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Construction of a Power Source Protective Device

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Abstract:
One of the major problems encountered in power electronics is that associated with voltage irregularity and instability (excess or under voltage). Devices from simple Cut-off fuse to sophisticated voltage Regulators, TV guards, etc. have been built to protect appliances and keep them functioning optimally. This is protecting appliances from power sources. What about protecting power sources against appliances? When appliances demand more power than a source is capable, it often leads to interruption in the operation or sometimes damages in the power source. In this work, we have designed, constructed and tested an electronic device to protect low power sources (such as domestic electric generators, inverter systems, etc.) especially when an attempt to drive heavy power appliances is made. This device was designed based on the operation of automatic switches which make use of microcontrollers. Use was made of a 10A relay that switches the line, a relay driver circuit to drive the main relay, an arduino Uno board that contains the set of instructions, a dc power supply, a 15A socket, a pushbutton switch and two indicator lights. The testing showed that generally, appliances connected to the device will not get energized, even though the appliance's power button is ON. At this point, only a red LED will be glowing showing that the device is receiving power but the power is not transferred to the load. When the user is sure that the power source can drive the appliance(s), the pushbutton switch is pressed and the green LED also begins to glow, showing that the appliance is powered. This result is exactly what the circuit is meant to achieve.

Keywords: *Power-sources, switches, arduino Uno, relays, C Programming*

1. Introduction

Power source protective device (PSPD), as the name implies, is a system or an electronic circuit that protects power sources from damage that could arise due to too much loads on them. Whenever we try to power heavy equipment or appliances using small power sources that have lesser power rating/capacity than the appliances themselves, especially when we have many of these heavy appliances running simultaneously, there tends to be a serious negative effect on the power source which most times leads to interruption in operation or even damage of the power source. Such negative effects are; over-heating of the component parts in the case of solar inverters or uninterrupted power supply (UPS) as source of power. If the source of power is a generator, the generator coil is at a high risk of getting damaged as a result of this attempt. Electronic loads increase day by day and they are very sensitive to voltage variations (Viet. *et al*, 2016). Making sure that these equipment (both the load and the power source) operate under very safe condition becomes so vital, hence, the need for a power source protective device. When we talk about protection in electrical or electronic systems, we are simply referring to the techniques employed in order to ensure that our electrical/electronic equipment operate under very safe conditions. Protective systems are built to protect our equipment from very many faults and disturbances which include but not limited to the following; over voltage, under voltage, over current, under current, voltage fluctuation, over load, surge, etc. We shall now move further to highlight in a nutshell few of these faults or harmful agents, their causes and how they have been managed.

1.1. Over Voltage

According to Bhosale *et al*, (2018), over voltage is an increase in the RMS value of ac voltage greater than 110 percent or 0.11pu at the power frequency for a duration longer than 1min. Over voltage is caused mainly by load switching, i.e. when a heavy load is suddenly switched off, in other words a reduction in current for this short period of time. Poor voltage regulation can as well lead to over voltage fault, and so on. In an attempt to solve this problem of over voltage, some components and devices like cut-out fuse and circuit breakers have been developed, which actually have gone a long way to solving this problem.

1.2. Under Voltage

An under voltage is a decrease in the RMS value of ac voltage to less than 90 percent or 0.90pu at the power frequency for a time period longer than 1min. Under voltages are the result of switching events that are opposite of those of over voltage, (Bhosale *et al*, 2018). Unlike the over voltage fault, the under voltage fault occurs more frequently especially in industries where there are very heavy and sensitive equipment that require high voltages. This leads to the damage of these equipment. Under voltage is caused by; closing and opening of circuit breakers, equipment failure, bad weather and pollution (like lightning strike), etc. Under voltage disturbance can be tackled by using a comparator to control the relay tripping coil. The comparator in this case, compares the supply voltage with the desired preset voltage and will trip the relay coil if the voltage drops below the desired preset value.

1.3. Over Load

What we have discussed so far are the effects of the irregularities that occur in power sources on equipment they supply power to. Over load is a direct opposite of this, such that the damage or the effect is on the power source, from the equipment. According to Doelect, (2019), 'overload faults are as a result of device doing work more than its rated capacity: when this happens, the device/machine will be drawing current more than its rated capacity which will result to a higher temperature in the device/machine and over time might cause it to burn and get damaged'. Devices like fuse, solid state power switches, overload relays, current transformers, etc. have thus far been used to protect our circuits from overload faults. Overload protective devices are analogous to this particular work, Power Source Protective Device (PSPD). The PSPD is an automatic or a smart switch that is based on the principles of relays and microcontroller. The circuit is designed in such a way that it will remain an open circuit until the user is sure that the power source is able to supply the needed power, and then he presses the push button to enable power transfer from the power source to the appliance.

