashes of molten metal;
- poisonous copper gas;
- very high pressure waves;
- harmful noise pressure.



A searing plasma and gas cloud is produced by an electrical arc in a testing box

European directives and regulations

A directive is a legal instrument of the European Union to harmonise national legislation within the union. Each member state is competent to choose the applicable method internally. Directives oblige member states to adapt their legislation in order to achieve the same agreed end result.

A regulation is directly applicable, which means that it creates law which has the same effect as national law in all EU member states, without national authorities having any influence on it.

Directives and regulations relating to arc hazard

The main regulations relating to electric arc hazard are:

- Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.
  89/391/EEC
- Council Directive of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace.
  89/656/EEC
- Regulation of 9 March 2016 on personal protective equipment of the European parliament and the council.
  (EU) 2016/425

Aspects of directive 89/391/EEC

The employer shall implement the measures on the basis of the following general principles of prevention:

- Avoiding risks;
- Evaluating the risks which cannot be avoided;
- Combating the risks at source;
- Adapting the work to the individual;
- Adapting to technical progress;
- Replacing the dangerous by the non-dangerous or the less dangerous;
- Developing a coherent overall prevention policy;
- Giving collective protective measures priority over individual protective measures;
- Giving appropriate instructions to the workers.

Aspects of directive 89/656/EEC

Employers obligations, general provisions

All personal protective equipment must:

- Be appropriate for the risks involved, without itself leading to any increased risk;
- Correspond to existing conditions at the workplace;
- Take account of ergonomic requirements and the worker's state of health ;
- Fit the wearer correctly after any necessary adjustment;
- If there is more than one risk, than it is necessary to wear more than one item of PPE simultaneously, the combination must be effective against the risks in question;
- PPE shall be provided free of charge by the employer;
- The employer shall first inform the worker of the risks against which the wearing of the personal protective equipment protects him;
- The employer shall arrange training and organize demonstrations in the wearing of PPE.

Safely removing NH fuses

Assessment of personal protective equipment

Before choosing personal protective equipment, the employer is required to assess whether the personal protective equipment he intends to use satisfies the requirements.
This assessment shall involve:

a. An analysis and assessment of risks which cannot be avoided by other means;
b. The definition of the characteristics which personal protective equipment must have in order to be effective against the risks referred to in (a), taking into account any risks which this equipment itself may create;
c. Comparison of the characteristics of the personal protective equipment available with the characteristics referred to in (b).

Aspects of regulation (EU) 2016/425

The following parties have responsibilities for bringing PPE to the EU market.

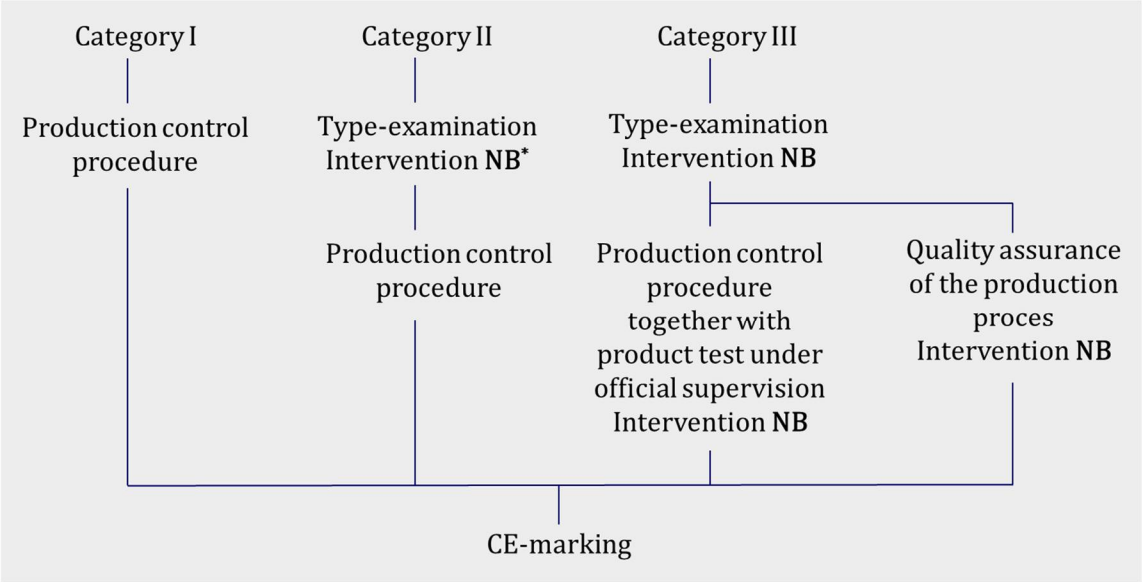
- Manufacturers;
- Authorised representative;
- Importers;
- Distributors.

Risk categories of PPE

The categories of risk against which PPE is intended to protect users.

- Category I: PPE protecting against minor risks;
- Category II: PPE protecting against moderate risks;
- Category III: PPE protecting against mortal injuries or irreversible harm.

