Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2022, 9(5):75-84**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Arduino-based 5kva automatic power transfer for three (3) different powers sources with alarm system

Ujunwa NDUANYA

Department of Computer Engineering, Enugu State University of Science and Technology (ESUT), Enugu State, Nigeria

Abstract The Arduino-based 5kva automatic power transfer for three (3) different powers sources is a design that controls the electrical power transfer of different power sources input, to give an output of one (1) selected input, depending on the set redundancy priority, according to the predetermined command/program. This system is designed for the purpose of switching the power source automatically within a short period of time. In Nigeria where there is constant power failure, there is a need for other power sources. These power sources are usually switched manually. The design of this system aims at reducing the time lapse between the outage of power and the switching to a different power source. The system is composed of power sources module/unit, power supply unit, indicator, switching system, alarm and the micro-controller (that controls the entire system).

Keywords Switching system, Power sources, Micro-controller

1. Introduction

With the advent of technology, society is now in the midst of a fast-paced technological revolution. Therefore, the automation of everyday tasks has become the norm. The application of automation in the home is evolving as the quality of living depends on how well and how fast things can get done around the home.

Automation is a method of operating or controlling a process by automatic means. Things such as electronic devices, machines, and even robots are used to automate tasks that used to be completed by humans (Goodwill Community Foundation, 2020, para. 2). Automation has revolutionized those areas in which it has been introduced, and there is scarcely an aspect of modern life that has been unaffected by it. The term automation was coined in the automobile industry about 1946 to describe the increased use of automatic devices and controls in mechanized production lines. The origin of the word is attributed to D.S. Harder, an engineering manager at the Ford Motor Company at the time. The term is used widely in a manufacturing context, but it is also applied outside manufacturing in connection with a variety of systems in which there is a significant substitution of mechanical, electrical, or computerized action for human effort and intelligence (Groover, 2020).

Miller (2016) infers that different types of changeover switches, fall into one of the two different categories: automatic or manual. The Arduino-based 5kva automatic power transfer for three (3) different powers sources is a design that controls the electrical power transfer of different power sources input, to give an output of one(1) selected input, depending on the set redundancy priority, according to the predetermined command/program. Transfer switches, both automatic and manual, provide fast access to power for critical functions in the event of an outage. Without the aid of a transfer switch, one has to manually connect the generator to the equipment wished to be powered. This is much less efficient and less effective. Transfer switches basically police the connections of a business or household to utility power source and generator or other power sources. The transfer switch prevents any form of overlap, and in the event of an outage gives a direct and simple method of powering critical functions, comfort solutions, lights, and emergency equipment (PSI control solutions, 2020).

A power supply, is a device that supplies electric energy to an electric load. Some power supplies are discrete, standalone devices, whereas others are built into large devices along with loads. Every power supply, must obtain energy it supplies to its load as well as any energy it consumes while performing that task from an energy source. Depending on its design, a power supply may obtain energy from various types of energy sources, including electrical energy transmission systems, energy storage devices such as batteries and fuel cells, electromechanical systems such as generators and alternators, solar power converter, or other power sources. (Industralin, 2020, para. 1).

2. Related Works

A switch is an electrical component that can disconnect or connect the conducting path in an electrical circuit (Wikipedia, 2020). To ensure the continuity of power supply, many commercial/industrial facilities depend on both utility service and on-site generation (generator set). And because of the growing complexity of electrical systems it becomes imperative to give attention to power supply reliability and stability. Over the years many approaches have been implored in configuring a power changeover system.

Mahnke (1949) designed a three-phase transfer relay. He said: "My invention relates to automatic bus transfer devices for three-phase alternating-current systems. Such devices are used in lighting and other electric load circuits for switching the load from a first to a second power supply line-usually from a preferred or main power source to an emergency…"

Robertson (1956) described what he termed an "automatic transfer switch control circuit". although he used the word automatic, it is actually manual because a lever is used to effect the transfer from the main power source to an auxiliary supply source.

Soors jr. (1958) describes a manually operated transfer switch, which transfers an electrical load from its normal power supply when the latter fails, to an emergency power supply. He describes it as having a lever, which is movable vertically between ON and OFF positions.

Russel (1966) describes a Load Transfer Switch, which provides an improved transfer switch for AC or DC systems.

