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TECHNIQUES OF INTRINSICALLY SAFE CIRCUIT EVALUATION, USED FOR FLAMMABLE GASES DETECTORS DESIGN

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Abstract

This paper gives a brief examination of the basic electrical considerations of power limiting to a safe level, in electric circuit design for the electrical and electronic equipment dedicated to be used in hazardous areas. The article explains how these techniques of intrinsically safe circuit assessment were applied in the design of a flammable gases detectors family developed in IPA, and how these can be used in the future by the developers and manufacturers to gain certification of electrical apparatus or equipment for potentially explosive atmospheres. (Products without an appropriate certification for risk areas, as they are defined in the EU Directive 137, will not legally allowed to be placed on the European market after July 1'st 2003)

Key words: hazardous areas; protection; intrinsically safety-apparatus

1. INTRODUCTION

Previously there has been no mandatory obligation to use certified equipment (or indeed to classify an area as potentially explosive). European Directive 137 *(The protection of workers from potentially explosive atmospheres*) makes it mandatory under European law to assess for an explosion risk and classify the area accordingly. This Directive has recently been ratified and will be mandatory under European law from July 1st 2003. Once an area is classified as potentially explosive, a risk analysis will normally dictate *that only electrical and mechanical equipment that is suitably certified can be installed*. Directive 137 will almost certainly increase the amount of 'Classified or Zoned' areas, and hence increase the demand for certified equipment. The Directive (94/9/EC) ***forces manufacturers to gain certification of electrical and/or mechanical products that can be used in a potentially explosive atmosphere***. Products without the appropriate certification will not legally be allowed to be placed on the European market after July 1st 2003. In order to certificate an electric equipment as "*suitable to be installed in zones classified as potentially explosive*", the design process must obey to some appropriate techniques of circuit assessment.

The article deals with the basic concepts and methodology of explosion protection, and refers to the protection concept "***Intrinsically Safety***" most used in hazardous areas electronic equipment developing. It will be presented how to use basic techniques of intrinsically safe circuit evaluation in electrical and electronic equipment designing, based on an algorithm applied by the authors in developing a flammable gas detectors and a supervising equipment for risk areas.

2. BASIC CONCEPTS OF EXPLOSION PROTECTION

2.1. Definitions and Codes

An explosion is any uncontrolled combustion wave. It appears when there are the following conditions: it has to be fuel (for example and explosive gas such as hydrogen), and oxidizer (such as the oxygen in air) and a source of ignition energy (for example, a hot surface or an electrical spark. These three items are commonly referred to as '*the fire triangle'*. For any mixture of a combustible gas or vapor with an oxidizer there is a critical ignition energy. If one releases less than that critical amount of energy into the mixture, there will not be a self-propagating explosion. At a critical concentration called the *most easily ignited concentration* (MEIC), is minimal the amount of energy required to cause ignition. If the ignition experiment is conducted under conditions where it is assumed that all the energy injected into the gas/vapor cloud is used in the combustion process, the critical energy at the MEIC is called *minimum ignition energy* (MIE). As the concentration is varied from the most easily ignited concentration the amount of energy required to cause ignition increases, until at certain points, the mixture is no longer explosive.

A hazardous area is defined as an area in which explosive atmospheres, or may be expected to be, present in quantities such as to require special precaution for the construction and use of electrical equipment. An explosive atmosphere consists of a mixture of flammable substances with air in the form of *gas, vapor or mist* in such proportions that it can be exploded by excessive *temperatures, arcs or sparks.* The gases, vapors or mists will only explode when mixed with air between specific percentage mixtures, these are called: Lower Explosive Limit (**LEL)** ; Upper Explosive Limit (**UEL**). Hazardous areas are further divided in zones, these zones relate to the predicted occurrence of when an explosive atmosphere may be present in the area. These zones are defined as being [4]:

ZONE 0, where an explosive atmosphere is continuously present, or present for long periods.
ZONE 1, where an explosive atmosphere is likely to occur in normal operation.
ZONE 2, where an explosive atmosphere is not likely to occur in normal operation and if it does occur it will exist only for a short time.

