The Requirement to Increase the Quality of Power Electronics in Warships

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Abstract—**Today's and future warship electrical systems are very different from traditional warship electrical systems in the past. Power electronics, which are found in systems such as propulsion systems, power distribution systems, auxiliary systems, weapon systems, sonar and radar systems, is the most fundamental difference in warship design. The technical specs also vary in parallel with the development of materials used in power electronic elements. Analysis results, which vary with respect to volume, yield and temperature, change more and more in a positive manner. However, what we cannot see in the positive sense of change in the power electronics technology is the inaccuracies that arise from experience. These faults are usually due to design faults, the interference caused by the switching elements such as IGBT, tristar and triac used in power electronics, current harmonics, voltage harmonics, malfunction of sensitive devices due to AC and DC leakage in the warship's body. To prevent this, it is necessary to develop systems using power electronic elements which will not interfere with the operation of the system but may prevent them from these faults.**

Index Terms — **Capacitor, Electronic, IGBT (Insulated Gate Bipolar Transistor), Fault**

I. INTRODUCTION

VERY DIFFERENT from civilian ships, design of warships can be seen as a work of art due to the requirement of a dense usage of devices, the possession of a large number of complex systems, the survival conditions and their dependence on each other [1].

Similar to the terrestrial power system, naval warships have employed electrical power systems for over 100 years [2]. The design philosophy for naval power systems is expressed as follows: The primary aim of the electric power system design will be for survivability and continuity of the electrical power supply. to insure continuity of service, consideration shall be given to the number, size and location of generators, switchboards, and to the type of electrical distribution systems to be installed and the suitability for segregating or isolating damaged sections of the system [3].

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Manuscript received August 28, 2018; accepted January 17, 2019.
DOI: 10.17694/bajece.455424

Electrical power systems did play a big role in the design of warships. The first change occurred with the introduction of electrically propelled warships. A further major push originated from the introduction of the concept of the all-electric ship proposed by the U.S. Navy. The key technology that has really changed the design options is power electronics and, in particular, the idea of a power electronic building block. The all-electric ship, at least as design concept, is one of the first real power-electronics-based power system that was ever considered [4-6].

A modern warship designed with today's technology and the technological equipments used in it are presented in Figure 1.

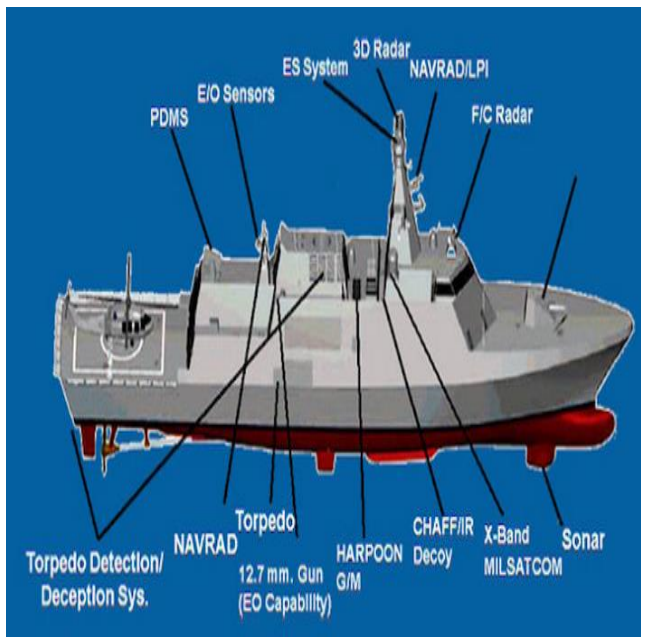

Fig.1. Modern warship and its technological equipments

The warships, which have been designed and launched in recent years and started to be produced in series, now contain quite a lot of electronic systems [7]. More electronic equipments have begun to be used because of the technological requirements such as reducing the number of personnel required, improving the efficiency of the device's survival, and facilitating the execution. Valves for control and control purposes are normally opened and closed by personnel for 10 years or even today [8]. But in newer systems, as seen in Figure 2, valve systems are opened and closed electrically at remote locations and can be seen on the machine control, on the bridge, on the open bridge, or on the scada screen [9]. Similarly, instead of mechanical governors electronic governors are used in order to get more efficiency from the propulsion machines and generators to reduce the fuel consumption and increase cruise range [10-16].