There are types of manually operated switches:

i. Push-botton switch: It is small sealed mechanism that completes an electric circuit when pressed. When it is ON, a small metal spring inside, makes contact with two wires, allowing electricity to flow. When it is OFF, the spring retracts, contact is interrupted and current will not flow.

ii. Toggle Switch: This is a type of electrical switch that is actuated by moving a lever back and forth to open or close electrical circuit.

iii. Single pole Single Throw (SPST): This is a switch that only has a single input terminal, and can connect to a single output terminal. SPST, serves in circuits as ON-OFF switch.

iv. Knife/Box Changeover Switch: It is a double input, double output electric switch that switches load between two electrical power sources. It is a manually operated type of changeover switch that has a plastic handle for the movement of the knife pivot between two different power sources.

2.1. Automatic transfer Switch (ATS)

Automatic power changeover is an electrical switching system with multiple input power sources but only one selected output. There are models of automatic power transfer switch with varying capacity, which comprise of:

i. Two power sources input terminals with one output terminal: The terminal to the control box to the load, is been energized in correspondence with the selection made (by the micro-controller) between the available power sources of the two input terminals via the relay.

ii. Advanced model of A.C Power Automatic Transfer System (ATS): An advanced model of ATS, has three input power sources with only one selected output terminals, more advanced ATS, can be designed to have multiple (n) power sources, with only one output of the selected input according to the set priority in the source-code. This approach of power transfer system is micro-controller based. It has the capacity to transfer power to the load from the varieties of available power sources without human intervention.

3. System Design

An a.c automatic power control transfer, is designed to control the transfer of electrical power supply from one of the power sources to the load with respect to the set logic priority. This control system consists of programmatic approach which entails the use of Arduino to detect and to transfer an electrical power supply to the load system.

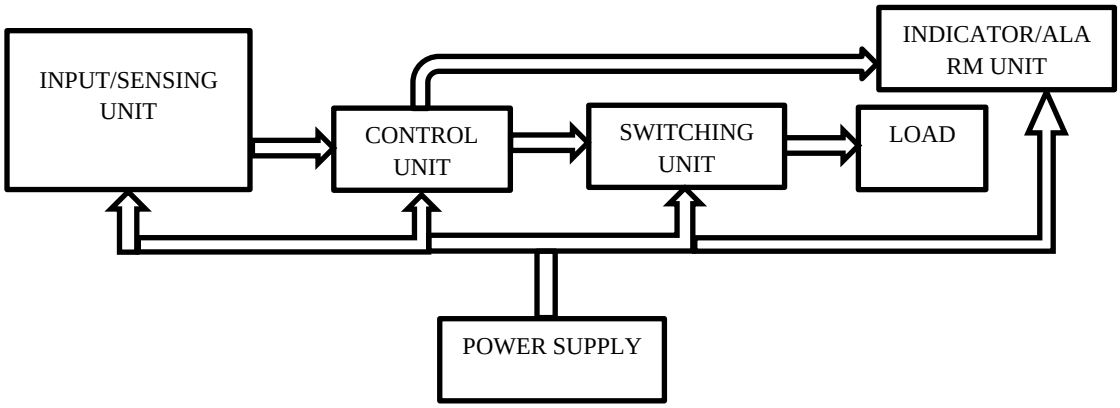

Figure 1: The system structure

The Arduino-based automatic power transfer system is structured as shown in figure 1. The system is made up of five modules:

- Power supply unit
- Sensing unit
- Switching unit
- Control unit
- Indicator/Alarm Unit

3.1. Power Supply Unit

The power supply unit (PSU) is designed to convert high voltage AC mains to a suitable low voltage supply for electronic circuits and other device. A power supply unit can be broken down into a series of blocks, each of the blocks perform a particular function.

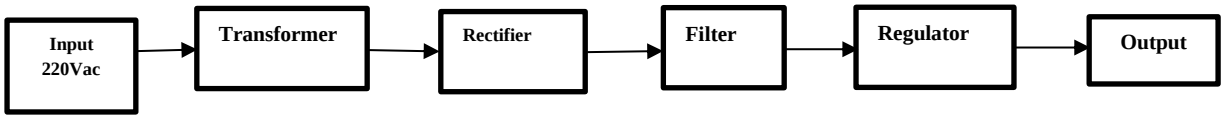

Figure 2: Block Diagram of the Power Supply Unit

i. *Transformer:* this is used to steps down high voltage AC mains to low voltage AC

ii. *Rectifier:* this is used to convert AC voltage to DC voltage. A full bridge (four diodes) or half bridge (two diode) rectifier can be used, but the DC output is always pulsating in nature.