Certification of PPE



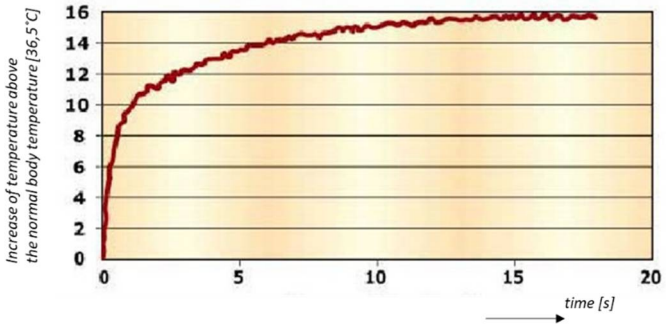
* *Notified body*

PPE protecting against the dangers of electricity are categorised in category III, so a product test is required.
There are two international test methods available for electric arc hazard:

- EN IEC 61482-1-1;
- EN IEC 61482-1-2.

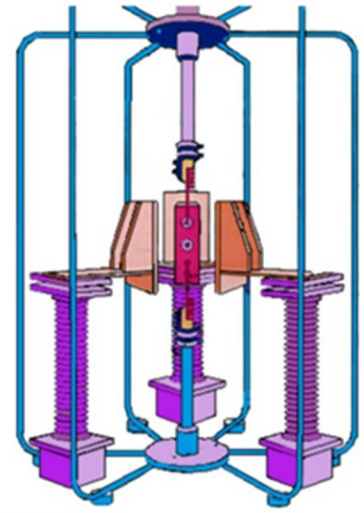
Stoll curve

At the end of the fifties Alice Stoll and Maria Chianta did research into the origin of a second-degree burn. This led to the Stoll curve, which shows the amount of thermal energy needed to cause a second-degree burn. When the curve is crossed, a second-degree burn occurs.



Test method 1

Test method 1 is described in IEC 61482-1-1 is better known as the 'Open Arc test' and there is a tiny difference with the ASM 1959F test. Test method 1 is intended for the determination of the arc rating of a material, or a combination of materials.



The test setup consists of 3 electrodes in an angel of 120 degrees to each other. The air gap between the electrodes (stainless steel) is 30cm.

The test material is placed in the middle of the electrodes to the sample holders and is equipped with two calorimeters. With high voltage (3kV) a electric arc is ignited; the arc current is 8kA. By varying the time of the arc, the amount of energy is determined.

The incident energy (*IE*), measured by the sensors, is calculated for 30s after ignition of the arc.

Since the arc does not reach the material, the test material is mainly affected by radiant heat.

The incident energy can be compared to three different arc ratings:

- ATPV Arc Thermal Performance Value,
- $E_{BT}50$ Energy Break-open Threshold,
- ELIM Energy Limit.

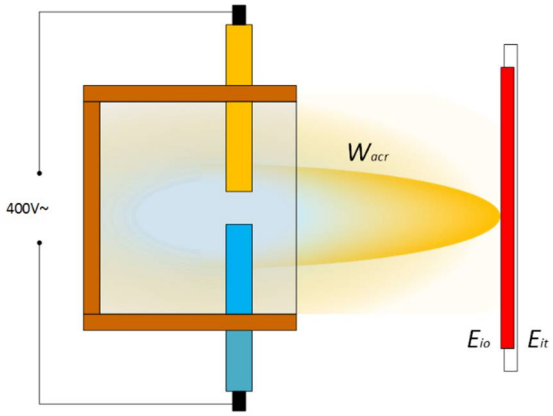
The test parameters ATPV and $E_{BT}50$ have a 50% probability of exceeding the Stoll curve., which could result in a second-degree burn. European regulations are based on 100% protection, therefore these arc ratings are not suitable for the European market.

The ELIM test parameter has been introduced into the 2018 PPE standard, IEC 61482-2 and have been defined by not exceed the Stoll curve. Due to the fact that the ELIM rating has no limit, it does not meet the European requirements.

Test method 2

Test method 2 is better known as the 'Box test' and is described in EN IEC 61482-1-2 and is used for CE-certification on the European market.

The test setup consists of an enclosed cabinet with an opening at the front. Inside, at the back, there is a plastered parabola. At the top and bottom there are electrodes (copper and aluminium) installed which are connected to a voltage of 400V (European low voltage level). The test produces an arc which is directed at the material to be tested. The test material is placed at a distance of 30 cm. Sensors are used to determine the thermal protection of the material.



There are two test values:

Test level	Result of the test	Class	Arc test protection level
Class 1: 4kA/0,5 sec	pass or fail	APC* 1	W_{arcP} = 158kJ
Class 2: 7kA/0,5 sec	pass or fail	APC* 2	W_{arcP} = 318kJ

**Arc Protection Class*

An important characteristic of the Box test consist of the energy level limited to 400V, -7kA/0,5s.