An explosive atmosphere will also have different: auto-ignition temperatures (AIT). The natural grouping of the gases based upon the MESG and MIC values does not bear any relationship to the auto-ignition temperatures (AIT) of the various substances.

The auto-ignition temperature is the temperature, in °C, at which a gas will ignite spontaneously without another source of ignition. Because these temperatures do not correspond with the above groupings, a temperature code was established.

The gas groupings and the temperature codes are reflected in the markings that appear on electrical equipment, which has been certified for use in a hazardous area. The marking of the gas grouping and temperature code on the equipment identifies to the user the type of explosive atmosphere in which it can be safely installed.

There are eight commonly recognized concepts of protection within Europe: Flameproof; Intrinsically Safety – Apparatus Or System; Pressurization; Increased Safety; Oil Immersion; Type N Protection (Non-sparking); Powder/Sand Filling ; Encapsulation. These are detailed in the European EN50 series of Standards; ***'electrical equipment for use in explosive atmospheres'***. These methods of protection have, over the years, been added to and expanded to satisfy the new equipment designs that have appeared.

In this paper we refer to the protection concept "*Intrinsically Safety*" most used in hazardous areas electronic equipment developing, and how to use basic techniques of intrinsically safe circuit evaluation in electrical and electronic equipment designing.

2.2. ***Intrinsically Safety Protection Concept***

Intrinsically Safety – Apparatus or System Protection Concept (*European harmonized Standard EN50 020.*) is a protection technique based upon the restriction of electrical energy within the apparatus and in the interconnecting wiring, exposed to a explosive atmosphere, to a level below that which can cause ignition by either sparking or heating effects. Its chief advantage over the alternative techniques is that it allows live working to be carried out in the presence of flammable atmosphere, subject to local operating practices and work permit system. An intrinsically safe equipment uses principles that electrical energy within the installation is insufficient to ignite a surrounding flammable atmosphere, even under prescribed fault conditions. The rules which govern the allowable levels of voltage and current for a given hazard are well established and are published as "*ignitions curves*". (Fig. 1 and Fig.2). [2]. The safety of an intrinsically safe equipment considers the compatibility of the separate items of apparatus and the cables used to interconnect them. The compatibility assessment ensures that no items of apparatus is subjected to higher levels of voltage, current or power than was accounted for when it was certified. The total energy storage in unsuppressed capacitance and inductance, in individual devices and interconnecting cables, is also taken into account.

The concept is divided into two sub types, which are dependent upon the number of allowable fault conditions. The symbols '*ia*' and '*ib*' denote the sub types.
This design concept is reflected in the equipment marking by the symbols 'Ex ia' or 'Ex ib'. In electrical circuits the mechanism for the release of the ignition energy is one or more of the following:

- Open circuit or short circuit components or interconnections in a resistive circuit
- Short circuit of components or interconnections in a capacitive circuit
- Open circuit components or interconnections in an inductive circuit
- Ignition by hot surfaces