iii. *Smoothing/Filter:* this is the process of reducing or eliminating the pulsating or ripple output of the rectifier it is usually done by capacitors which are parallel connected and produce a fixed DC voltage.

iv. *Regulator:* this is an arrangement of electrical component which is used to stabilize the DC output voltage to a certain value irrespective of fluctuation in the supply. The regulator voltage is 5volts it is supplied to the power and signal/sensing units

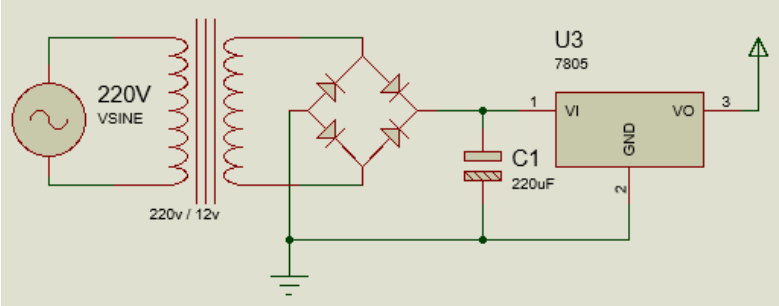

Figure 3: Circuit Diagram of Power Supply Unit

Calculation to determine the value of the filter capacitor:

$C = I_o/(2\pi f V_o)$

Where,

C = Filter Capacitor

I_o = Load current = 500mA

Vo = Output Voltage = +5Vdc

f = Frequency = 50Hz

Here:

By using the capacitor formula, we have;

C = 500mA/(2 x π x 50 x 5) = 3.1847×10^{-4}F

But the nearest available filter capacitor is 470uF

3.2. Sensing Unit

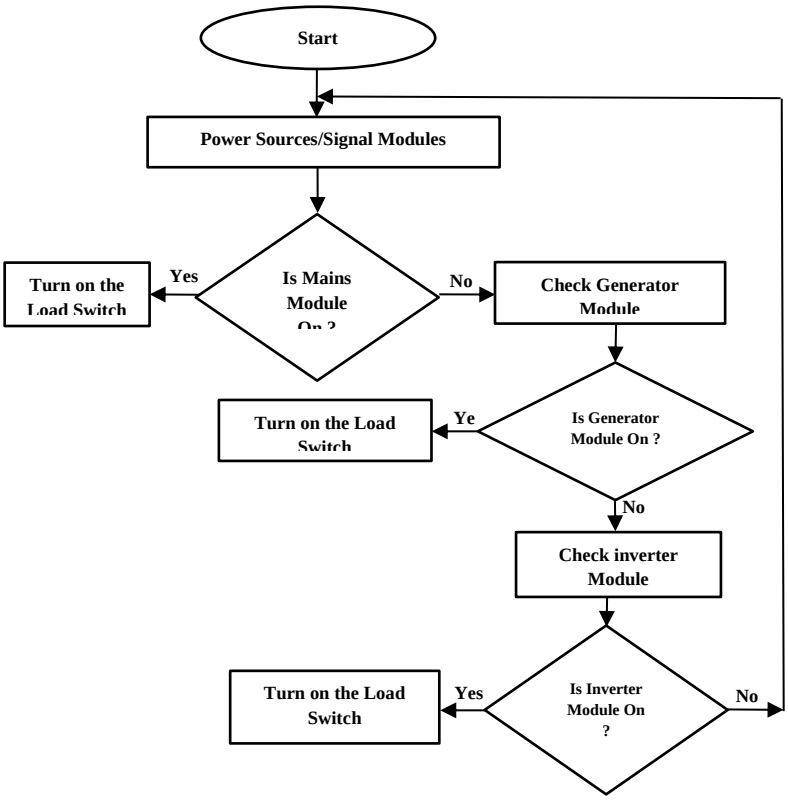

Figure 4: Flow Chart of the Sensing Unit

The sensing unit is made up of modules of +5v dc output signals of the various power sources that are available at a given time. Each of the input connected terminals to the microcontroller, are connected to the 1Kohms pull-

down resistor, this ensures that the terminals maintain low state when not initialized. There may be input signals from the different power sources, but only one of the input affects the output of the microcontroller at a particular time to actuate the switching circuitry. The priority in the power transfer is based on the logic set in the microcontroller. In this design, the priority is set such that whenever the generator power supply is ON, the other power sources are set to redundancy, whereas the generator power supply is selected as the only output supply to the load. When the generator power source is in the Off-state, it hands over the priority control to the Utility or mains power supply (with LED2 as an indicator of the selection). The inverter system is set as the last priority power source, which gives power supply to the load whenever it is the only standing power source to the electrical load system.