A limitation of the energy level is required within the framework of the European directives. If the energy level increases, the hazards also increase. Hazards such as explosion pressure (arc blast) and toxic gases are a serious threat to human health. The available garments and PPE do not protect workers against these hazards.

Standard IEC 61482-2

In addition to both test methods, there is a standard for the clothing requirements, IEC 61482-2. The standard was revised in 2018 and the pictogram indicating the kind of protection was changed. In the past, the well-known double triangle symbol has been used; since it is also used for electrical insulation this symbol creates confusion. One or more of the following values shall be indicated below the pictogram:

Old pictogram

- ATPV xxCal/cm^2 (no CE-marking)
- $E_{BT}50$ xxCal/cm^2 (no CE-marking)
- ELIM xxCal/cm^2 (no CE-marking)
- APC Class 1 of 2 (CE-marking)

New pictogram

The new European PPE regulation has been made more stringent than its previous one. A change in the design results directly in the expiry of the CE certification. The application of logos or name tags is subject to strict conditions. This also applies to repair of and adjustments to the garments.

The garments range

Overall APC 1

Based on CE certified clothing, class 1 is considered to be standard clothing. The wearing comfort of the clothing makes it possible to wear it all day long. If (operational) work has to be carried out, it is important that the clothing is worn closed.

In places where class 1 does not offer the required protection, class 2 clothing is used. This is called additional clothing and consists of two layers of fabric (at the front). If a class 1 shirt is worn with a class 1 jacket over it, this can be considered as class 2. Whether the combination offers sufficient protection is shown by the risk analysis.

If an industrial installation is well designed and maintained, the clothing provides good protection for the workers. There is a wide range of CE certified clothing in both Class 1 and Class 2.

Face shields

A face shield consists of a visor and a carrier. The carrier can be a helmet but also a construction of textile is possible. Face shields are currently still covered by the EN 166 (8) standard, hopefully this will soon change since there is a great need for a specific (international) standard* for electric arc face shields.

The visor is currently being tested in a similar way to the Box test (GS-ET-29). Notified bodies have agreed that CE-certification will take place on the GS-ET-29 test. A face shield consists of a visor and a carrier, so there are products on the market with CE certification for the visor while the complete face shield does not meet the European requirements.

APC 1 face shields are characterized by a clear visor and APC 2 screens that have a tinted screen to offer extra protection. APC 2 screens that are mounted on a helmet are equipped with a chin protection.

Because the tinted visors do not transmit all the visible light, extra light may be necessary. The user must have a minimum illuminance of 30 lux behind the screen. Face shield manufacturers provide LED lighting that can be mounted on top of the shield.

In accordance with EN 166, the visor is marked with the code for protection against arcs (8) and must be followed by the class of the arc (APC 1 or 2) and the transmission for visible light (VLT class 0, 1 or 2).

VLT	**V**isible **L**ight **T**ransmittance
Class 0	Visible light transmittance ≥ 75%
Class 1	Visible light transmittance 50% ≤ VLT < 75%
Class 2	Visible light transmittance < 50%

Example of marking: 8-1-0

* *To develop IEC 62819 Ed.1.0*
Live working - Eye, face and head protectors against the effects of electric arc - Test methods and requirements

Gloves

In the event of an electric arc fault accident, the hands often suffer the most severe burns when they are not protected by PPE. This is because the hands are usually closer to the source of the hazard. The energy level increases quadratically as the distance to the source of the hazard is reduced.

Test method for arc protective gloves is under development. The test method uses the Box test by which the test distance is reduced to 150mm.

Standards* will be developed for gloves that protect against electric arc hazards. Although there is no standard yet, some manufacturers offer tested gloves with good protection.

In the future there will be 3 different types of gloves for live working or in the vicinity of live parts:

- Protection against electric shock;
- Protection against electric shock and electric arc;
- Protection against electric arc.

** To develop IEC 63232-1-2 ED1*
Live Working – Hand Protective Devices Against The Thermal Hazards of an Electric ARC – Part 1-2: Test methods – Method 2: Determination of arc protection class hand protective devices by using a constrained and directed arc (box test)

Insulating mat

In situations where workers may come into contact with the plasma of the arc, protection against electric shock is necessary. This is because the plasma of the arc is voltage carrying. An insulating mat can be used to prevent the employee from being electrocuted. In the low voltage this can be a 1 000V mat, but in the medium voltage it is insufficient and a mat must be chosen that matches the voltage level.

Standard EN 50110-1

Scope

The European Standard EN 50110-1 "Operation of electrical installations" is applicable to all operation of and work activity on, with, or near electrical installations. These are electrical installations operating at voltage levels from and including extra-low voltage up to and including high voltage.

EN 50110 consists of two parts:

- Part 1 of EN 50110 contains minimum requirements valid for all CENELEC countries and some additional informative annexes dealing with safe working on, with, or near electrical installations;
- Part 2 of EN 50110 consists of a set of normative annexes (one per country) which either specify the present safety requirements or give the national supplements to these minimum requirements.