Fig.2. Examples for traditional and new technological equipments

Main engines and related machine control systems, communication systems, some communication devices, radar etc. used in civil ships are commercial products. They are not only used in civil ships but also in warships after modification for usage in warships. All of the vital components of warships, such as communication, fire control, war systems, navigation systems, machine control systems, require 24 VDC. To be able to use these type of devices globally, even when the power is cut off, the control systems part is generally operated with 24 VDC in order to prevent the energy requirement from being cut down by providing the energy requirement from the battery.

The need for 24 VDC in warships is fulfilled with AC/DC converters and these devices are designed to backup each other. If the current protection does not work, a voltage elevation that may occur at the output of the 24 VDC source may damage all devices that are fed by itself as a result of domino effect. The damage of the vital components may result in sinking of the warship and this may cause the loss of war. [17-19]

II. PROPOSED METHOD

There are two important components that can fail in the power electronics: electronic filtering capacitors and controllable power semiconductors (MOSFET and IGBT) [20]. The increase in the need for power electronics has led us to increase the quality of the power electronics. The capacitors and MOSFETs used in the power electronics have started to lose their technical values temporarily depending on the operating conditions. Related international shipbuilding enterprises has not yet proposed a system to protect against instantaneous change of devices.

Input voltage used on board having 440VAC 60 Hz output 30A 24VDC single output AC / DC converter is shown in Figure 3 and its open circuit diagram in Figure 4.

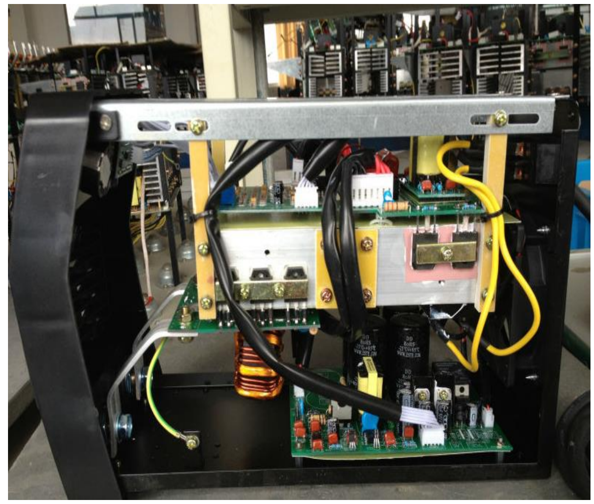

Fig.3. AC/DC converter

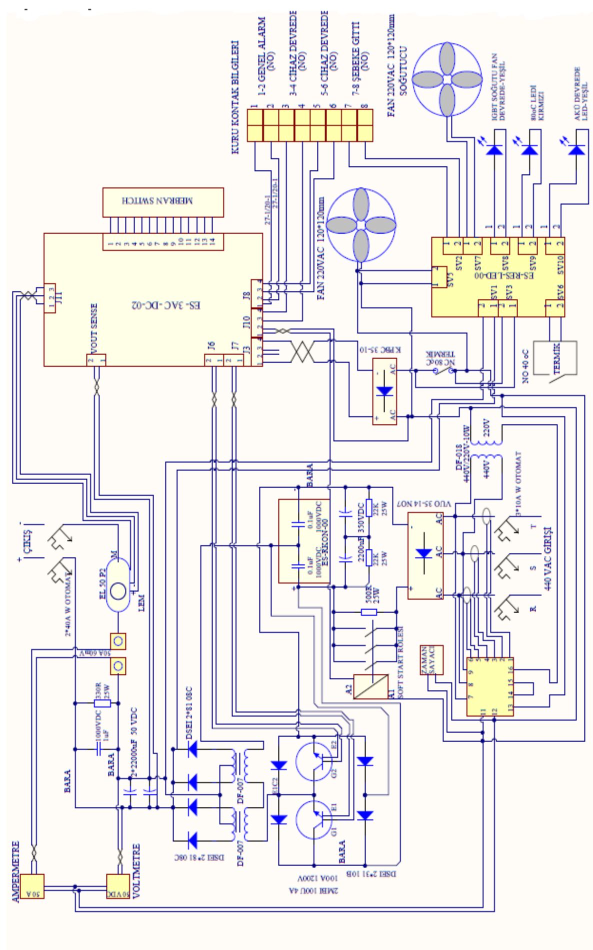

Fig.4. Open circuit diagram of AC / DC converter with 380 VAC 50 Hz / 24 VDC at 15 kVA