3.3. Switching Unit

In this design, the switching unit is made up of NPN transistors, relays and contactors. The NPN transistors are used to activate the electromagnetic relays that actuates the contactors. The choice of NPN transistor is based on its principle that signal flows from the collector to the emitter whenever the base is biased. Also the choice of the BC547 transistor is because of its high switching speed and reliability.

The output signal from the microcontroller biases the base of the transistor, which in response, initializes the relay. The initialized relay then actuates the contactor which powers the load.

Calculation to determine the rating of the contactor device

If the changeover is to be applied on a 220V/415V, 5KVA generator operating at 50Hz and a power factor of about 0.8. To determine rating of contactor to be used.

Recall;

Apparent powers = 5 x 10^3VA (5KVA)

Line voltage = V_L = 415v

Phase voltage = V_P = 220V

hence;

Active power "P" = Apparent power x power factor

= 5 x 10^3 x 0.8

= 4KW

$P = I_P V_P \cos \emptyset$

4000 = I_P x 220 x 0.8

I_P = 4000/(220 x 0.8)

I_P = 22.73A

$I_P \approx$ 22.73A

The contactor required will have a minimum current rating of 22.73A

For increased efficiency a tolerance of about +25% will be given

Thus contactor rating will be

22.73A + (25 x 22.73) /100 = 22.73 + 5.68

= 28Amps or nearest allowable.

Switching Time: The switching time of the power transfer system is dependent on the electromechanical device (contactor). The pickup or closing time of a contactor is measured from the moment the coil supply is switched on to the initial contact of the main poles. The dropout or opening time is measured from the moment coil supply is switched off to the moment the main poles separate (Schneider electric, 2020). , The contactor used in this design is 8502S contactor.

Pickup time = 9.0ms to 23.0ms, Dropout time = 5.3ms to 15.9ms

3.4. Control Unit

The control unit was designed with Arduino Nano Micro-controller. A microcontroller is a single computer chip that executes a user program, normally for the purpose of controlling some device.

3.4.1. Basic Features of Arduino Nano:

Here are few of basic features which must be known for one to work on this microcontroller board:

- It has 22 input/output pins in total.
- 14 of these pins are digital pins.
- Arduino Nano has 8 analogue pins.
- It has 6 PWM pins among the digital pins.
- It has a crystal oscillator of 16MHz.
- It's operating voltage varies from 5V to 12V.
- It also supports different ways of communication, which are:
    - Serial Protocol.
    - I2C Protocol.
    - SPI Protocol.
- It also has a mini USB Pin which is used to upload code.
- It also has a Reset button on it.

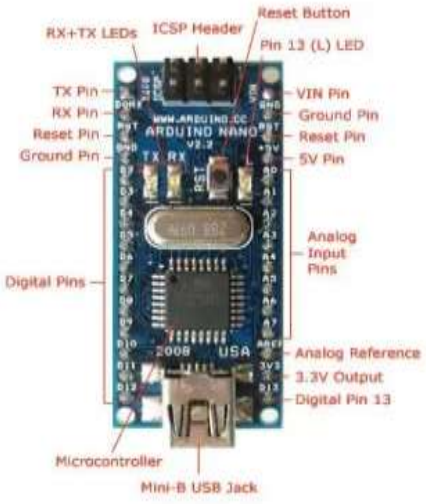

Figure 5: Pin Diagram of Arduino Nano Microcontroller

There are some resistors connected to certain pins of the microcontroller to ensure its proper functioning and protection. They are:

i. *Pull-up Resistor-:* This is connected to ensure that the given pin of the microcontroller is maintained at a given voltage level.

ii. *Pull-down Resistor-:* This is connected to ensure that the given pin of the microcontroller is maintained at zero voltage level.

iii. *Limiting Resistor -:* This is used to restrict or regulate the amount of current flowing from the microcontroller to the device or from external source to the microcontroller.

