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Analysis of the intrinsic safety for the installation of electrical and electronic devices onboard ship

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Abstract. Preventing a dangerous situation on board a ship which is responsible for transporting flammable cargo is an important requirement in ensuring the ship's navigation and the protection of the ship's personnel. Thus, when installing electrical and electronic devices / equipment in a hazardous area, select that devices / equipment intended to operate in that area and to ensure that any thermal effect under normal conditions of use, operation and specified damage, may not cause the atmosphere in the area to ignite. The paper presents an analysis of the intrinsic safety in order to highlight the characteristics as well as the requirements for the installation of electrical and electronic devices / equipment in hazardous areas on board.

1. Introduction

Ensuring the safe transport of liquefied gases by sea-going vessels involves taking the necessary measures to prevent an explosion on board. Thus, the elements that are taken into account in the construction of such a ship are: type of cargo to be transported, conditions of transport (fully pressurized, semi-pressurized, fully refrigerated), type of trade and flexibility of handling cargo on board, terminal facilities available for loading and unloading the ship.

The construction of ships intended for the carriage of liquefied gases and the equipment used on board them shall be governed by:

- chapter VII of the International Convention for the Safety of Life at Sea (SOLAS), 1974 (Carriage of dangerous goods);
- Resolution MSC.5(48) – IGC Code (International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk), as amended;
- IBC Code (International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk), adopted by the Maritime Safety Committee of the Organization by resolution MSC.4(48), as amended;
- IEC 60092-502, Electrical installations in ships – Part 502: Tankers – Special features;
- the rules of the ship classification societies (for guidance on the requirements of IGC Code).

The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk applies to ships built after 1.07.1998, regardless of their size, including those with a gross tonnage of less than 500 tons engaged in the transport of liquefied gases with a vapor pressure exceeding 2.8 bar absolute at 37.8 ° C and other products covered by this Code when transported in bulk [11].

The on-board gas storage system provides: primary barrier (cargo tank), secondary barrier (if provided), thermal insulation, intermediate spaces, structural elements to support the entire system [3].

The existence of hazardous areas on board ships (areas where there is or may be an explosive gaseous atmosphere) requires that the necessary measures be taken regarding the installation and use of electrical equipment and the protection of personnel.

Hazardous areas that may be encountered on board a ship carrying gas may be: inside the cargo tank, pressure relief pipes, ventilation systems, barriers, spaces between the hull and the cargo tank acting as a second barrier, spaces intended loading systems, vents in the space intended for loading systems, areas delimited by distance from certain elements with a high risk of explosion (for example, areas on the open deck or semi-enclosed spaces on the open deck at a distance of 1, 5 m from the entrances to the loading area, open deck areas above the cargo area and 3 m ahead and the stern of the cargo area on the open deck to a height of 2.4 m above the weather deck, an area located at a distance 2.4 m from the outer surface of a load isolation system, if this surface is exposed to the weather) etc. [2, 3, 6, 9]. All these areas can be grouped into:

- zone 0 - where an explosive atmosphere is present continuously or for long periods;
- zone 1 - where an explosive atmosphere is possible during normal operations;
- zone 2 - where an explosive atmosphere is unlikely, may occur or will only exist for a short period of time.

2. Intrinsic safety - requirements for electrical and electronic devices installation

Intrinsically safe (IS) can be defined as the safe operation of electrical / electronic devices / equipment in explosive atmospheres, in the sense that any spark or thermal effect under specified normal operating and emergency conditions cannot cause a specified explosive atmosphere to ignite. Ensuring intrinsic safety can be achieved by using circuits (Zener Barriers, Galvanic Isolators) that protect the circuit in the hazardous area from exposure to harmful voltages and / or currents from sources in safe areas, ie prevent accidental connection of a supply voltage to a device installed in a hazardous area, the intrinsic circuit must also be protected against electric and magnetic fields.

Some of the benefits of using IS devices are [1, 2]:

- intrinsic safety is a technique accepted in all local legislation in the field (e.g., ATEX and OSHA Directives) and equipment made in accordance with the standards / norms in this field ensures a high protection of areas with danger of explosion;
- the circuits are installed in a non-explosion resistant housing, the maintenance personnel thus having access to the system components;
- the circuits are low voltage which determines the protection of the personnel;
- no safety permits are required for their maintenance;
- standard wiring methods and materials may be used (e.g., no explosion-proof enclosures or connecting elements required), etc.