Personnel

- Nominated person responsible for an electrical installation;
  - *nominated person with the overall responsibility to ensure the safe operation of the electrical installation by setting rules and organisation or framework.*
- Nominated person in control of an electrical installation during work activities;
  - *person who is responsible during work activities for the safe operation of the electrical installation.*
- Nominated person in control of a work activity
  - *person nominated with the ultimate responsibility for the work activity at work location*
- Skilled person (electrically);
  - *person with relevant education, knowledge and experience to enable him or her to analyse risks and to avoid hazards which electricity could create.*
- Instructed person.
  - *person adequately advised by a skilled person to enable him or her to avoid dangers which electricity may create.*

Personnel shall wear clothing suitable for the locations and conditions where they are working. This could include the use of close-fitting clothing or additional PPE (personal protective equipment).

Risk assessment (general)

Before starting any work, a suitable risk assessment shall be completed and the necessary protective measures shall be applied.

Only the nominated person in control of an electrical installation during work activities shall give authorisation.

Arc hazard

Persons working in the vicinity of electrical installations are exposed to hazards caused by an electrical arc. Electrical arcs are a rare event. Nevertheless, a reliable protection is required as the appearance cannot be excluded particularly since they can be caused by actions during working. Electric arcs are not only a result of a short circuit, but also separating burdened live parts without special measures (lines, cable connector, switchgears, fuses, etc.).

The thermal impact of an electric arc depends on the incident electrical energy, that determines the energy converted in the arc (depending on the arc voltage, arc current and arc duration), and the heat flux transmission conditions including the exposure conditions and the distance to the arc.

In the case that any work in the vicinity of an electrical installation or under live conditions is necessary, risk assessment should be done.

Measures to prevent an Arc Fault

Directive 89/391/EEC:
The employer shall implement the measures referred on the basis of the following general principles of prevention:

- *Avoiding risks.*

In practice this means that the nominated person responsible for an electrical installation (EN 50110) must implement a preventive electrical safety policy that is also aimed at preventing electric arcs faults.
The following items are part of the safety policy:

- Constructive measures in the installation design;
- Replacement or renewal of components and devices (retrofitting);
- Use materials and equipment suitable for the load;
- Using materials and equipment of better quality;
- Prevent incorrect handling;
- Measures in operational management (work permit)
- Proper maintenance of equipment;
- Carry out regular inspections.

Infrared inspection

Technical measures to limit the impact

Directive 89/391/EEC:
The employer shall implement the measures referred on the basis of the following general principles of prevention:

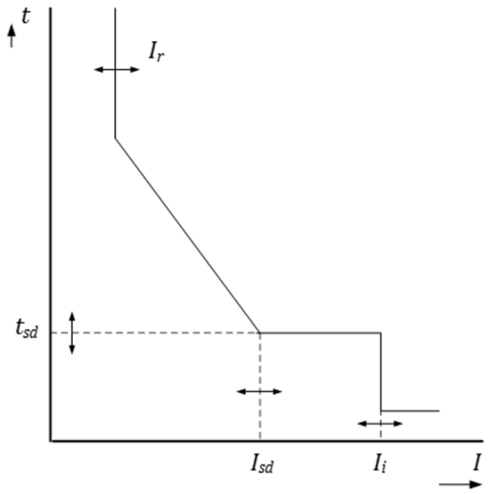
- *combating the risks at source;*
- adapting to technical progress;
- *replacing the dangerous by the non-dangerous or the less dangerous;*
- *giving collective protective measures priority over individual protective measures.*

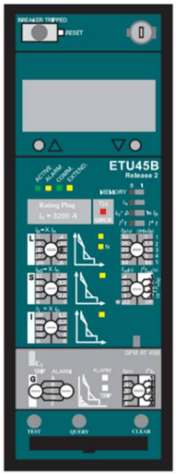
Technical measures cannot always prevent an electric arc but can reduce the impact. Various techniques are available for this purpose:

Limitation of the arc time

The energy of an electric arc is determined by the factors voltage, current and time. By limiting the duration of the arc, the energy level can be significantly reduced:

- Arc fault detection:
  A monitor device guards (di/dt) in combination with a flash light or Δp. If a set value is exceeded, a short-circuit system is activated that short-circuit the phases. The duration of the short-circuit current is limited to <4ms.
- Tripping time fuses:
  A fuse may interrupt the short-circuit current before the maximum value of the short-circuit current is reached. If the design of the installation takes into account the current limitation of the arc fault current, the fuse will directly blow and the time of the arc will be limited to a very short time (10ms).
- Circuit-breaker tripping time:
  A circuit breaker consists of a disconnector and an electronic trip unit. Depending on the type of trip unit, different settings can be made. Important data are: I_{sd}, t_{sd} & I_i.





Discrimination of protective devices

Discrimination is selecting protective devices and adjusting their settings to minimize the downtime of the electrical installation under fault conditions. That is why it is also called selective coordination. Discrimination of protective equipment often has more to do with financial consequences than with safety. Although in some sectors it can be very important that the installations remains available.