3.4.2. Memory in Arduino Nano:

It has memories embedded in it which are used for different purposes and are as follows:

- Flash memory of Arduino Nano is 32Kb.
- It has preinstalled bootloader on it, which takes a flash memory of 2kb.
- SRAM memory of this Microcontroller board is 8kb.
- It has an EEPROM memory of 1kb.

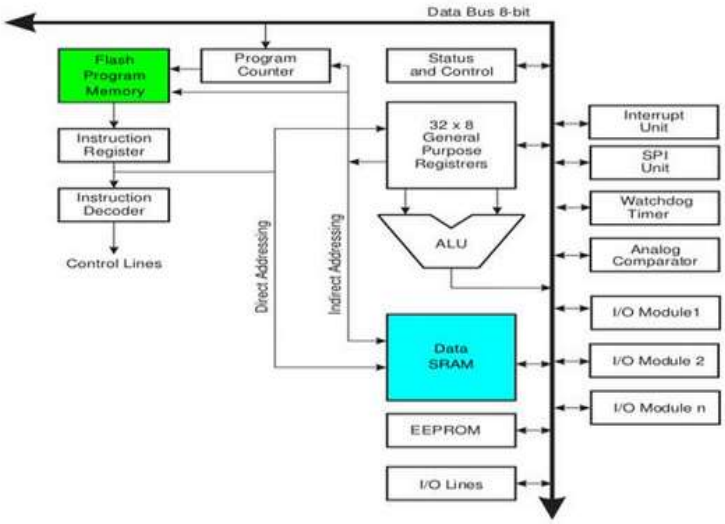

Figure 6: Arduino Architecture

3.5. The Indicator/Alarm Unit

The indication unit comprise of both the visual and audio system.

The visual indicator comprise of LEDs, which show the state (on/off) of the output terminal of the system, thereby indicating which of the control switch is in active state.

The audio indicator; comprise of buzzer, which is been activated to alert the household owner that there is availability of power supply in the Mains-power supply.

The buzzer turns on when the mains electric power supply source is available, and switches off with a time delay of approximate three (3) seconds, it then remains in off state until its initialization.

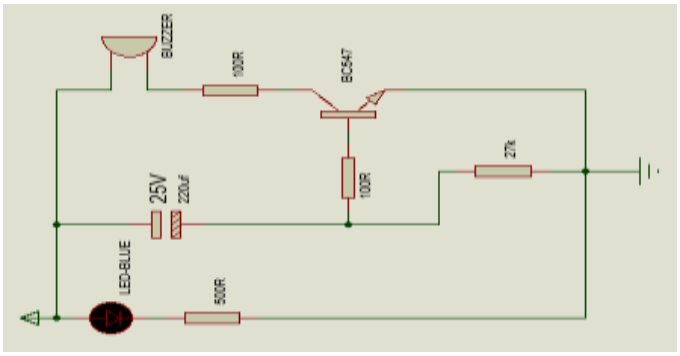

Figure 7: Circuit Diagram of the Alarm System

The 12v dc passes through the capacitor thereby charging the capacitor which correspondingly turns on the buzzer. Once the capacitor is fully charged, the buzzer stops; the delay time between the turn on and turn off of the buzzer is dependent on the value of the capacitor and resistor (27Kohm) as shown in the circuit diagram above.

Calculation to determine the delay off time of the buzzer:

$T = RC(V_s/V_c)$

Where

R = charging resistor = 27,000(ohms)

C = charging capacitor = 220uf

Vs = voltage supply = 12vdc

Vc = voltage of the capacitor = 25vdc

T = Time delay off of the buzzer

Hence:

T = 27000 x 220x10^-6 x (12/25)

T = 2.8 = 3secs

4. The Arduino-based 5KVA Automatic Power Transfer System

The Arduino-based 5kva automatic power transfer for three (3) different powers sources with alarm system controls the electrical power transfer of different power sources input, to give an output of one(1) selected input, depending on the set redundancy priority, according to the predetermined command/program.