The aim of this work is to totally eliminate the problem of low power rating power sources like; U.P.S, Inverters, small capacity generators, etc. supplying power to gadgets/appliances of high power rating such as; air conditioners, water pump, electric heaters etc.

To get a clearer picture, imagine a faculty building consisting of many staff offices, lecture rooms, laboratories, etc. equipped with air-conditioners, refrigerators, electrical lab equipment, etc. whose total power demand is about 30 kilowatts, say. The building is connected to the grid with a changeover to an electric generator of just about 3.5kVA capacity. Obviously, this generator cannot power all the appliances in the building. It may be desired to power only the main administrative offices (like the HOD's office), all light bulbs, ceiling-fans and some sockets for the rest of the building, in event of grid power failure. Such standby power sources are highly desirable in places where grid power failure is rampant. But financial constraints may not allow for purchase of a Generator of adequate capacity. The options to use the affordable generator are as follows:

- Modify the building wiring to select points to be powered by the generator – this could be cumbersome.
- Move from room to room to manually switch off appliances that would constitute overload for the auxiliary power source (Generator, Inverter) – this could be quite clumsy and you may meet most the offices locked.

We here propose the option of connecting every heavy wattage appliances (HWA) in the building through the PSPD as shown in the block diagram (Fig. 1). The HWA is plugged to a socket in the PSPD while the PSPD is plugged to the Mains-socket connected to the power source.

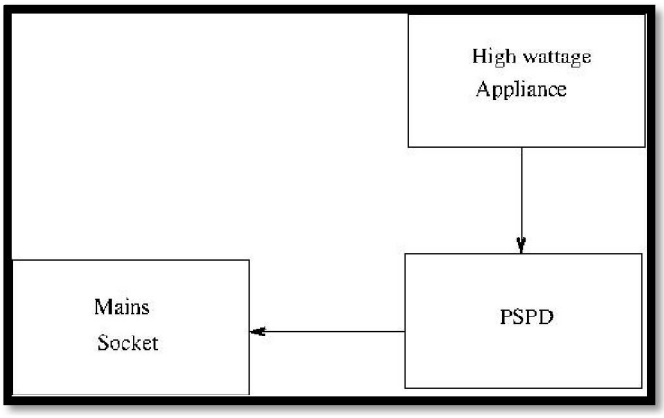

Figure 1: The Block Diagram of the PSPD Connection with the Power Source and Appliances

When there is power (either from the grid or generator), the device will not allow for transfer of power to the gadget automatically whether the gadget was previously on or not. The gadget is manually powered through a push-button on the PSPD once the user is sure that the power source is of enough capacity.

The PSPD will help to elongate the life span of our home and office appliances by reducing their operation time, with or without the knowledge of the user, thereby saving energy cost. Ultimately it will help to protect our low power source (generator or inverter) from getting damaged when it tends to automatically supply power to plugged appliances especially those with high power rating.

Fig. 2 shows pictures of some examples of low-power sources – a 3.5kVA generator and a 2.5kVA Solar Inverter system, which may not be able to drive HWAs especially when you have many of such appliances running simultaneously. The solar-inverter system comprises of a PVC panel, an inverter, batteries and a charge controller.

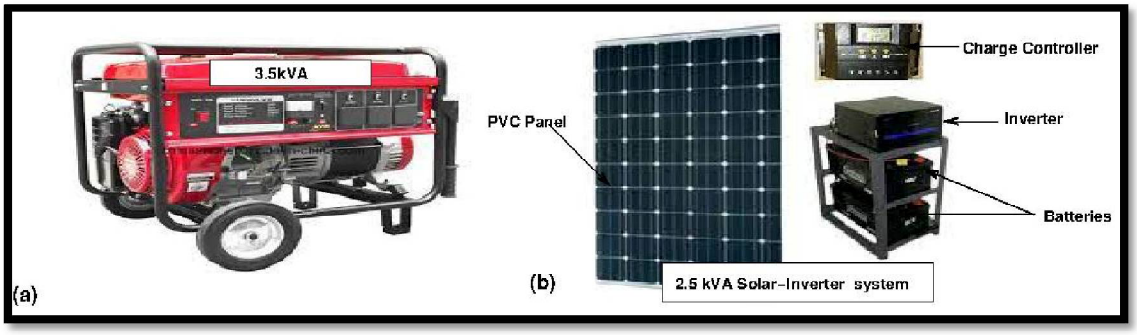

Figure 2: Examples of Some Common Low Capacity Power Sources: 3.5KVA Petrol Generator and (B) A 2.5kva Solar-Inverter System