There are two ways to achieve discrimination:

- Current discrimination;
- Time discrimination.

If current discrimination is used in an installation, this usually does not cause any problems in the risk analysis. This is different in the case of time discrimination. Time discrimination is an old technique but is still in use. In the event of an incident, the fault current is only disconnected after a few tenths of a second. Usually the energy level is so high that proper protection of the employee is not possible.

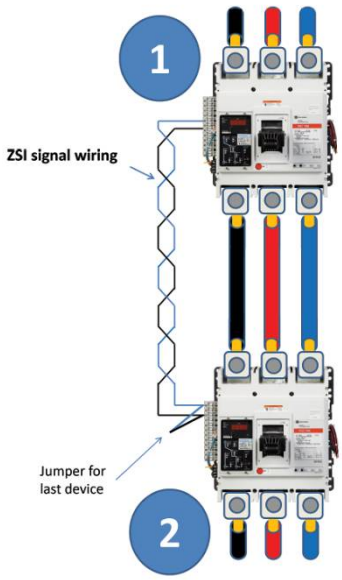
Directive 89/391/EEC:
The employer shall implement the measures referred on the basis of the following general principles of prevention:

- *Adapting to technical progress.*

New techniques are available and can be supplied by most manufacturers. This is called zone-selective interlocking and is based on communication between the various protective devices.

Zone Selective Interlocking ensures that circuit breakers communicate with each other. If a fault current occurs, it is isolated and, without time delay, disconnected by the first circuit breaker upstream. The other circuit breakers, also upstream, remain in operation so that the other installations remains undisturbed.

There are also circuit breakers with a built-in maintenance mode. When activated, the settings go down and the disconnector responds directly to an electric arc fault.



Circuit breakers whit zone-selective interlocking

Spatial restriction

Switch & control gear operated by competent personnel, properly maintained and designed according to IEC 61439 series minimizes the chance of an internal arc. If the currents and therefore the energy level increase, the consequences of an error can be very serious.

There are switchgear and distribution boards that protect the user in case of an internal arc. The switchgear and distribution board are tested according to IEC/TR 61641. The protection provided by the switchgear and control gear is only valid when the control gear is closed.

For medium-voltage distributors IEC 62271-200 applies, whereby the protection of the user can be implemented in different ways.

Distribution board with limited energy level

If the switch & control gear has a limited energy level, an electric fault arc cannot cause much injury and damage. If the power level in the switch & control gear is 100kJ or less, the damage to the electric panel will be limited. After removing the fault and cleaning the surrounding area, the system can usually be put back into operation.

If the electric arc energy does not exceed 250kJ, the effects of the electric arc will only cause damage within the switch & control gear. The hazard of the electric arc do not reach the user, provided that the assembly is correctly closed.

Most smaller switch and control boards have a limited energy level. When starting an arc hazard risk assessment, a choice is made for which parts of the installation a study is useful.

Remote control

To protect the operator against arc hazard, remote control may be used. With modern systems, this can be done electronically when the system is being installed.

For existing switchgear, products are available for which remote control is carried out by the user. The physical action is then carried out by a device that is powered electrically or by compressed air.

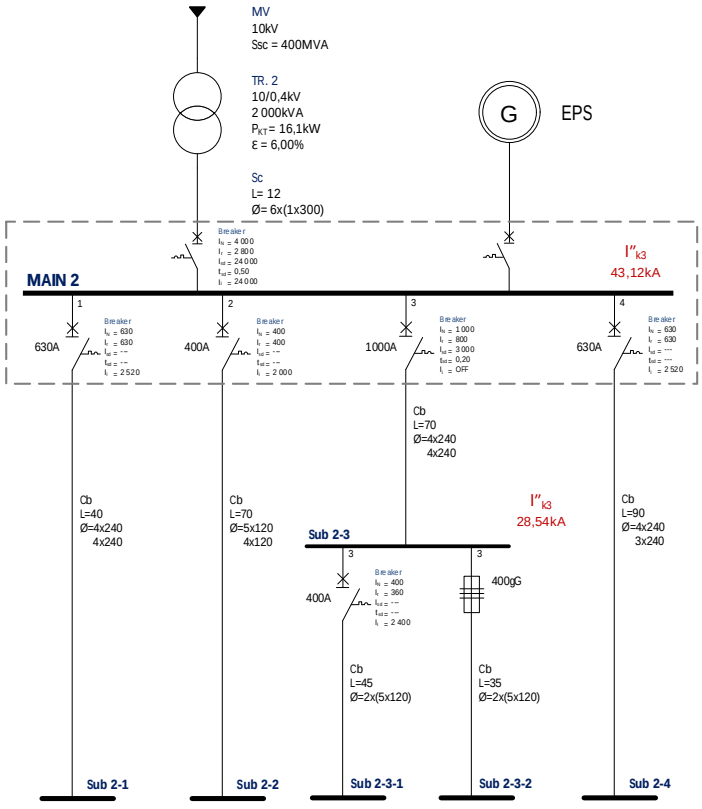
These methods offer protection only to the user and not to the assembly.

