Safety of Technogenic Environment

doi: 10.7250/ste.2013.008

2013 / 4

Electric Arc Hazards

Valdis Ziemelis, *Riga Technical University*, Aivars Birznieks, *JSC Latvenergo*, Kaspars Ziemelis, *LLC AME systems*

Abstract. **This article aims to analyse the electric arc exposure hazards to human health and to develop proposals for improvement of safe operation of electric equipment in organizations. The study is carried out on the situation in the field of regulatory documents governing the safe operation of electric equipment; moreover, recommendations are also given. It is concluded that the standard IEC 61482-1-2 (LVS EN 61482-1-2) is adapted in the Republic of Latvia, which puts forward the requirements to protective clothing against electric arc exposure, but this standard only takes into account the spectrum of partially served electric devices. It is, therefore, necessary to introduce the international standard IEC 61482-1-1, which takes into account the actual short-circuit current magnitude and environmental layout of electric devices.**

Keywords: **international standard IEC 61482-1-1, requirements, protective clothing, electric arc exposure**

I. Introduction

Electrical burns are the most widespread local electrical injuries. 60–65% of electric shock victims have electrical burns, while one third of them have also other types of injuries. Electricians most often suffer from electrical burn injuries. Electrical burns can occur from direct exposure to electric current as well as without direct contact with electric equipment [1-4], [13].

Burns from **direct exposure to electric current** are possible if a strong current (more than one ampere) flows for a short duration through the human body. If a person touches a conductive part of electric equipment, electric current flows through the human body and electrical energy is converted into heat energy. Reaching 60°C temperature, the protein substances begin coagulating and cause the occurrence of burns. Since human skin has a much higher electric resistance than the soft tissues, the largest amount of heat is released in the skin. Electrical burn is a skin burn just at the spot of human body contact with conductors. Such burns are deeply pressed into human body tissues. Burns from direct exposure to electric current most often occur with electric equipment under voltage up to 1000V.

Burns without direct contact **with electric equipment** can appear on the human body if voltage is above 1000V. Closely approaching high-voltage electric equipment, a person starts being exposed to possible electric arc discharge. First, sparkling arc discharge takes place, then going into electric arc. Current flowing through human tissues heats them while the temperature of electric arc on human tissues reaches about 4000°C. As a result, human body tissues get charred. Electric arc can cause extensive and deep burns of human body. Such short-time current impact usually does not cause respiratory and circulatory disorders, but the received burns are very dangerous and can result in the death of the victim.

Electrical burns are divided into 4 degrees:

- degree I – redness of the skin;
- degree II – burn blisters;
- degree III – charring of the skin;
- degree IV – charring of the tissues, muscles and bones.

Burns are divided into electrical current burns received by the victim from direct contact with current conducting parts and electric arc burns occurring upon formation of electric arc, mainly due to incorrect operations with the switching devices. Electric arc often switches over to a person and then very high current flows through the human body, resulting in the death of the person.

Electrical burns that occur in electric equipment under voltage to 1000V are mainly first- or second-degree burns, while severe electrical burns occur much less frequently.

In electric equipment above 1000V, electric arc occurs between current-carrying parts and the human body, causing another type of burns – arc burns. Arc burn occurs when the human body is exposed to electric arc of high energy and temperature. Arc burns are third- or fourth-degree burns. Severe health disorders are caused by third- and fourth-degree burns, which cover at least 10% of the human body surface and can also endanger the life of a person [13], [14] .

II. Risk of Electric Arc Occurrence

Electric arc is an electric discharge that occurs when electric current flows through the gap between electric contacts. Electric arc occurs in a circuit wherein electric current is flowing at sufficiently high voltage when such a circuit is mechanically interrupted or if the distance between electrodes is reduced: fast-moving electrons cannot stop and fly out into the circuit break, ionizing the gas, heating and forming the plasma, which is a good electrical conductor. Electric current continues to flow through the formed plasma tunnel between the contacts. Formation of plasma is accompanied by release of very high energy, which results in a very high temperature reaching 22000°C. Exposure to very high temperatures can result in injuries of personnel within close proximity. Arc energy, in its turn, is dependent on short-circuit current magnitude, voltage magnitude and short-circuit effect duration. Degree of electric arc impact upon people depends on short-circuit power and distance to the arc [1].