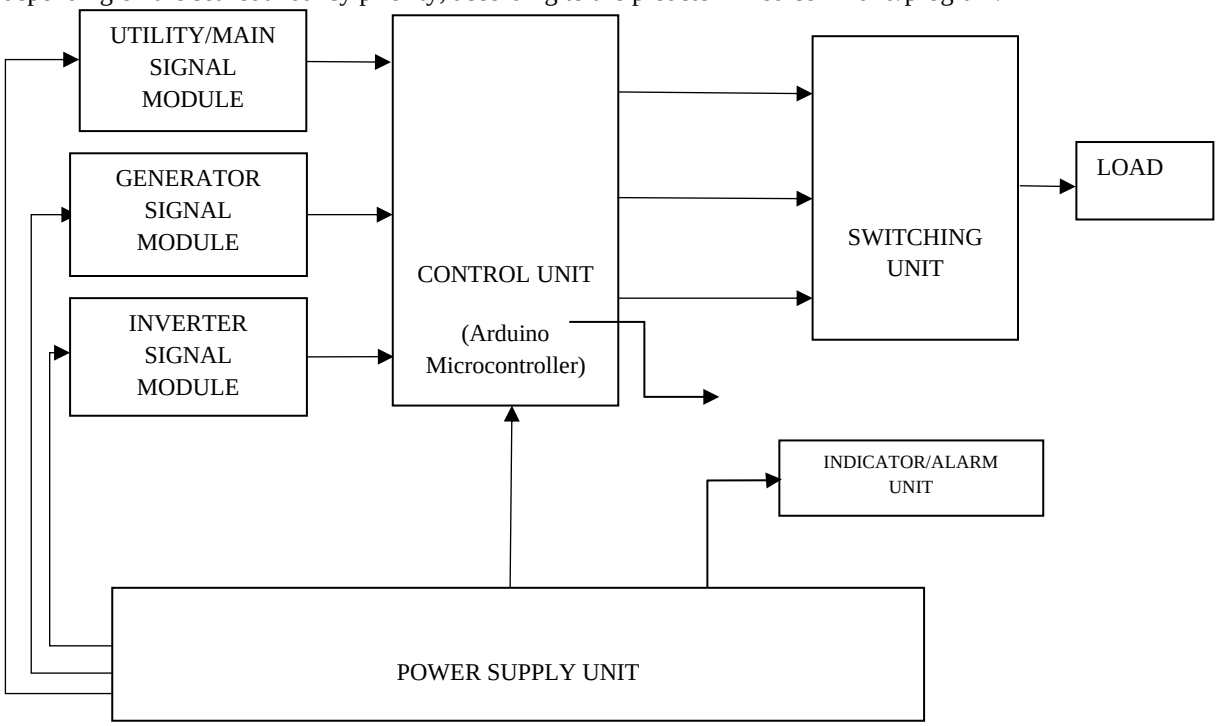

Figure 8: Block Diagram of Arduino-based 5KVA automatic power transfer system

4.1. Operation

The system initializes with the sensing unit determining the detection of a voltage. The Mains module is checked at first. If there is no power detected, the next module: the generator module, is checked. In the absence of power, the inverter module will be switched to. At any point of the detection of power, the load is switched to that module. The explanation is given in more detail with a truth table below:

Table 1: Truth table for the system design

Input Signal to Microcontroller			**Output signal from the microcontroller**		
Mains	**Generator**	**Inverter**	**P1**	**P2**	**P3**
0	0	0	0	0	0
1	0	0	1	0	0
0	1	0	0	1	0
0	0	1	0	0	1
1	1	0	1	0	0
0	1	1	0	0	1
1	0	1	1	0	0
1	1	1	1	0	0

Explanation of the Truth Table:

- Whenever there is no available electrical power in any of the three power sources, there will be no output signal from the microcontroller, hence the load is powered "off".

- When only the Mains power supply is available, the microcontroller, makes the selection of the available power source. The activated P1 of the microcontroller, actuates the relay/contactor, which power "on" the load.
- When only the generator power supply is available, the microcontroller, makes the selection of the available power source, the activated P2 of the microcontroller, actuates the relay/contactor, which power "on" the load.
- When only the inverter power supply is on, the microcontroller, makes the selection of the available power source, the activated P3, actuates the relay/contactor, which power the load.
- When both the mains and generator power supplies are on, the microcontroller, makes the selection of the available power sources according to the set priority, the activated P1 as first priority, actuates the relay/contactor for the mains power supply, which power the load.
- When both the generator and inverter power supplies are on, the microcontroller, makes the selection of the available power source according to the set priority, the activated P3 as the second priority, actuates the relay/contactor for the generator supply, which power the load.
- When only the mains and inverter power supplies are on, the microcontroller, makes the selection of the available power sources according to the set priority, the activated P1, actuates the relay/contactor for the mains supply, which power the load.
- When all the three (mains, generator and inverter) power supplies are on, the microcontroller, makes the selection of the available power sources according to the set priority. The activated P1 as the first priority, actuates the relay/contactor for the mains supply, which power on the load.