According to IEC 60079-11 the intrinsic safety levels are:

- „ia” - under normal operating conditions, the device does not start ignition if a combination of two faults occurs (permissible zones 0, 1, 2);
- „ib” - under normal operating conditions, the device does not start ignition in the event of a fault (permissible zones 1, 2);
- „ic” - under normal operating conditions, the device is not capable of causing ignition (permissible zone 2).

Regarding intrinsic safety, the following 3 elements can be considered: intrinsically safe devices used in hazardous areas, intrinsically safe associated equipment (e.g., Zener Barriers, Galvanically isolated barriers / Isolators) and interconnecting cables, Figure 1.

The parameters that are considered in these elements for the sizing of intrinsic safety are [8]:

- for intrinsically safe devices used in hazardous areas - maximum values of the following parameters: input current, input voltage, input power, internal capacitance, internal inductance and the ratio between internal inductance and internal resistance;
- for associated devices - the maximum values of the following parameters: output current, output voltage, output power, external capacitance, external inductance and the ratio between external inductance and external resistance;
- for interconnecting wiring - capacitance and inductance of interconnecting wiring.

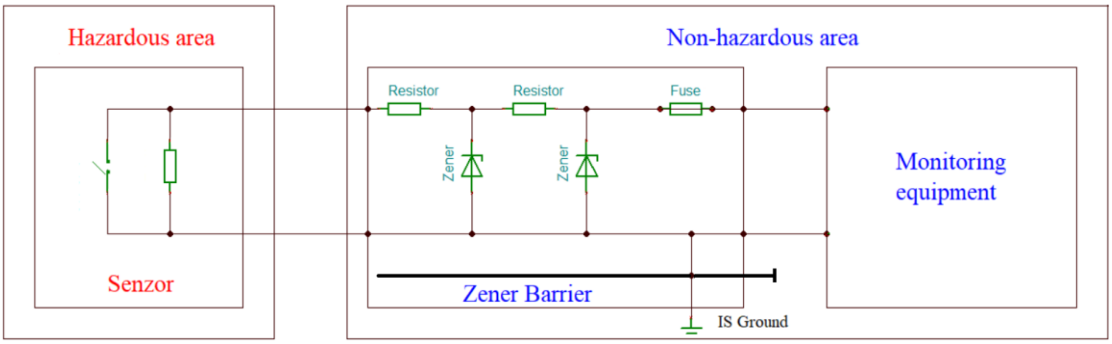

Figure 1. Zener Barrier

The selection and installation of these elements is done after the zones in which a potentially explosive atmosphere may occur have been classified, the access points to these zones have been identified and there is certainty that the minimum security requirements for those zones can be met. Intrinsically safe devices / devices and associated intrinsically safe devices / devices are in the „ia" or „ib" category. For zone 0, the intrinsically safe device / apparatus and associated equipment must comply with IEC 60079-11, category „ia". The standard stipulates that galvanically isolated devices / devices are preferable between intrinsically safe and non-intrinsically safe circuits, as a single failure of the equipotential bonding system could, in some cases, lead to an explosion hazard.

The requirements for selecting electrical devices / equipment to be installed in hazardous areas are as follows [11 - 14]:

- electrical and electronic devices / equipment installed in a hazardous zone must be certified for installation in that zone (electrical and electronic devices / equipment certified for installation in an zone may also be installed in zones with lower requirements);
- the type of Ex protection must comply with any requirements for the area concerned;
- electrical and electronic devices / equipment and cables are not installed in hazardous zones unless they are essential for operational purposes and when the relevant regulations allow it;
- the gas group and temperature class of the electrical equipment must be in accordance with the relevant requirements for gas or vapors that may be present [9].

Electrical and electronic devices / equipment shall be installed on board ships in such a way as to minimize the risk of fire and explosion from flammable products and shall be installed in accordance with IEC 60092-502, Electrical installations in ships - Part 502: Tankers - Special features. Also, electrical equipment or cables must not be installed in hazardous areas, unless they are essential for operational purposes or to improve safety.