Because of the IGBT structure at the output of the AC / DC inverter shown in Figure 4, the latching of the microprocessors used in these systems may cause the inverter to generate an instantaneous 50-55 VDC voltage due to the wrong control signal sent to the power elements. This situation is based on a real scenario in life. In this case, we will see that 24 VDC power units of all devices powered by 24 VDC in the warship suffer from damage as there is no protection against instantaneous 50-55 VDC of the devices supplied by the device. After this situation, the warship becomes an easy target. This scenario unfortunately happened in the past.

We designed a voltage protection card that can protect the device from instantaneous voltage surges due to the sudden high DC stress-free protection of the systems that require 24 VDC from the input sources. The aim is to protect this card, which is intended to prevent the malfunction of the devices, and to protect the ability of the ship to move and strike.

The open circuit diagram of the voltage protection card is presented in Figure 5.

III. DETAILS OF THE OPEN CIRCUIT DIAGRAM

The purpose of this circuit is to stabilize the device supply voltage by trimming the rising voltage of the devices, which are fed to the high-voltage-supply devices, that rise above the critical voltage level of 33 VDC, which is the critical level voltage of the precision electro-static devices, provided that the 24 VDC voltage is fixed instantaneously or permanently due to any reason, the operation is kept at 24 VDC so that the operation of the device or devices is maintained.

All of the electronic systems (navigation systems main control systems, battle systems, etc.), that we experienced in the past years, have experienced the burning of all systems by raising the 24 VDC system voltage, which is a high voltage resulting from the ship. This is because the operating voltage of the electronic systems used in the new type warships is max 33 VDC and in these systems the operating voltage of 24 VDC is not controlled in any way and the voltage level is not protected but the system is not protected. It has become a necessity to prevent such incidents in our new type warships.

Our aim is to minimize the likelihood of failure in such events and to prevent ships from becoming inactive. Because, the damage caused by these events is too high to be underestimated. However, with this system that we designed, we will have a chance to overcome these events at a very low cost. The cost of repairs of new types of warships, as well as the cost of operation and cost of tackling, as long as the operating costs are defective, will also be seen if the time taken for the ship to be active is calculated. For this reason, we proposed that this design must be used in all warships very soon. In addition, the cost of a module will not even be a problem in the face of enormous damage.

The circuit is powered from the system battery supply or from the DC source. On the output side, the systems to be protected are connected.

The fuses F1 and F2 at the input of the circuit prevent any excessive current draw from the system during a short circuit that occurs in any of the circuit elements. Fault conditions that will occur in the F1 or F2 fuse will alert the user with the F1 led and F2 led indicators.