Preforming an arc hazard risk assessment

When carrying out an electric arc hazard risk assessment on an electric power installation, it is first be determined which installation parts need to be examined. When the scope of the study is clear, all the specifications of the electric system will be collected such as:

- Short circuit power of the mid voltage;
- Transformer data;
- Values and settings of safety devices;
- Length and cross-section of cables;
- Large connected motors.

This data can be used to make short-circuit calculations according to IEC/TR 60909. Drawing up a single line diagram is a useful help to make the relationship between the different parts clear. Calculate the short-circuit currents at the workplaces, usually these are switch & control gears.



Single line diagram

Once the short-circuit currents have been calculated, the risk analysis can be started. There are two ways to do the risk analysis (IEC 61482-2):

- IEEE 1584 or NFPE70E, with a result in Cal/cm^2;
- ISSA Guide or DGUV-I 203-077, with a result in kJ.

Risk Analysis (general)

A risk analysis is only a part of the overall risk assessment. With the risk analysis, only the energy level at the workplaces will be determined. Other parts of the risk assessment are:

- Is the installation suitable for the (live) work activities?
- Do the workers involved have the necessary training and experience?
- Are there environmental influences such as light & moisture?

The nominated person in control of an electrical installation during work activities (EN 50110) is the only person to give authorisation for starting the work.

In Europe we see different ways to calculate the arc energy in an electrical facility, sometimes with inimitable creative solutions. The outcome of the calculations are Cal/cm^2 or kJ.

Manufacturers and resellers both have a different strategy when it comes to advising on garments and PPE. There are manufactures that base their advice on the CE-certification, APC 1 or APC 2. There are also manufacturers that use arc ratings in Cal/cm^2.

The question is how these methods relate to European regulations.

Risk Analysis (example)

A risk analysis is performed for a part of the installation on the previous page. The calculations are not explained in detail because this is not the intention of this document. A risk analysis is carried out for the following work locations: Main 2 and Sub 2-3.
The risk analysis is performed according to:

- IEEE 1584:2018;
- ISSA Guide, in detail.

IEEE 1584:2018, Main 2		
Short-circuit current	I''_{k3}	43,12 kA
Arcing current	I_{arc}	25,19 kA
Arc fault current time	t	0,05 s
Work distance	a	400 mm
Air gap	d	30 mm
Incident Energy	IE	5,89 Cal/cm^2

ISSA Guide, Main 2		
Short-circuit current	I''_{k3}	43,12 kA
Arc fault current	I_{arc}	36,50 kA
Arc fault current time	t	0,05 s
Work distance	a	400 mm
Air gap	d	30 mm
Arc energy	W_{arc}	512 kJ

IEEE 1584:2018, Sub 2-3		
Short-circuit current	I''_{k3}	28,54 kA
Arcing current	I_{arc}	18,85 kA
Arc fault current time	t	0,20 s
Work distance	a	400 mm
Air gap	d	30 mm
Incident Energy	IE	17,08 Cal/cm^2

ISSA Guide, Sub 2-3		
Short-circuit current	I''_{k3}	28,54 kA
Arc fault current	I_{arc}	21,82 kA
Arc fault current time	t	0,20 s
Work distance	a	400 mm
Air gap	d	30 mm
Arc energy	W_{arc}	1 217 kJ

Results of the risk analysis

IEEE 1584:2018, Main 2

If a work activity is carried out, the worker must wear **single** layer protective clothing and a face shield with a **clear** vizor.

ISSA Guide, Main 2

If a work activity is carried out, the worker must wear **double** layer protective clothing and a face shield with a **tinted** vizor.

IEEE 1584:2018, Sub 2-3

If a work activity is carried out, the worker must wear **double** layer protective clothing and a face shield with a **tinted** vizor.

ISSA Guide, Sub 2-3

$W_{arc} > W_{arcP}$

Work activities are **not** safely possible. Other measures must be taken.

The setting 'Ii' from the breaker must be set at ≤18kA.The switch-off time becomes then 50ms and the energy level is reduced to 305kJ

*Work activity is possible by wearing **single** layer protective clothing and a face shield with a **clear** vizor.*

There is no relationship between the two risk analyses and the results can differ considerably. A risk analysis based on the ISSA manual requires more frequent adjustments to the installation in order to reduce the arc energy. This is necessary in order to remain within the framework of European regulations.

Directive 89/391/EEC:
The employer shall implement the measures referred on the basis of the following general principles of prevention:

- *combating the risks at source;*
- *replacing the dangerous by the non-dangerous or the less dangerous;*
- *giving collective protective measures priority over individual protective measures.*

A proper risk analysis is mainly about the functioning of the electrical installation and not about the amount of PPE needed.
The study being performed focuses in particular on:

- Evaluate settings of protective devices;
- Evaluate value and characteristic of fuses;
- Maintenance and inspection of the installation, in particular of the breakers;
- The operator's training level (skilled or instructed person);
- Protection level when the installation is closed;
- Can resets be performed remotely or on the outside of the panel?
- Are there possibilities to increase the work distance.