In order to install electrical and electronic devices / equipment on board a gas carrier, the following general requirements and specific requirements for installation in a hazardous area shall be observed [3 – 5, 7, 9, 10]:

- general requirements:
  - electrical and electronic devices / equipment must be permanently and securely installed from an electrical point of view [15];

- ensuring electromagnetic compatibility with other electrical and electronic devices / equipment installed in the same electromagnetic environment;
- electrical and electronic devices / equipment must be placed in accessible places, so that when manual operation is required it can be performed;
- electrical and electronic heat dissipation devices / equipment shall be installed in such a way that, at high temperatures, they do not damage the cables and associated cables or damage the surrounding material or equipment and thus become a fire hazard [15];
- the installation of electrical and electronic devices / equipment must be carried out in such a way that the airflow to and from them or the associated enclosures is not obstructed (the temperature of the ventilation / cooling air must not exceed the ambient temperature for which the device / equipment was produced and tested);
- compliance with the installation requirements provided by the device / equipment manufacturer.

- specific requirements [5 – 8, 10, 16]:
  - electrical and electronic devices / equipment are firmly installed at the place of installation;
  - the power and signal cables are connected by crimping, preventing their disconnection and the occurrence of a short circuit;
  - shielded signal and power cables are used and protected to prevent mechanical damage (in the event of mechanical damage, the cables must be of such a length as to allow the connections to be reconnected at least once);
  - disconnection of the shields / metal protection of the cables is done in such a way as to eliminate the earthing loops.
  - cables installed in hazardous areas must have a non-metallic waterproof outer protection;
  - the power and signal cables installed in zones 0 and 1 must have a metal shield (metal braid) between the conductors and the waterproof protection (the cables in the composition of a certified safety device must not have a metal shield);
  - multi-pair cables, for intrinsically safe circuits, must have a metal shield (installation in all areas) and, in addition, have individually shielded pairs, unless all the following elements are observed - the cable must be installed as fixed installation, mechanically protected, the circuit voltage must be less than 60V, the cable is type approved;
  - flexible cables for circuits that are not intrinsically safe must not be installed in hazardous areas and must not be used permanently in zone 1, unless this is necessary for operational purposes;
  - in zone 2 a short flexible cable can be used to connect the devices / equipment to the connection boxes;
  - cable penetrations through bulkheads and decks shall be gas-tight and shall be type-approved when used as a seal between or between hazardous and non-hazardous areas;
  - shields or enclosures in intrinsically safe circuits must be earthed at both ends and also grounded at intermediate junction boxes or panels, as appropriate (where grounding at both ends is impractical, it may be earthed only one);
  - the screen of the cable with a single pair or with several pairs, is connected to the ground in the non-hazardous area only at the end from the barrier;
  - connections for intrinsically safe and non-intrinsically safe circuits must be separated by a physical distance of 50 mm or by a grounded metal shield;
  - conductors for circuits of category ,,ia” intended for zone 0 and conductors for circuits of category ,,ib” will not be part of the same cable;
    conductors for intrinsically safe circuits and conductors for circuits that are not intrinsically safe will not be part of the same cable;
  - inside metal housings / cabinets, shielded circuit cables that are not intrinsically safe may be placed in the same metal channel or pipe as intrinsically safe designed circuit cables. If the parallel length between unshielded conductors in intrinsically safe circuits and

conductors that are not intrinsically safe is less than 1m, it is not necessary to distance them and for lengths greater than 1m, the distance between the 2 conductors must be at most at least 50 mm or a grounded screen is inserted between them.

Devices / appliances without galvanic isolation (e.g., Zener barriers) associated with the intrinsically safe device installed in the hazardous area may only be used if [8]:

- are connected to earth through a system of equipotential bonding system the shortest possible connection; or
- are connected to a high-integrity grounding point, so that the impedance from the connection point to the grounding point of the main power system is less than 1Ω (only for TN-S systems);

The earthing connection may consist of at least two separate copper conductors, each with a cross-section of 1.5 mm2, or - at least one copper conductor with a cross-section of at least 4 mm^2 [8].