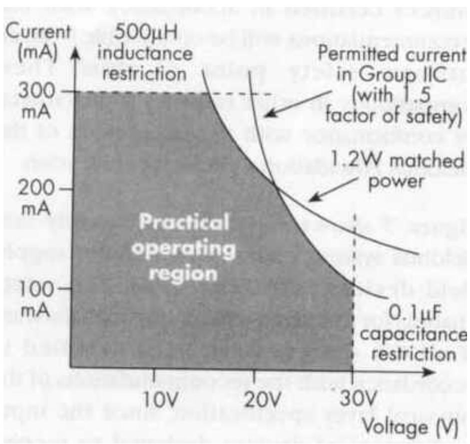

Fig. 1. Practical operating region for intrinsically safe circuits

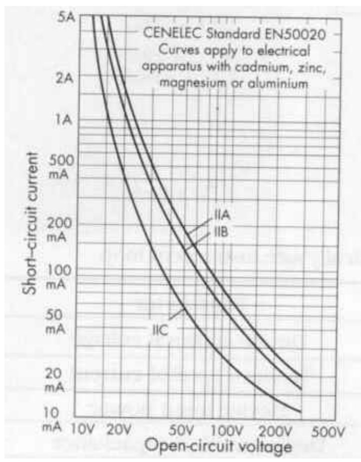

Fig. 2. Ignition curves for resistive intrinsically safe circuits

3. TECHNIQUES OF INTRINSICALLY SAFE CIRCUIT EVALUATION

3.1. Assessing the resistive circuits

In a circuit that is non-reactive (quasi non-inductive/capacitive) there is no stored energy to be released in an arc. The main consideration, therefore, is the amount of energy in the circuit. The power provided to intrinsically safe equipment is normally derived from batteries, a Zenner barrier or a galvanic isolator. Barriers are widely used in intrinsic safety to allow connection to power supply lines. They are used to limit both voltage and current (and hence power) into the hazardous area equipment. If a circuit can be proven to have no means of dissipating stored energy, and the voltage and current to it were proven to be safe, then the circuit will be safe electrically. The thermal data of components would still need to be assessed so that ignition could not occur due to their heat in operation.

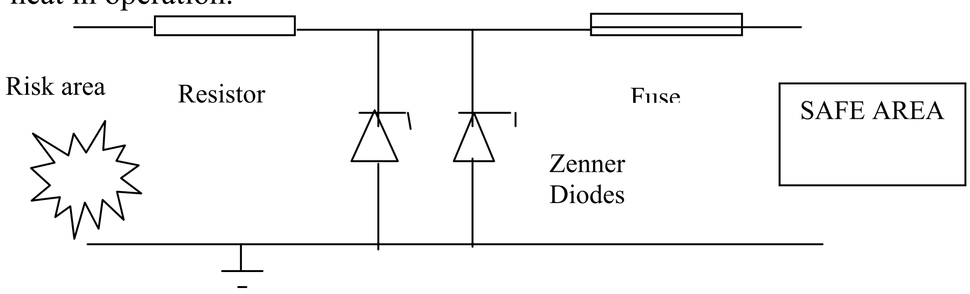

Fig.3. Typical barrier

3.2. Assessing the reactive circuit

Stored energy in capacitors that could be released as a spark is an obvious problem. Two types of capacitance are considered for analysis, capacitance that can discharge without resistance and capacitance that can only discharge through resistance.
The worst case condition is if all the circuit capacitance was connected in parallel at worst case tolerance. The total resistance added in parallel at worst case tolerance would give the least resistive protection. This will then give the largest capacitance with the lowest amount of resistive safety. A typical equated circuit is shown below.

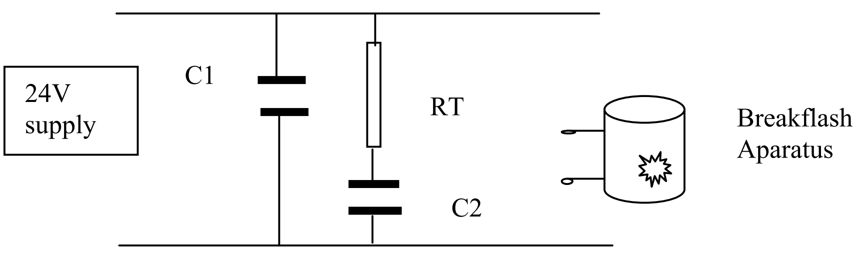

Fig.4 A typical equated circuit

Cl = All circuit capacitance not through resistance added (with tolerance added)
C2 = All circuit capacitance through resistance added (with tolerance added)
RT = All circuit resistance acting on C2 added in parallel (with tolerance subtracted)
These simplified values could then be checked against graphs of collated test data to see if there is a dangerous condition.

3.3. Practical circuit evaluation

In a practical circuit it may be found that when all components are added in their worst case combinations, the circuit is found to be ignition capable. The practical operating region for intrinsically safe circuits is shown in Fig.1, where the usable region is bounded not only by the ignition curves but also by limitations imposed by stored energy at highers levels of voltage and current and by matched power restriction (typically 1.2 W at 60ºC) to govern surface temperature. These factors define an operating region below about 30V, 300mA and 1.2W for a typical intrinsically safe circuit. A circuit can be made safe by employing various design techniques.