Electric arc occurrence risk depends on several factors:

- how often the personnel works with live equipment;
- complexity degrees of assigned task;

- size of ambient premises;
- boundaries of safety zones in premises;
- personnel preparedness level;
- coordinated activities between personnel and assistants;
- tools used by personnel;
- technical condition of equipment;
- environment (humidity, dust, dirt);
- condition of protection devices.

The main risk factors that cause threats to human life and health in accidents associated with electric occurrence are the following:

• suddenness effect – fear and confusion resulting in person's inability to timely leave the accident place;

• high energy concentration – large amount of energy released within a short period of time in the form of light and heat, resulting in burns and possible vision injuries;

• shockwave under impact of which a person can be injured from falling, falling from height, falling onto other current-conductive parts;

• electric arc blast with the shockwave splashes of molten metal and various fragments;

• clothing can flame at the distance of few metres, and if made of synthetic material, it can melt and stick to the skin and the skin under clothing can suffer more than uncovered parts of the body;

• giving first aid is usually difficult since the helper should assess hazards from exposure to electric current and take necessary measures while ordinary work clothes can continue burning and causing more severe injuries.

Electric arc thermal energy that affects the human body is called the arc incident energy Ei; it is electric arc thermal energy that gets onto the human body surface (cal/cm2; kJ/m2). This energy value determines the degree of severity of human injury that can occur as a result of electric arc thermal exposure. Therefore, it is necessary to know this energy value for typical places and modes of electrical network. This amount of energy can be determined by engineering calculations. Calculators for evaluation of this energy are developed in the world: computer programmes (Fig. 2), which after input of actual electrical network parameters allow easy identification of the electric arc thermal hazards (Fig. 3.). These programmes are used in organizations for ensuring safe work with electric equipment and for the optimal selection of personal protective equipment to protect people from burns that may arise from electric arc exposure. Results of this programme cannot be used for the evaluation of risks caused by shock wave, molten metal splashes and toxic vapours, because it requires additional studies [1], [10].

Making calculation on the basis of acquired information, the warning marks can be printed (Fig. 3), which are recommended to be placed in respective spots of electrical network.