All earthing connections must have the following properties:

- low impedance at high frequency;
- the shortest possible length (low inductance);
- vibration resistance of connectors and conductors;
- corrosion resistance;
- access for routine inspection.

All points of contact must ensure safe contact, without paints, oxides or other insulating layers.

Analyzing Zener Barriers we can say that they are intrinsically safe, because they are made without components that will produce sparks or can accumulate enough energy to produce a spark, which makes only low voltages (less than 30 V) and currents (less 50 mA) to enter the hazardous area and all power and signal wires are protected by Zener safety barriers, Figure 1.

Safety and operational features are described for Zener barriers. Safety characteristics refer to the output voltage and current in overvoltage or fault conditions in the safety zone, important features to securely connect the barrier to an IS circuit, and the operational characteristics are those necessary for the design of the distortion-free signal transmission circuit so the system as a whole must be secure and work properly.

Regarding the signal protection of the device installed in a dangerous atmosphere, compared to Zenner Barriers and Isolators, Zenner Barriers ensure a low rejection of the common mode while the insulators ensure a high rejection, which determines a special attention to the installation of barriers.

The intrinsic safety of a Zener Barrier can be compromised due to:

- mechanical damage;
- non-compliance with the installation instructions or unauthorized modification of the installation mode;
- high humidity or dust at the installation site (damage to the protective housing);
- increase of the ambient temperature above the allowed level;
- connecting non-intrinsically safe circuits to intrinsically safe circuits.

3. Safety factor and analysis of Zener Barrier

An intrinsically safe circuit / device must meet three basic requirements:

- it must achieve adequate separation from other circuits / devices;
- it must be rated according to operating temperature to ensure that ignition is not a result of hot surfaces (estimation of the maximum surface temperatures of components taking into account their thermal behavior and the maximum power to which they are subjected under appropriate fault conditions);
- when the circuit / device is tested or evaluated no spark ignition shall occur.

To evaluate a circuit/device the following steps are taken:

- determine the most dangerous situation for its operation taking into account component tolerances, voltage variations, probability of failure of its components and insulation degradation;

- determine the appropriate safety factor according to the type of circuit/device, the electrical apparatus group;
- check that the parameters of the circuit/device are meeting the intrinsic safety conditions (e.g. the current through the circuit, depending on the protection level „ia”, „ib”, „ic” and the safety factor corresponding to the protection level will not cause a spark ignition).

Taking into account the safety coefficients according to the levels of protection, Figures 2 and 3 shows the permissible short-circuit current corresponding to the voltage and the apparatus group for a simple inductive circuit, Figure 4 [7].

- protection level „ia" - the safety coefficients are 1.5 in normal operation and with one fault and 1 in normal operation and with two faults;
- protection level „ib" - safety factors are 1.5 in normal operation and with one fault and 1 in normal operation and with two faults, if the equipment does not contain unprotected spark-generating contacts;
- protection level „ic" - safety coefficient is 1.

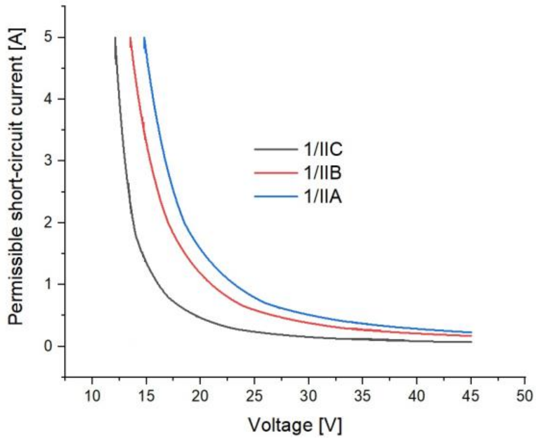

Figure 2. Permissible short-circuit current for safety coefficient 1 and Group IIC/B/A apparatus