Unlike the above mentioned sources, power sources like; sound proof diesel generators, national power grids, industrial generators, etc. could comfortably drive as many HWAs running at the same time. Images of such power sources are shown in Fig.3

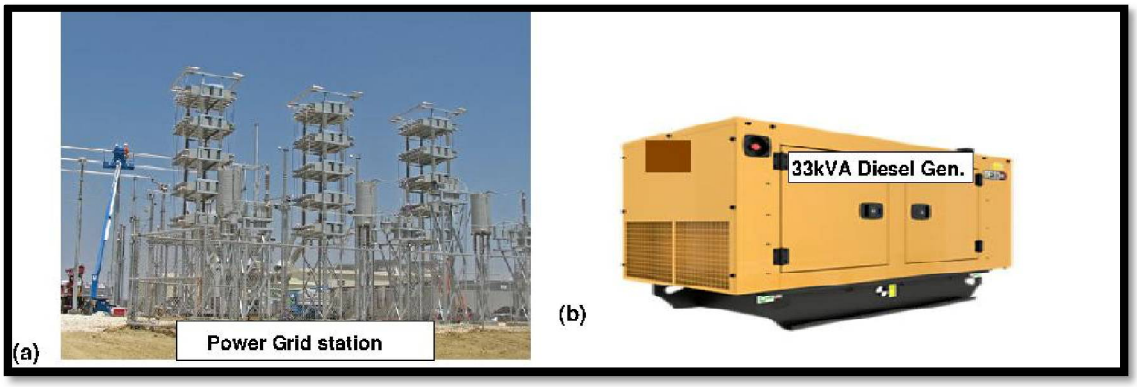

Figure 3: Examples of Power Sources That Can Drive High Wattage Appliances Without Problem: (A) National Grid Sub-Station and (B) A 33kva Diesel Generator

We would like to state clearly that although PSPD is primarily for low capacity power sources, it is also useful in the case of high capacity power sources for energy cost saving as stated earlier.

2. Materials and Method

The Power Source Protective Device (PSPD) is composed of the following parts:

2.1. Power Supply

The primary function of a power supply is to convert electric power from a source to the correct voltage, current, and frequency to power a load. The power from the mains enters the system through the power supply.

2.2. Relay and Relay Driver

The relay is responsible for switching an external load connected to its contacts in response to a relatively smaller electrical power applied across an associated coil. A relay driver on the other hand is an additional transistor stage attached with the relay which needs to be operated.

2.3. Arduino Uno Board with Atmega328 Microcontroller

An arduino is an open-source microcontroller development board. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on computers, used to write and upload computer code to the physical board.

2.4. Pushbutton

The work of the pushbutton in this circuit is to disconnect and reconnect the appliance and the power source whenever it is pressed.

2.5. Socket

Electric socket is a device where you can plug electrical equipment for electricity supply.

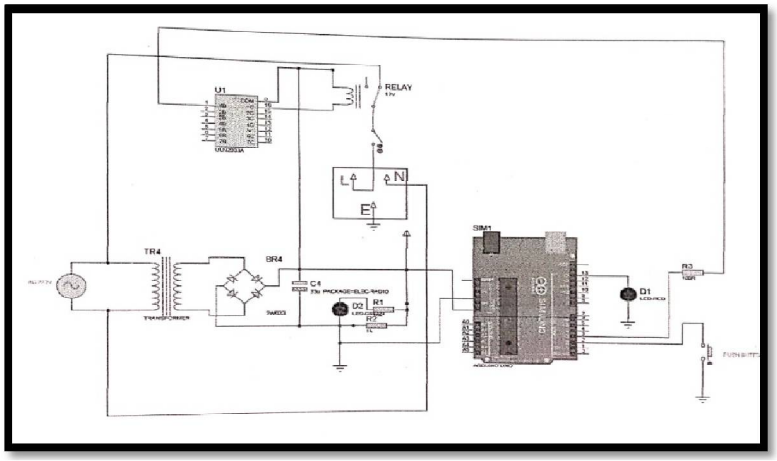

Figure 4: The Circuit Diagram of the Power Source Protective Device

The circuit diagram containing the above mentioned parts of the PSPD is shown in Fig. 4. After construction and assembling, the system was coupled as shown in Fig.5.

