ISSN 2522-9400 **European Modern Studies Journal** *Vol 5 No 3*
available at journal-ems.com

Design and Implementation of a Microcontroller-Based Automatic Transfer Switch with an Overload Protection

Jamiu Babatunde Oyetola
Principal Lecturer, Department of Electrical and Electronics Engineering, Lagos State Polytechnic, Ikorodu, Lagos, Nigeria

Abstract. Unreliability in electric power supply has elicited the proliferation of alternative power sources particularly in developing countries. However, the manual strategies and equipment employed to affect power supply switching remain fraught with various challenges. This paper presents a microcontroller based automatic transfer switch with an overload protection. The method employed in the design involves AC voltage sensor, power supply unit, PIC microcontroller, the relay driver circuit, electromechanical relays, overload protection unit, and LCD display to display the present state of the power source. The automatic transfer switch also consists of an alarm system for indicating generator failure or fuel outage. The result of the automatic transfer switch demonstrates its ability to perform transfer switching activities easily with little or no human intervention and isolated the output in case of an overload condition.

Keywords: PIC microcontroller, contactor, electricity, overload

Introduction

Electricity is the wheel of growth to any nation's economy which forms the premise of this study, with interests in human, infrastructural and economic development (Agbetuyi et al., 2011; Ehiabhili, Ezeh, & Orji, 2018; Osaretin & Ibhadode, 2016). The focus of any electric power industry is to supply nonstop power supply at all times to all its clients. However, the persistent increase in human population in developing nations like Nigeria widens the vast difference between energy supply and demand. The supply of electricity for industrial, commercial and domestic use is highly unstable in most developing and undeveloped parts of the world. This gives rise to the frequent use of alternative of power supply to meet up with the energy demand (Adoghe & Odigwe, 2009; Amuzuvi & Addo, 2015; Ananth et al., 2019; Roy et al., 2014). The power supply instability experienced in this region creates a need for automation of electrical power generation or alternative sources to back up the utility supply. Most industries and commercial processes are partly dependent on generators and public power utilities (Agbetuyi et al., 2011). This is however unhealthy for most processes or systems which are dependent on electric power. As a result of this power outage, developing countries like Nigeria, encounter slow development processes in both the public and private sectors of their economy. Investors from foreign lands do not feel secure to come and set up commerce or business in spite of the giant market made accessible in such populated nations because of frequent power failures experienced (Ehiabhili, Ezeh, & Orji, 2018; Ezema, 2019; Osaretin & Ibhadode, 2016). Furthermore, delicate processes and operations such as surgery cases in hospitals, transfer of money between banks, manufacturing process in the industries, data and information transfer at data centres requires constant power supply in order to prevent the loss of life or data resources which can be exceptionally costly to business operations (Eshovo & Salawu, 2017; Ilomuanya & Okpala, 2016; Olatomiwa & Olufadi, 2014; Onipede et al., 2017). The influx of these alternative sources of supply brings forward the challenge of switching smoothly and timely between the mains supply and the alternative sources whenever there is power failure. Hence, it is for these reasons that change over or transfer switches were developed. Initially, these switches were designed for manual operations, but with the technological development in electrical power control, automation and electronics comes the Automatic transfer switches (ATS). It dispenses the element of manpower interaction in starting a generator and changing power supply from one source to another (Amuzuvi & Addo, 2015; Osaretin & Ibhadode, 2016; Sotelo-Valer et al., 2020).

An ATS is an electrical device for transferring power sources to an electrical load. It makes sure the supply of power to the load with minimum small gap between the power failure and reconnecting the load to secondary power supply. The ATS is usually connected between load and the power supplies whose main function is to transfer the load from primary source of electricity or public utility power supply on its failure to secondary source of electricity or generator and then transfer the load back to utility mains supply when it restores. In contrast to the manual changeover switch system that requires manual stress in starting the generator and switching over from public supply to generator and vice – versa. Hence, the need to develop a system that will effectively manage power supply between two sources (power utility and a standby power generator) therefore influenced the motivation for this study (Adoghe & Odigwe, 2009; Eshovo & Salawu, 2017; Ilomuanya & Okpala, 2016; Olatomiwa & Olufadi, 2014; Sotelo-Valer et al., 2020). An intelligent or logic control unit to constantly monitor the condition of the power sources and so provide brain necessary for switching and related circuit to operate correctly (Ananth et al., 2019; Ezema, 2019; KASSIM, 2011; Onipede et al., 2017; Sohail et al., 2015). However, a good switch should be the one whose contact is made in such a way as to limit the arc formation by having no contact-bounce and by having contacts made of good conductive, corrosion resistance and wears resistance materials. Change-over switch must have appropriate insulation and must be so contracted and located as not to constitute a potential hazard (Amadi et al., 2019; Ehiabhili, Ezeh, & Orji, 2018; Onipede et al., 2017). A good change-over switch should also have tight contact points so as to limit or eliminate the possibility of partial contact at the contact point. The partial contact may lead to fire outbreak or possible damage to the contactor itself (Adedokun et al., 2016; Agbetuyi et al., 2011; Amadi et al., 2019; Ezema, 2019). The ATS monitors the supply of voltage from single phase line and a generator supply, it then base its control operation on the availability or unavailability of power supply from either source (Abiodun et al., 2018). The automatic change over switch has proven to be a better device compared to the manual change over as it gives no noise, eliminate wear and tears, reduces damages to lives, and maintains high quality of services as it provide quick response for the interchanging of power to the load automatically from the main supply to the generator and vice – versa (Amuzuvi & Addo, 2015; Eshovo & Salawu, 2017; Kolo, 2007; Roy et al., 2014).