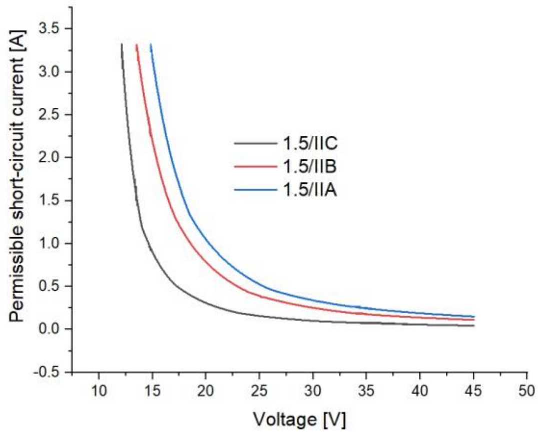

Figure 3. Permissible short-circuit current for safety coefficient 1.5 and Group IIC/B/A apparatus

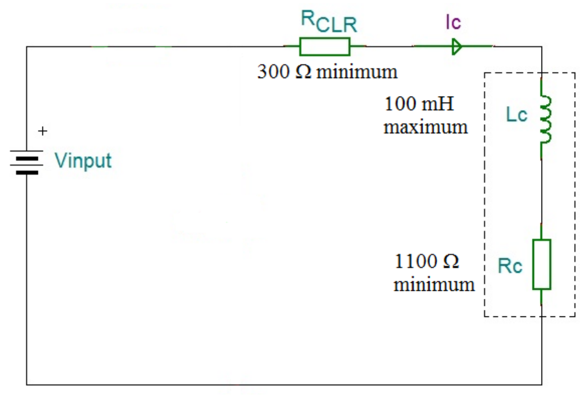

Figure 4. Simple inductive circuit

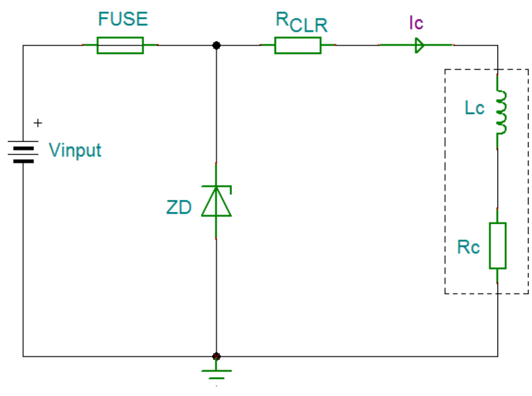

Figure 5. Single channel Zener Barrier

The stabilizing voltage of the Zener diode determines the current through the circuit, limiting it is done by the R_{CLR}, Figure 5 and Figure 6. Keeping the R_{CLR} constant (300Ω) and having a stabilizing voltage variation (for example) of 5.1V, 6.2V, 7.5V, 8.2V, 9.1V, 10V, 11V, 12V, 13V and 15V, we observe an increase of the current through the circuit as a function of the stabilizing voltage and the input voltage increase. In this case for a given stabilization voltage the current limiting is performed by the R_{CLR} (V_{ZD} = 9.1V), Figure 7.