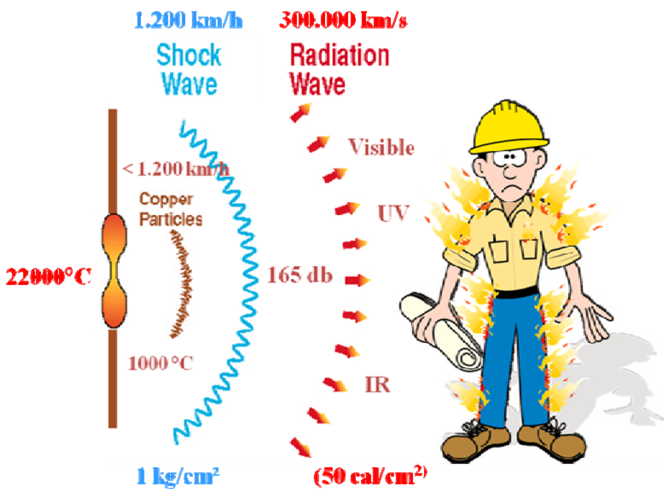

Fig. 1. Electric arc hazards

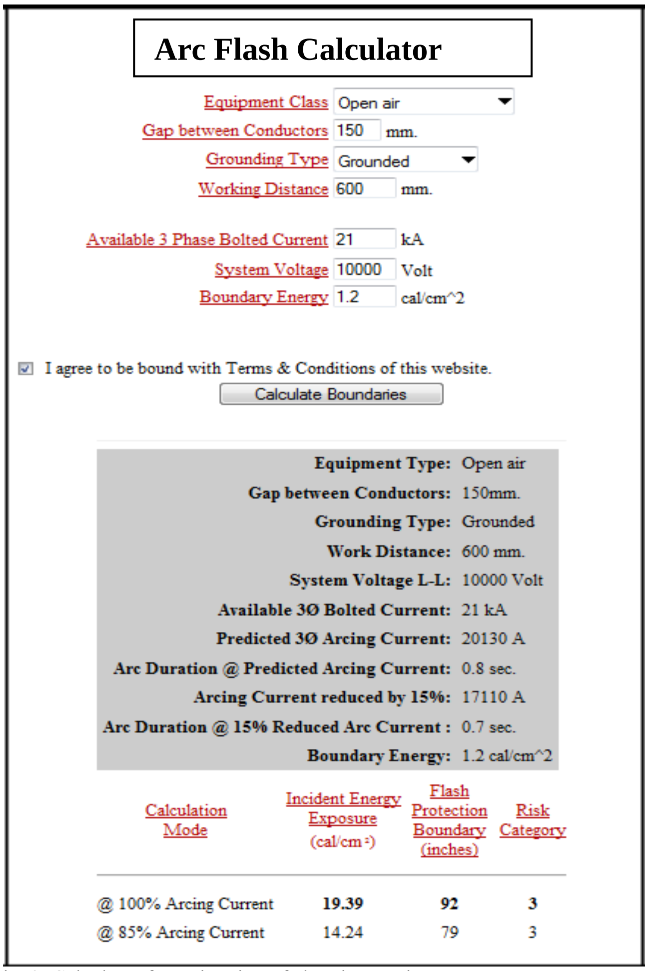

Fig. 2. Calculator for estimation of electric arc Ei

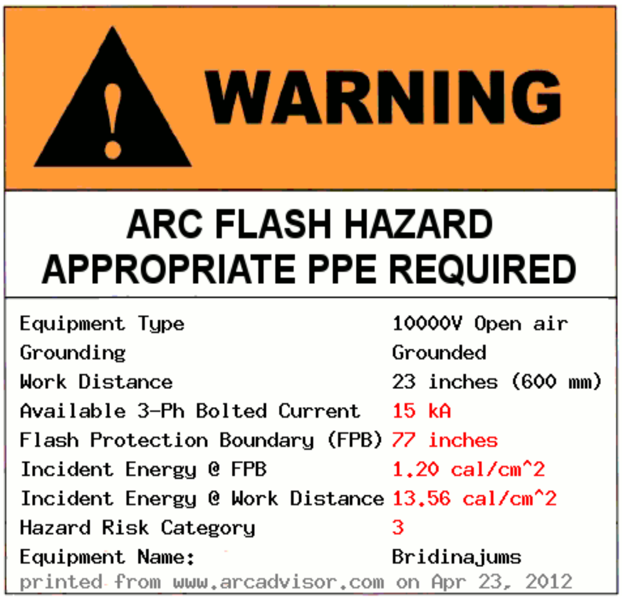

Fig. 3. Warning marking

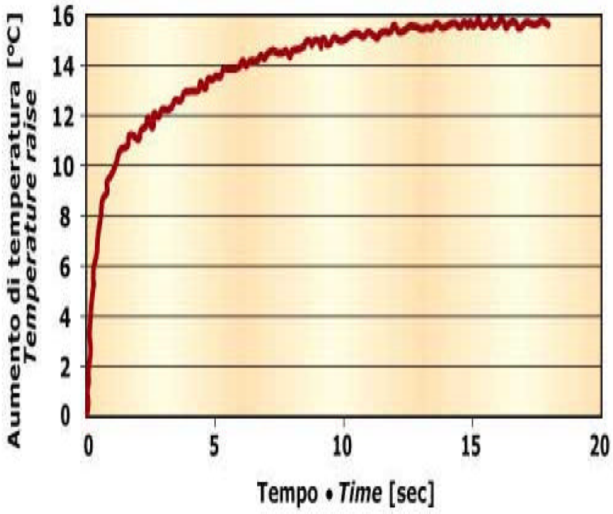

Fig. 4. Stoll curve

III. Selection of Protective Clothing

The possibility of injuries caused by electric arc exists in electric devices and it cannot be completely excluded. People working within potential electric arc exposure areas should be additionally protected by means of personal protective equipment.