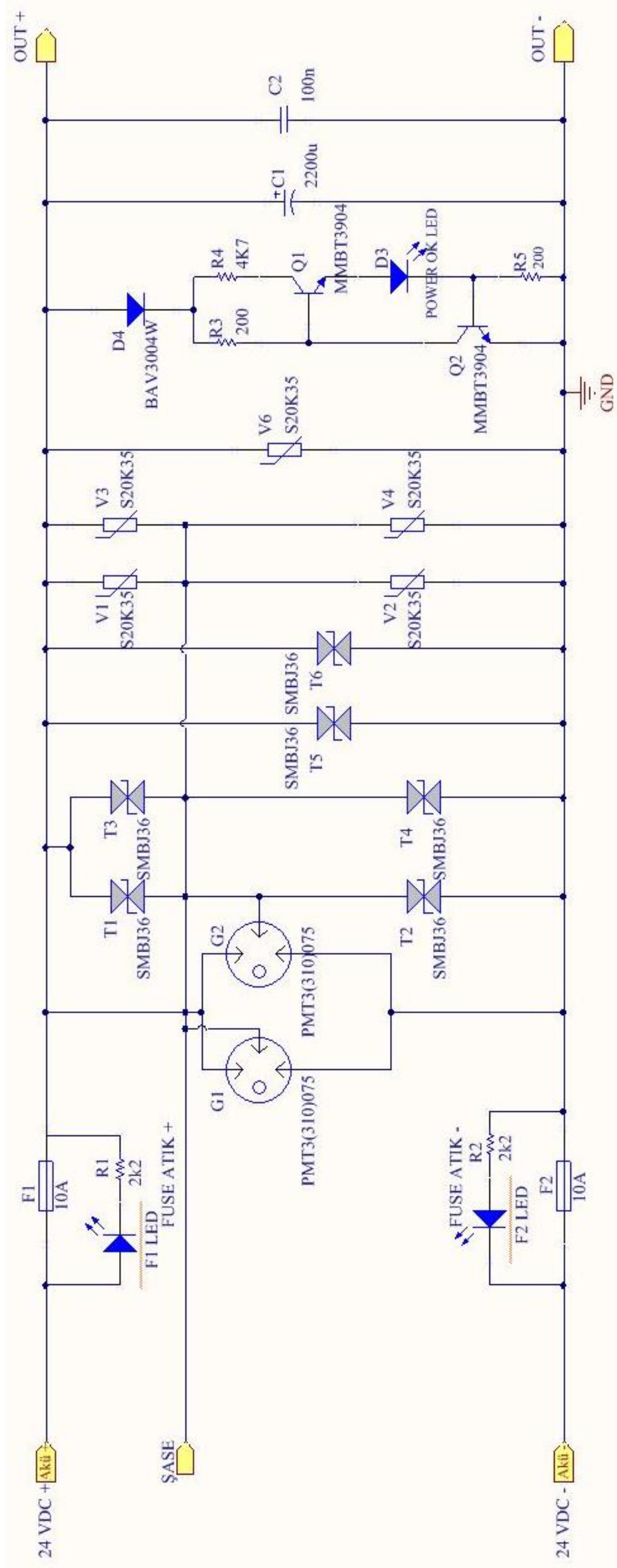

Fig.5. Open circuit diagram of the proposed voltage protection card

The G1-coded PMT3 (310) 075, which is to be used in the circuit, provides a flow of current through the electrodes in the case of a voltage higher than 75 VDC between ground and DC plus or minus and prevents the voltage level from exceeding 75 volts.

The varistors V1 and V2 try to reduce the voltage level by decreasing the internal resistances at 45 volts and over which will occur between the chassis and the plus and minus. It prevents the voltage level from exceeding 45 volts.

The V3 varistor directly prevents the 45 volt potential between the plus and minus from rising.

The T1 transient protection diode is activated at voltages up to 36 volts and tries to limit the voltages that occur on this voltage to its voltage.

In addition, these protection elements are active in a very short period of time to prevent this rise, even if there is any increase in AC or DC. They try to protect the system at high speed.

If the system protection elements remain on their protection voltage for a certain period of time, they short-circuit themselves to ensure that the F1 and F2 protection fuses at the system entrance are protected.

System protection elements temporarily or permanently stop the voltage which does not exceed the maximum operating voltage of 33 VDC. Thus, a system that is connected to proposed device can be protected by operating in any voltage condition.

In the proposed circuit we have three types component to protect our instrument in the output from voltage transient at the input. We have Transient Voltage Suppression Diodes (TVS diode) in bidirectional type (SMBJ36A) (See Figure 6).

The SMBJ is designed specifically to protect sensitive electronic equipment from voltage transients induced by lightning and other transient voltage events.

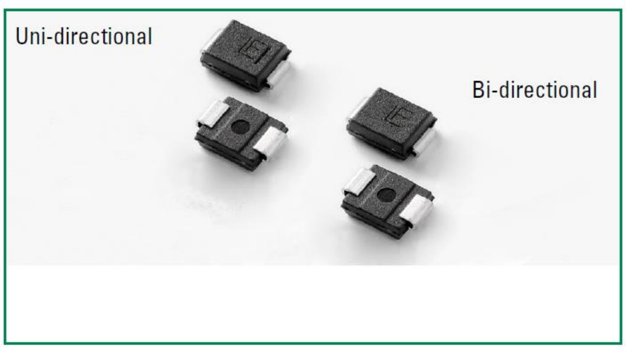

Fig.6. Uni-directional and bi-directional TVS diodes

It is used between “+24v line and -2v line”, “+24v line and ground” and “ground and -24v line”. This component limit the output at maximum 36 volts, the SMBJ diode is an ultra-fast protection diode, so it is working in the fast voltage transient but in maximum 600W Power, but incase our input has a big and powerful voltage transient, we have another component, that is Gas Discharge Tube (GDT) Products, as part number PMT3(310) Series (See Figure 7).