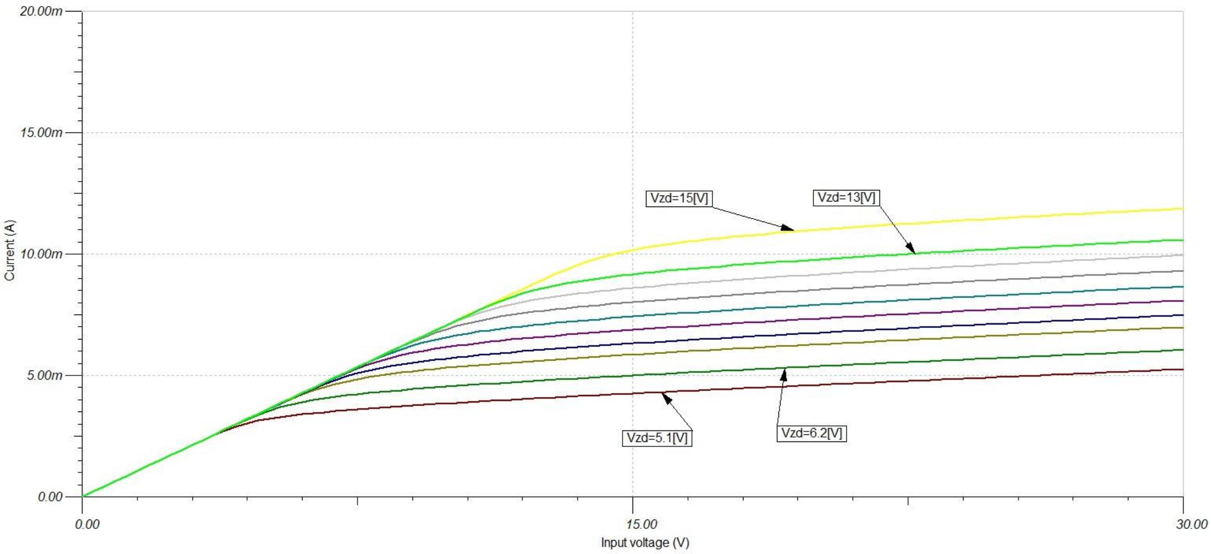

Figure 6. Current through the circuit as a function of stabilizing voltage

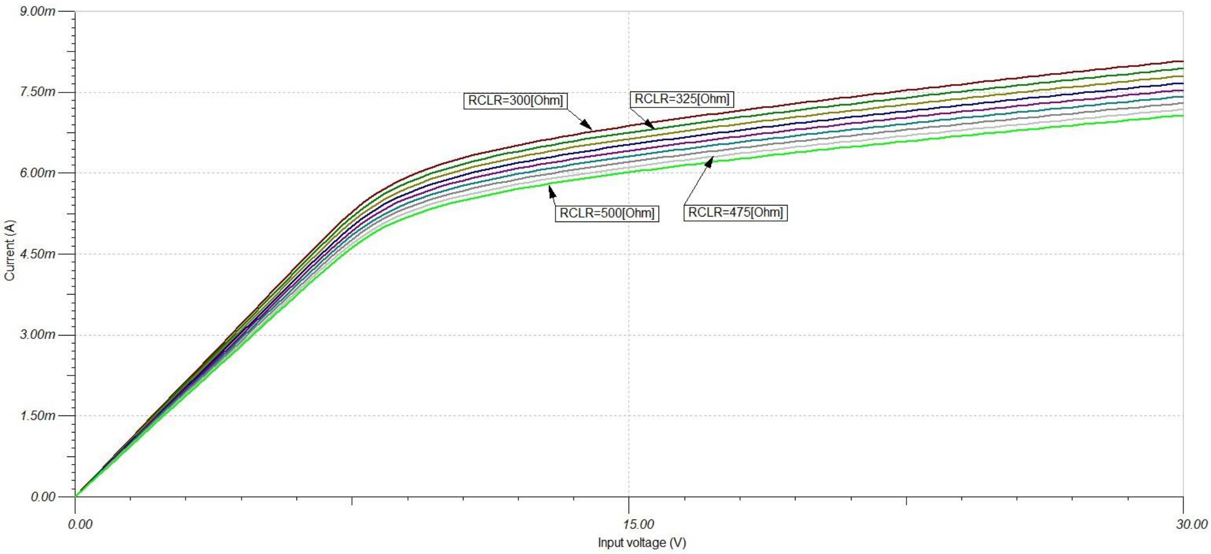

Figure 7. Current through the circuit as a function of variation of R_{CLR}

The variation of short-circuit current as a function of R_{CLR} for V_{ZD} = 9.1V is shown in Figure 8, (R_{CLR} = 300 ÷ 500Ω, ΔR_{CLR} = 25Ω).

The introduction of a Zener barrier limits the energy transmitted into the hazardous area by limiting the voltage across the circuit and limiting the current (short circuit current) by the RCLR resistor, Figure 8.