Personal protective equipment against electric arc injuries is the protective clothing. In order to be sure of its protective properties, it should be checked (tested) in accordance with the conditions of use. The testing methods depend on practically predictable working conditions and electric arc parameters.

International Electrotechnical Commission (IEC) has developed a number of international standards for clothing in order to protect against electric arc exposure.

Depending on properties of the electrical network and electric equipment, place in the electrical network where works are carried out, magnitude of voltage, the potential arc energy is different; therefore, the protective clothing should be chosen with different levels of protection. Depending on these factors, in Europe the protective clothing against electric arc is tested in accordance with IEC 61482-1-1 or IEC 61482-1-2. The user should specify the required test method. In Latvia the adapted standard is LVS EN 61482-1-2 “Determination of arc protection class of material and clothing by using a constrained and directed arc (box test)”, which is also observed by JSC Sadales tīkls (Distribution Network).

Testing methods are based on experimental data, Stoll curve (Fig. 4), which determine the physiological ability limit of the human skin to withstand heat without second-degree burns.

The curve gives the limiting values of skin surface temperature change rate at which burns will not be caused. During the testing the amount of heat that passes through the closing is measured from the time when the arc starts and till its end. Incident energy upon clothes and energy going through the clothing is measured by means of special electrodes.

The obtained results are compared with the Stoll curve (Fig. 4) and used to predict the possibility of second-degree burn occurrence. The clothing will meet the required criteria, if points fixed in the testing lie below this curve.

Clothing design requirements:

• Clothing fastening function (for example, zipper) remains effective after the clothing was exposed to electric arc.

• Threads and connections will not make the wearer’s injuries more severe. Sewing thread must be made of flame resistant fibres and must not begin melting when tested at 260°C (ISO 3146).

• No external metal is allowed to be present in the clothing.

• All parts of clothing must be made of arc resistant materials in accordance with LVS EN 61482-1-2.

• Clothing label must reflect the lower arc rating.

• Additional user information must be provided: what underwear should be worn and what personal protective equipment should be used in order to ensure full body protection.

IV. Conclusions and Recommendations

The analysis and study of normative documents allow concluding that Latvia practically does not have all normative documents that would regulate safe work with electric equipment. Electric current impact upon people is different, and one of most dangerous effects is the multilateral electric arc exposure. The range of work operations is even broader using the voltage-active working methods that are associated with increased risks of electric arc exposure. Not all legal acts are valid in Latvia, which would regulate the electric arc exposure, and necessary standards have not adapted, which would cover the whole range of arc exposures.

The obtained data demonstrates that the methodology for identification of electric hazards associated with the electric arc exposure and risk assessment is implemented as protective clothing testing in accordance with LVS EN 61482-1-2 (IEC 61482-1-2), which in cases where the short-circuit current is higher than 7 kV as well as under middle and high voltage, does not provide sufficient information on the required protection level.

The analysis and study of legislation and regulatory documents associated with labour protection have led to a conclusion that standard IEC 61482-1-2 (LVS EN 61482-1-2) is adapted in the Republic of Latvia, which sets forward the requirements to protective clothing against electric arc exposure. This standard only takes into consideration the spectrum of partially served electric equipment. It is, therefore, necessary to introduce the international standard IEC 61482-1-1, which takes into consideration the actual short-circuit current magnitude and environmental layout of electric devices.