In order to make a correct evaluation of the circuit design, we propose ***an algorithm*** to be applied in the development of an electronic device to be used in hazardous areas.

a) Step 1: Assessing if all the electrical circuit components fulfill the requirements imposed by the following techniques used in intrinsic safety design:

Types of protection used in intrinsic safety design [4]

• Zenner diodes must be used within 2/3 of all their specified ratings. Clearance distances would have to comply with table values and duplicated diodes would be employed.

• Diodes are used when blocking is required, they must be used within 2/3 of their ratings and be either duplicated for redundancy.

• Resistors would be used to dissipate power and limit current. They are often employed to limit the instantaneous release of charge from capacitors. They would also have constructional requirements.

• Capacitors can be used as safety components for blocking DC voltages, but must be duplicated in series. Electrolytic and tantalum capacitors can not be used, and capacitors that are used are required to pass specific high voltage tests.

• Fuses must be potted if it is used in a hazardous area. It must have a breaking capacity of 1500A (so as not to conduct after breaking) if it is used to protect a main's transformer. It limits power only and is not used to limit instantaneous current.

• Transformers and opto-couplers can isolate intrinsically safe from non-intrinsically safe circuits. They are subject to creepage and clearance requirements and special tests, such as high voltage break-over tests on transformers.

b) Step 2: Assessing if the device circuit electrical parameters are in the limits recommended for certification (*for a specified certification code*)

Parameter	Recommended value
Device voltage	24Vcc
Device current	250 mA
Device residual capacitance	Less than 5 nF
Device residual inductance	Less than 20uH

Table 1. Example of recommended certification parameters for field devices in hazardous area (certification code Eex ia IICT4)

Parameter	Recommended value
Open circuit voltage	Max. 24 V
Short circuit current	Max. 250 mA
Matched output power	Max 1.2W

Table 2. Example of recommended certification parameters for power supply for field devices (certification code Eex ia II C)

c) Step 3*:* Assessing if are fulfilled the device electrical circuit temperature requirements of an intrinsically safe circuit

(*For the simplification of temperature assessment, EN 50020:1994 states that small components from 20mm^2 to 10cm^2, that can draw a maximum power of 1.3W can be* *said to have a maximum temperature of 200^{0}C. If the component is less than 20mm^2 then it can be given a maximum temperature rating of 275^{0}C).*

d) Step 4: Assessing if there are fulfilled the requirements for Connections to others devices .

(When calculating the maximum safe values of reactive components consideration must be given to the capacitive and inductive values of any cable that may be required to connect to the circuit. A value of capacitance and inductance must be stated as a maximum allowable connection value to the intrinsically safe circuit).

If all the above mentioned requirements (in *step1 ...step4*) are fulfilled, the device can be considered as "intrinsically safe".

4. INTRINSECALLY- SAFE FLAMMABLE GAS DETECTOR

The evaluations techniques that are presented above, were considered and applied at IPA Cluj in the development of an flammable gas detector,[1](based on Figaro TGS2611 methane gas sensor), and in designing of a supervising system for potentially flammable atmospheres in risk areas. The detector have to be used in hazardous areas as a field device (*certification code EEx ia IIC T4*) and can be integrated in the supervising system.

Basic detector circuit for gas detection is is composed of:

- Gas detector circuit module (using Figaro TGS2611 methane gas sensor)
- Temperature compensation circuit
- Heater malfunction detection circuit
- Sensor malfunction detection circuit
- Antichattering circuit;
- Alarm delay circuit

The circuit is operating with low power (12Vdc) and acceptable temperatures (max 55ºC), and the device power is less than 1.2W, so that it does not have the required energy to ignite a flammable atmosphere. This is obtained of the types of used circuit (relatively low cost) and of the design techniques employed. The device is "*intrinsically-safe*".

5. CONCLUSIONS

Intrinsically safety is dependent on a circuit operating with low power and acceptable temperatures so that it does not have the required energy to ignite a flammable atmosphere. This can be obtained for most types of circuit at a relatively low cost if certain design techniques are employed. When designing or certifying an intrinsically safe circuit, all possible scenarios for connections of components are considered (unless they can be proven infallible) and many safety factors have to be included when calculating the safe circuit parameters. It is this combination of factors that allows intrinsically safe electrical equipment be sited in the most hazardous areas

5. REFERENCES

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