Three electrode PMT3(310) series GDTs are designed primarily to protect telecommunications equipment requiring simultaneous crowbar action of two signal lines. GDTs function as switches; dissipating a minimum amount of energy and can handle much higher currents than other types of transient voltage protection. It is used between “+24v line and -2v line” with base voltage of ground. If any voltage transient happens that is more than SMBJ-diode’s power, we have PMT3(310)075 for maximum 25k amperes to protect the system.

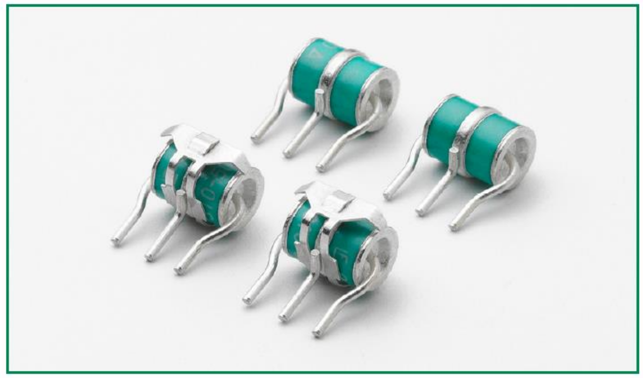

Fig 7. Three electrode PMT3(310) series GDTs

For more protection, we have SIOV metal oxide varistors (S20K35). Varistors are nonlinear two-element semiconductors that drop in resistance as voltage increases. Voltage-dependent resistors are often used as surge suppressors for sensitive circuits. It is used between “+24v line and ground” and “ground and -24v line” (See Figure 8).

Fig 8. SIOV metal oxide varistors (S20K35)

We also used 2 types of capacitors: Electrolyte capacitor (2200uF) and Ceramic capacitor (100nF). Our aim is to stabilize output voltage for filtering the high-frequency noise.

Various voltage tested on the board.

The input and outpu voltage of the voltage protection card was optained. (See Figure 9)

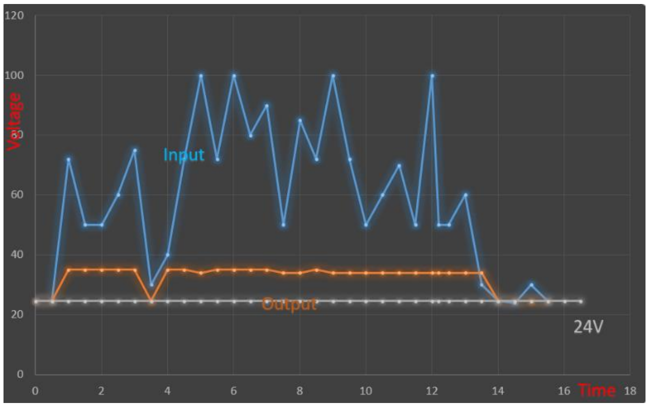

Fig.9. The input and output voltage of the voltage protection card

IV. Conclusion

In electronic systems, care must be taken to prevent malfunctions. In this case, we must change capacitors and IGBTs even if they do not fail at certain intervals, but we must take precautions before the malfunctions that may occur on the power generation components.

Due to the power electronics of the currently used inverter in battery charging systems used as a 24 VDC generator, it is necessary to put devices that will dampen the instantaneous voltage rise to the input of 24 VDC voltage demanding systems, because all the devices fed by the system will be damaged if the device generates momentary high voltage.

Furthermore, we believe that the design of the oscillator as an individual analog in such systems would be a more suitable design in the output control units by controlling the analog plus microcontroller with microcontrollers on the output side.

This system can be improved by further technological possibilities. Progressive protection systems can be created to provide continuous protection against future shocks.

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 ISSN: 2147-284X