V. References

[1] Birznieks, A. *Extension and improvement of live voltage works carried out by service personnel of electric equipment*: Master's degree thesis / Thesis advisor: V.Ziemelis – Computer typesetting - Riga: RTU, 2012. – 100 p.

[2] Ziemelis, V. *Electric safety. Textbook. Second supplemented edition*. – Riga: RTU Publishing House, 2008 – 233 p.

[3] Ziemelis, V. *Electric safety*. – Riga, Ministry of Higher and Secondary Special Education, 1987. – 112 p.

[4] *Electricity and associated risk factors*. – Riga, LR Ministry of Welfare, 2003. – 27 p.

[5] *Guidelines for selection and use of personal protection equipment*. - Riga: LR Ministry of Welfare, 2003 – 28 p.

[6] *Safety requirements in performance of works on electric equipment*. Latvian energy standard LEK 025. Third edition, 2007. – 119 p.

[7] *Technical operation of power plants, networks and users*. Latvian energy standard LEK 002. Second edition, 2000 – 224 p.

[8] *Use and testing of electric protection means used in electric equipment.* Latvian energy standard LEK 056, 2007 – 52 p.

[9] Stoll, A. M. and Chianta, M. A. *Method and Rating System for Evaluation of Thermal Protection. Aerospace Med*. 40: 1232 - 1238, 1968

[10] Electric arc power calculator http://www.arcadvisor.com/arcflash/ieee1584.html

[11] European parliamnet anc council directive 2012/11/ES

[12] *Special clothing for protection against thermal risks of electric arc; general technical requirements and testing methods*, All-Russian standard GOST R 12.4.234-2007 http://www.z-r-d.ru/electric/110

[13] Labor protection. Lecturesabstract. Part two./ Kozlovs, V., Večena, R., Ziemelis, V.. – Riga RTU. 202. – 116 p.

[14] Fundamentals of industrial hygiene.-4th ed./Barbara A. Plog, editor; Jill Niland, asst. editor, Paricia Quinlan, asst. editor. 1996-1011p. – (Occupational safety and health series). Printed in the United States of America.

Valdis Ziemelis, Electrical and Mechanical Engineer (1970), Faculty of Electrical Engineering, Riga Polytechnic Institute; Mg.sc.ing., Baltic Institute of Futurology Science and Development of New Technologies (2009). He is an Assistant Professor (1998) at the Faculty of Engineering Economics and Management, Department of Labour and Civil Protection. He is a Director of Consultative and Training Centre of Technogenic Safety. He is a President of the Latvian Association of Labour Protection (2006).
Address: 1-114 Kalku Street, Riga, LV–1058, Latvia
Phone: +371 29454252, fax: +371 67089483, e-mail: Valdis.Ziemelis@rtu.lv

Aivars Birznieks, Electrical Engineer (1979), Faculty of Electrical Engineering, Riga Polytechnic Institute; Professional Master Degree in Labour Protection (2012), Riga Technical University. Work experience: Electrical Engineer (1979), Engineer Officer, Labour Protection Specialist (2007) and Engineer Inspector (2009), public limited company Latvenergo, subsidiary Sadales tīkls JSC.
Address: 12 Pulkveza Brieza Street, Riga, LV-1230, Latvia.
Phone: +371 29299657, e-mail: Aivars.Birznieks@latvenergo.lv

Kaspars Ziemelis, Mg.sc.ing. (1995), Mechanical Engineer, the field of production engineering (1993), Faculty of Instrumentation and Automation Engineering, Riga Technical University.
He is a member of the Latvian Association of Labour Protection (2009).
Employment history: 2010 – AME systems Ltd, Member of the Board, Owner; 2008 – Parker Hannifin Corporation, Regional Manager for Baltics; 1996 – Festo Ltd, Operational Manager.
Address: 4 Dunu Street, Jelgava, LV–3001, Latvia
Phone: +371 29215368, e-mail: info@amesystems.lv