Using the ISSA method (method 2, IEC 61482-2) provides the best guarantee that employees are well protected against the thermal hazards of an electric arc. It also prevents personnel from being exposed to other hazards such as explosive pressure (arc blast) and toxic gasses.
European directives require that workers are protected against all hazards present in the workplace.

Manufactures layer principal

There are several manufacturers in Europe who commission their products to be tested according to EN-IEC 61482-1-2, in order to gain access to the European market. They have their products tested according to EN-IEC 61482-1-1 as well. These products have a level of protection expressed respectively in:

- APC 1 or 2 and;
- Arc rating xxCal/cm^2.

Manufacturers advise to wear different layers of clothing on top of each other in order to get a high level of protection.

Combining different CE marked products does not mean that the assembly is also CE marked, this a well-known fact under the machine directive.
The European PPE regulation does not allow more than two single layers of protective material to be used. Workers may not be exposed to risks that can cause a serious risk to their health. Severe and irreparable injuries can occur if workers are exposed to such high energy levels.

The only combination of clothing that is allowed is e.g. a shirt APC 1 and a coat APC 1.

Checking whether this combination give a fully APC 2 protection is the responsibility of the user (IEC 61482-2).

A video of a high energy arc fault test can be found here.

https://www.youtube.com/watch?v=DS06Q6oMRYY

Conclusion

When it comes to buying clothes and PPE, it's easy, there are only two choices, class 1 or 2.
They have a CE certificate and comply with Regulation (EU) 2016/425.
Of course there are also manufacturers in Europe that offer other items without a certificate although their number is decreasing.

However, there are manufacturers and suppliers who sell more and more arc hazard related products such as underwear and balaclava. But with a risk assessment that meets the European requirements, these products are not necessary or are even not allowed.

The real safety in case of electric arc hazard is not in the purchase of clothing and PPE but in the performance of a proper risk assessment. The person carrying out the risk assessment must check whether the electrical installation is functioning properly. This means, in the event of an arc fault, the installation switches off as soon as possible. With modern techniques this is possible.

Directive 89/391/EEC:
The employer shall implement the measures referred on the basis of the following general principles of prevention:

- *combating the risks at source;*
- *replacing the dangerous by the non-dangerous or the less dangerous;*
- *giving collective protective measures priority over individual protective measures.*
- *adapting to technical progress.*

The outcome of the risk assessment can have 4 different results:

1. Energy level is so low that use of PPE against electric arc hazard is not necessary.
2. Use PPE class 1;
3. Use PPE class 2;
4. Search for other options.
   a. *Explore decrease of disconnection.*
   b. *Explore increase work distance.*