Figure 9: Arduino-based 5kva Automatic Power Transfer System

5. Software Overview

The basic structure of the Arduino programming language is fairly simple and runs in at least two parts. These two required parts or functions enclose blocks of statements.

```
void setup()
{
statements;
}
void loop()
statements;
}
```

Where setup() is the preparation, while loop() is the execution. Both functions are required for the program to work. The setup function should follow the declaration of any variable at the very beginning of the program. It is the first function to run in the program, it runs only once and is used to set pinMode or initialize serial communication. The loop function follows next and includes the code to be executed continuously - reading

inputs, triggering outputs, etc. This function is the core of all Arduino program and does the bulk of the work (Evans as cited in Orji et al. (2018)).

6. Results

When there is no power detected at the output of each module, the load remains off. Once power is sensed, the system determines which module is the source and according to the programmed priority, a module is selected by the switching unit, which switches the load to the detected power source.

7. Conclusions

This paper presents a prototype of an Arduino-based 5KVA Automatic Power transfer system. This power transfer automatic system uses a sensing unit to detect power and a switching unit to switch to a power source according to the set priority. Once there is detected power and switching, the connected load is powered on.
This automated system helps save time and energy expended in the manual changeover system.

8. Limitations

This technique does save time and energy in some aspects but it does not incorporate the automatic switching on of the generator prior to detection. It also does not contain a feedback system, which indicates voltage fluctuations in any power source.

References

[1]. Academic Research International (2019). *About Design Of Automatic Change Over Switch*. Retrieved from http://www.journals.savap.org.pk
[2]. Electrical engineering and technology (2018). *Manual switch changeover.* Retrieved from https://mobile.facebook.com/Engineering11222/posts/957791081068344?_rdc=1&_switch
[3]. Goodwill Community Foundation (2020). *The Now: How will automation impact our lives.* Retrieved from https://edu.gcfglobal.org/en/thenow/how-will-automation-impact-our-lives/1/
[4]. Groover, M. P. (2020). *Automation.* Retrieved from https://www.britannica.com/technology/automation
[5]. Industralin (2020). *Power Supply.* Retrieved from https://industrialin.com/power-supply
[6]. Kurt Mahnke (1949). *Three-phase transfer relay.* Retrieved from https://www.freepatentsonline.com/2486305.pdf
[7]. Lloyd James Robertson (1956). *Automatic Transfer Switch Control Circuit.* Retrieved from: https://www.freepatentsonline.com/2745971.pdf
[8]. Miller, N. (2016). *About power transfer system.* Retrieved from http://www.nelson-miller.com
[9]. Orji E.Z., Oleka C.V. & Nduanya U. I. (2018). *Arduino Based door Automation System Using Ultrasonic Sensor and Servo Motor.* Journal of Scientific and Engineering Research, 05(04), 341 – 349.
[10]. Paul H. (2019). *About the need for power transfer system.* Retrieved from https://www.consumerreports.org/portable-generators/portable-generator-needs-a-transfer-switch/
[11]. Prime Power (2020). *About automatic power transfer.* Retrieved from https://www.primepower.com/blog/an-automatic-transfer-switch
[12]. PSI control solutions (2020). *Why does a generator need a transfer switch?* Retrieved from https://www.psicontrolsolutions.com/blog-why-does-generator-need-transfer-switch
[13]. Raymond G. Russell (1966). *Load Transfer Switch Mechanism.* Retrieved from https://www.freepatentsonline.com/3246100.pdf
[14]. Schneider electric, (2020). *About contactor timing*. Retrieved from https://www.se.com
[15]. Steven W. Soos, Jr. (1958). *Transfer Switch.* Retrieved from https://www.freepatentsonline.com/2861198.html
[16]. Swagatam Innovation (2021). *About homemade circuit projects.* Retrieved from http://www.homemade-circuits.com/simple-delay-timer-circuits-explained/
[17]. Wikipedia (2020). *Electric Switch.* Retrieved from https://en.m.wikipedia.org/wiki/switch