Various approaches have been deployed in the literature for the implementation of automatic transfer switch. For example, the study carried out by Ezema (2019) in (Ezema, 2019) present an automatic switching mechanism that transfer the consumer loads to a power source from generation in the case of power failure in the main supply. This design employs the use of contactors, relays, and phase failure detector and generator starter mechanism. Also this mechanism was tested and holds an important key in the provision of a continuous power supply through a near seamless switching between the mains supply and an alternative standby source like the generator set. Consequently, this lacks voltage sensing and monitoring function that senses phase failure and under voltage in the system. Kolo (2007) in his study designed an automatic transfer switch that switches between the main power supply and an alternative power supply, such as a generator. The basic principle of this study was to switch ON an auxiliary power supply to the load after a time interval and uses the control oscillator (4060B) which carries out the control logic unit operation and relays is used for switching abilities. While a study carried out by Roy et al. (2014) shows the design and construction of a three phase automatic transfer switch that utilized discrete components which include the contactors, phase failure relays and change over delay mechanism. In this work, the method utilized in designing the ATS involves the use of electromechanical type relays, contactors, voltage, voltage sensing relays and delay timer relays as the crucial components of the system. This system was realised using less components, hence affordable, portable and durable. Also the study carried out in presented the design and construction of an automatic power change over switch that switches power supply from public supply to generating set whenever there is any power outage or inadequate voltage with the use of flip-flop circuit for logic control, switch transistor and voltage sensing. The automatic phase change-over switch is relatively affordable and reliable. Many contributions have been made by various authors and have been documented in the open literature. For example, the study presented by Agbetuyi et al. (2011) proposed an Automatic Transfer Switch (ATS) for a Three Phase system. In their research, the methods utilized in designing the ATS involve the contactors, voltage sensing relays and delay timer relays as main components of the system. Also, reference (Adoghe et al., 2015) stipulates an automatic transfer switch which ON the back-up generator and connects back to the utility supply when the power restored. The circuit consists of time delay integrated circuit which is used for delay time mechanism and switching relays for switching from the mains to the alternative power source. Again, Olatomiwa and Olufadi (2014) present single phase automatic transfer switches, the main design was carried out with a low cost solid state electronic component such as: transformer, contactor, relays, 555 timer, voltage regulator, op amp, transistor, capacitor, resistors and diodes. Reference (Adedokun et al., 2016) presents the development of an automatic transfer switch for seamless transfer of power between different power sources between different power sources to deliver fail safe performance in critical applications. This research has been achieved by the use of microprocessor control technology to effect the monitoring, and switching whatever there is need. Also are the LED display, relay drivers and the generator start/stop function embedded in this research. Thus unavoidable delay and human errors that usually accompany manual switching from one source to another are eliminated. Reference (Amuzuvi & Addo, 2015) presents a microcontroller-based automatic transfer switching system (MBATSS), which eliminates the challenges of a manual transfer switch. The circuit comprises of an AC voltage sensing circuit, an electromagnetic relays, a Hall Effect current sensor, LCD were all coordinated using PIC16F877A microcontroller. This mechanism has been tested and holds an important key in the provision of a continuous power supply through a near seamless switching between the main supply and an alternative standby source like generator set. The study presented in (Roy et al., 2014) reports on the design of a three phase automatic change over switch which utilized the generator control mechanism is designed to choose between two available power sources, in this case, generator and utility with preference to utility. The system will process the following features: phase failure, AC voltage monitoring, over or under voltage supply in the earnest time. This work was achieved with the combination of discrete electrical and electronics components which are divided into units: the power supply unit, sensor unit, central processing unit, switching unit, and display unit while (Osaretin & Ibhadode, 2016) combined twin functions of automatic changeover and sequential (gradual or step) loading of five seconds to eliminate the need for manual transfer, protect the loads, extend the lifespan of the generator set and enhance reliability of power supply. Reference (Ilomuanya & Okpala, 2016) presented a microcontroller based automatic power transfer switch with artificial intelligences was presented for auto switching from main source to alternative source and vice versa. The method adopted for the construction is the top-down design method. The microcontroller forms the control system, hence monitors the signals both sensors of the sources, and are quickly reported to the user via SMS. The output interface and the feedback unit are realized with the use of relays, transistor, diodes and resistors. This design employs the SMS feedback for critical application with zero tolerance for power outage while (Abiodun et al., 2018) uses major components like a step down transformer (220V – 12V DC), atmega 8 microcontroller, 555 timer, rectifiers, voltage regulator, relays, circuit breaker and others like resistors, diode and capacitors. In this work, the design is divided into different unit which are the main supply section, the backup unit, oscillator circuit, switching circuit and the relay and load section. The atmega8 microcontroller used for control and the generator stop and start function is utilized with a delay of 4 seconds in starting and switching off the generator.