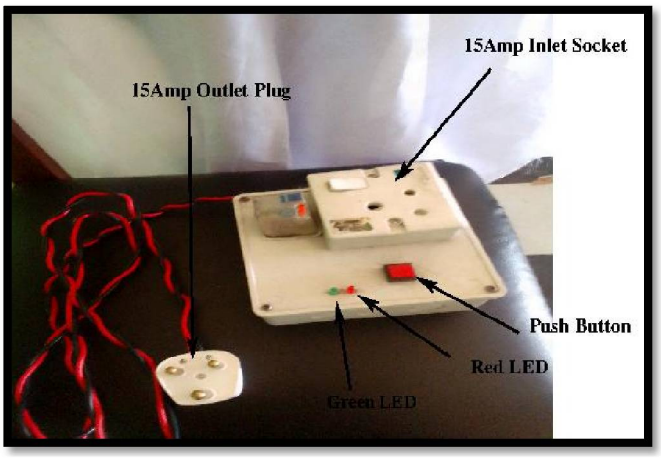

Figure 5: The Power Source Protective System in Its Final form Showing Most of Its Features

3. Results and Discussion

After construction and coupling (see Fig.5), the system was tested with a 1.5hp (~ 1.12kW) air-conditioner. The arrangement is shown in Fig.6.

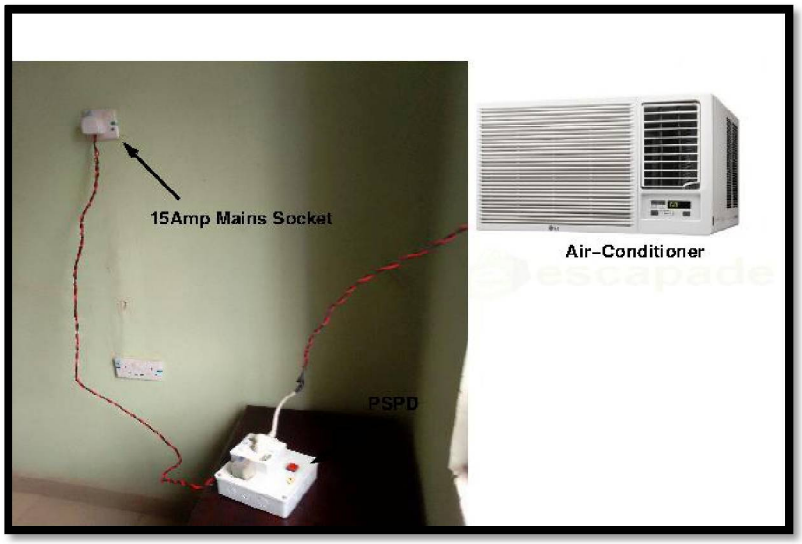

Figure 5: The PSPD in Its Operating Mode, Showing the Device Connected to a 1.5Hp Air-Conditioner and Wall Mains Socket

The picture shows that the device plugged to a 15Amp mains socket on the wall, while the air-conditioner is plugged to the 15Amp socket of the PSPD. If there is power and the mains socket is switched on, the red LED on the PSPD comes ON, but the air-conditioner would not start. When the user is sure that the source of power in the mains socket will comfortably power the air-conditioner, the red button on the PSPD is pushed twice and the green LED on the PSPD turns ON, indicating that power has been transferred to the air-conditioner. The second push of the button serves as confirmation.

In event of power failure, everything goes off. No switch is turned off. On return of power, either from the grid or a standby generator, only the red LED comes ON. The air-conditioner receives no power until again, the pushbutton is pushed twice.

4. Summary and Conclusion

When appliances demand more power than a source is capable, it often leads to interruption in the operation or sometimes damages in the power source. In this work, we have designed, constructed and tested an electronic device to protect low power sources (such as domestic electric generators, inverter systems, etc.) especially when an attempt to drive heavy power appliances is made. This device was designed based on the operation of automatic switches which make use of microcontrollers. Use was made of a 10A relay that switches the line, a relay driver circuit to drive the main relay, an arduino Uno board that contains the set of instructions, a dc power supply, a 15A socket, a pushbutton switch and two indicator lights. The testing showed that generally appliances connected to the device will not get energized, even though the appliance's power button is ON. At this point, only a red LED will be glowing showing that the device is receiving power but the power is not transferred to the load. When the user is sure that the power source can drive the appliance(s), the pushbutton switch is pressed and the green LED also begins to glow, showing that the appliance is powered.

It is recommended for further work that this device be entirely automated (i.e. both the isolation and restoration processes taking place automatically) without any need for pushbutton. The system can also be miniaturized and incorporated into the internal circuitries of these heavy wattage appliances.

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