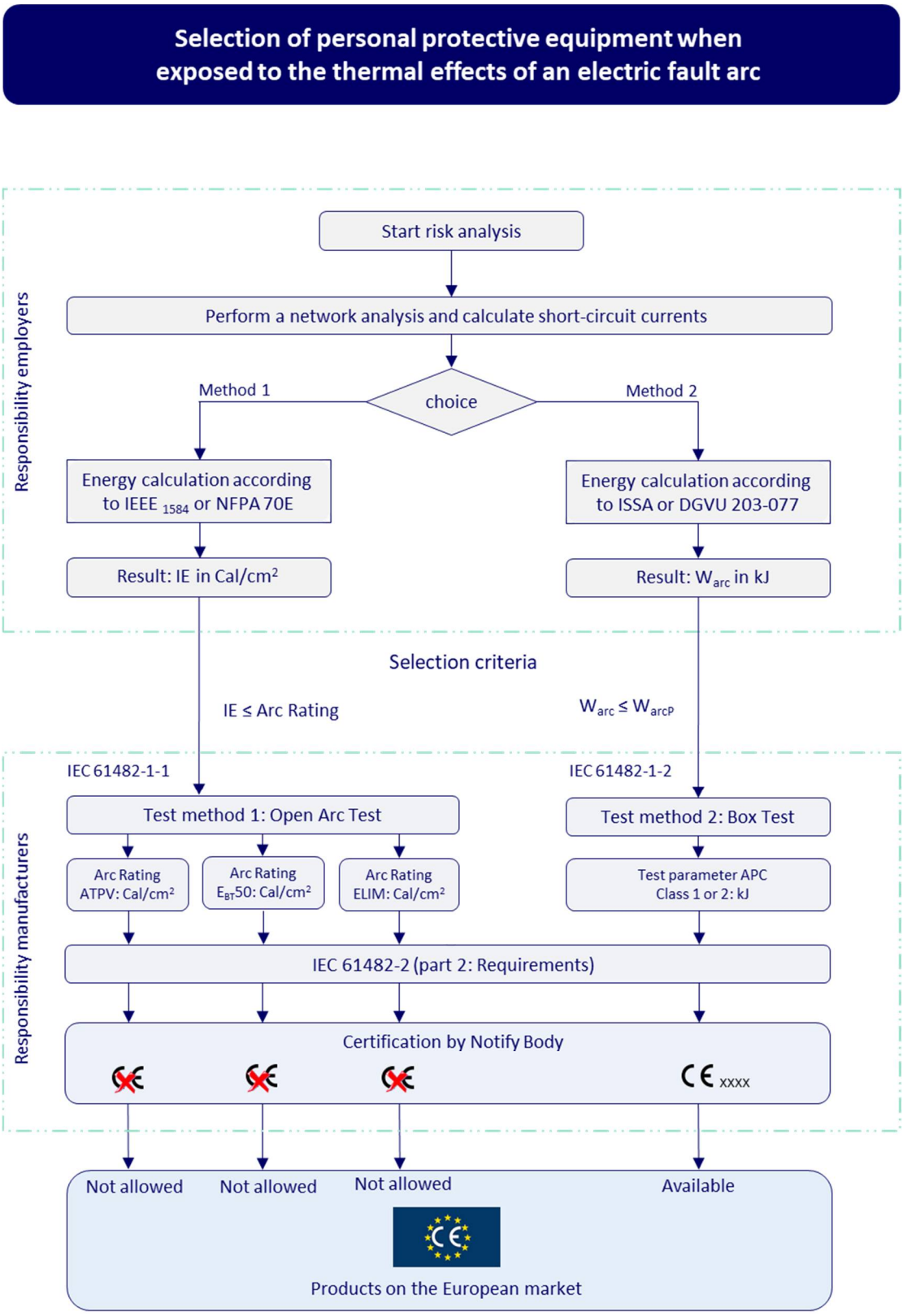
increase work distance

Lucien of the Sanden
Electric arc hazard specialist from the Netherlands

If you have any questions,
eu.archazard@ziggo.nl

Annex A

Flow chart for the selection of suitable protective equipment (IEC 61482-2).



Annex B

Example of a detailed calculation.

Method		**Transformer**		
issa		Power	1 000	kVA
		Voltage	10/0,40	kV
Electrical installation		Rated current	1 443	A
Distrubution board	**MS1A**	Short circuit current	24 056	A
Protective device	Breaker	% Short-circuit voltage	6,00	%
Set parameters		Symbol	Value	
Distance between conductors		d	40	mm
Work distance		a	400	mm
Transmision factor		k_T	1,70	
Calculations		Symbol	Value	
Short-circuit current		I''_{k3}	22,11	kA
Max. Short-circuit current		$I''_{k3p\ max}$	23,11	kA
Min. Short-circuit current		$I''_{k3p\ min}$	21,00	kA
Peak current		i_p	46,68	kA
Minimum fault current		I_{arc}	16,38	kA
Pre-arcing time		t_k	0,05	s
R/X Ratio		R/X	0,243	
Current limitation		k_B	0,780	
Normalised arc power		k_P	0,361	
Calculated PPE level at work distance		a	400	mm
Class 1 (Boxtest 158kJ)		W_{arcP}	477	kJ
Class 2 (Boxtest 318kJ)		W_{arcP}	961	kJ
Prognosis Arc Energy		W_{arc}	291	kJ
Result: $W_{arc} \leq W_{arcP}$				

Protection level of PPE: APC 1

Annex C

Examples of labelling.

ISO W012: Warning Electricity

Taking care to avoid coming into contact with electricity

ISO W042: Warning Arc Flash

Taking care to avoid opening electrical enclosures unless electrical components are de-energized or specialized personal protective equipment is worn

IEC 61482-2: labelling garments

Each garment or garment system complying IEC 61482-2 shall have a marking label.

References

1. Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.
2. Council Directive 89/656/EEC of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace.
3. Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC
4. ISSA: Guideline for the selection of personal protective equipment when exposed to the thermal effects of an electric fault arc (ISBN 978-3-937824-08-6).
5. IEEE 1584: Guide for Performing Arc Flash Hazard Calculations.
6. Schau, H.; Halinka. A.; Winkler, W.: Elektrische Schutzeinrichtungen in Industrienetzen und anlagen. Hüthig & Pflaum Verlag München/Heidelberg, 2008 (ISBN 978-3- 8101-0255-3).
7. IEC 61482-1-1: Live working - Protective clothing against the thermal hazards of an electric arc - Part 1-1: Test methods - Method 1: Determination of the arc rating (ELIM, ATPV and/or EBT) of clothing materials and of protective clothing using an open arc.
8. IEC 61482-1-2: Live working – Protective clothing against the thermal hazards of an electric arc. Part 1: Test methods – Method 2: Determination of arc protection class of material and clothing by using a constrained and directed arc (box test).
9. IEC 61482-2: Live working - Protective clothing against the thermal hazards of an electric arc Part 2: Requirements.
10. EN 50110: Operation of electrical installations - Part 1: General requirements.
11. IEC/TR 60909: Short-circuit current calculation in three-phase AC systems.