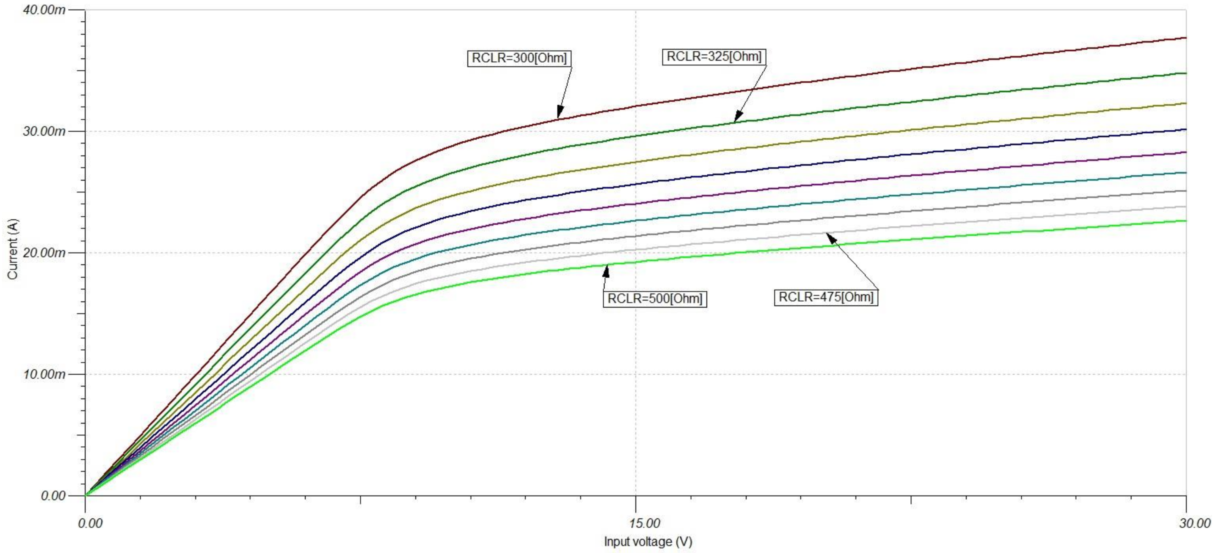

Figure 8. Variation of short-circuit current as a function of R_{CLR}

4. Conclusions

Electrical and electronic devices shall be installed in such a way as to minimize the risk of fire and explosion of the flammable products carried. High protection of potentially explosive atmospheres is achieved by intrinsically safe protection of the circuit in the hazardous area against exposure to electromagnetic disturbance from sources in safe areas. Circuits separating the two areas with different potentials for occurrence of an event and the way in which they are installed may increase the risk of an explosion on board.

Zener Barriers are intrinsically safe, because they are don't have components that will produce sparks or can accumulate enough energy to produce a spark, which makes only low voltages and currents to enter to the hazardous area.

References

[1] Bottrill, G., Cheyne, D., Vijayaraghavan, G., Practical Electrical Equipment and Installations in Hazardous Areas, Newnes, 2005.

[2] McMillan, A., ElectricaI Installations in Hazardous Areas, Butterworth-Heinemann, 1998.

[3] McGuire, J., White, B., Liquefied Gas Handling Principles on Ships and in Terminals, Third Edition, McGuire and White, 2000.

[4] Torben Jespen, ATEX - Explosive Atmospheres - Risk Assessment, Control and Compliance, Springer International Publishing, 2016.

[5] IEC 60079 -1, Electrical apparatus for explosive gas atmospheres - Part 1: Flameproof enclosures „d”.

[6] IEC 60079 -10, Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas.

[7] IEC 60079 -11, Electrical apparatus for explosive gas atmospheres - Part 11: Intrinsic safety „i”.

[8] IEC 60079 -14, Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas.

[9] IEC 60092-502, Electrical installations in ships – Part 502: Tankers – Special features;

[10] IEC 60533, Electrical and electronic installations in ships - Electromagnetic compatibility (EMC) - Ships with a metallic hull

[11] IMO, Resolution MSC.370(93), Amendments to the International code for the construction and equipment of ships carrying liquefied gases in bulk (IGC Code).
[12] IMO, Resolution MSC.5(48) – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).
[13] IMO, MSC.4(48) - International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC Code), as amended.
[14] IMO, MSC.1/Circ.1557, Hazardous area classification.
[15] IMO, SOLAS 1974 - Safety of Life at Sea.
[16] DNV GL, Rules for classification – Ships, Part 4 Systems and components, Chapter 8 Electrical installations, 2018.