Furthermore, the application of programmable logic controller in regards to this area has witnessed a remarkable success over years. For example, reference (Suryawanshi et al., 2019) presents the design and implementation of an auto changeover switch using a programmable logic controller (PLC). The switch turns ON the generator automatically and connects the load to the generator output whenever there is mains failure and alternatively it switches OFF the generator automatically when power is restored and returns the load to the mains power with the help of the desired range of parameters which may be set by programming. This helps in reducing the time consumption required for switching operations. Hence, the continuity of supply is maintained. The study presented in (Khan et al., 2015) proposed an economical and easy way for switching application of generator through PLC and monitoring through SCADA incorporated with GSM alerts in industries. This design enables backup generators, DC to AC inverters redundant UPS or other AC power sources to be used for a single load. This can be recommended when no down time from a power outage can be tolerated. This present study, therefore, presents the design and implementation of a microcontroller-based automatic transfer switch incorporating an overload relay.

Methods

Study Design and Specifications

This automatic transfer switches are used to provide a steady power for the load by automatic transferring between two or more sources when the main source are down or decreased below a certain limit. The ATS automatically disconnects the faulty source and connects the load to the other healthy source. The following practical considerations are taken into account in the design of ATS in this study.

Maximum power capacity

In this study, the maximum power capacity is 5kVA, hence generator or load less than or equal to 10kVA is utilized.

Number of power sources

The PHCN and generator set are considered as the power source in this study.

Number of phases

This study is a single phase automatic transfer switch

Maximum current capacity

Maximum power capacity = 5kVA
Voltage = 220 volt
Frequency = 50 Hz
For single phase system,

Power = voltage (V) x current (I) (1)

Current $= \frac{5000}{230} = 21.74A$ hence, the maximum current is 21.74A

Generator start/stop functions

In this study, the generator start/stop function is embedded.

Alarm and LCD display

This design will include functions like the alarm circuit, the LCD display, the output indicator. Therefore, the specifications of this design are presented in Table 1.

Table 1. Design specification

Power rating	10KVA
Operating voltage	415/240 volt
Maximum current	42A
Generator start/stop function	YES
Number of phases/frequency	3

Design Stages /Components

The design of this study can be divided into various functional blocks which work together to perform the switching function as shown in Figure 1.

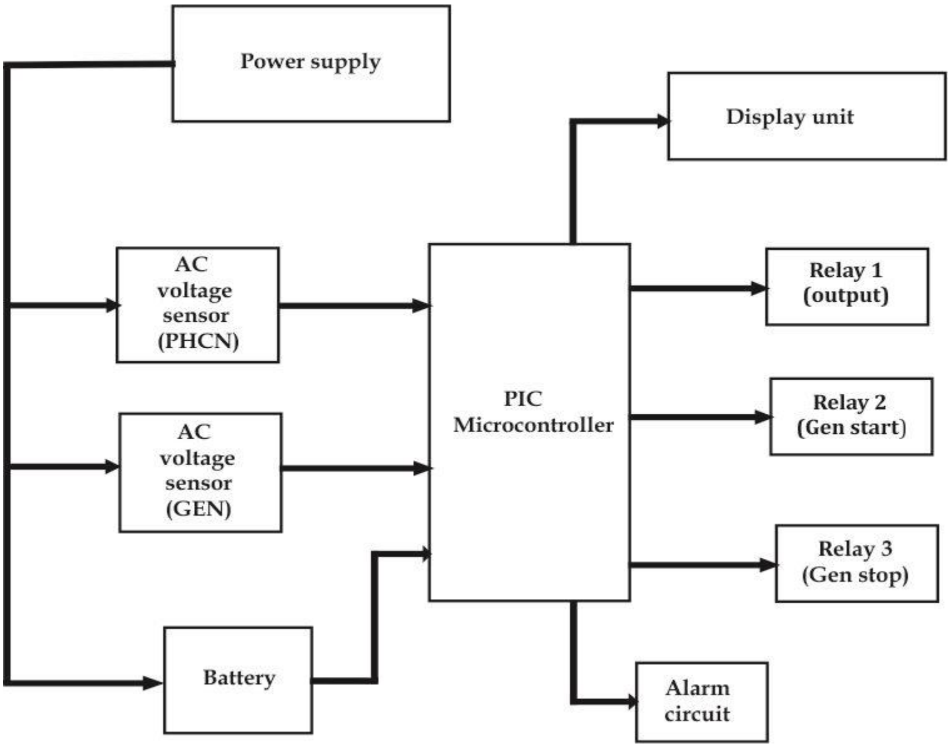


Figure 1. Detailed block diagram of the Automatic transfer switch

Power Supply Unit

The main function of the power supply is to provide a rectified, filtered and regulated dc output to all other sub-unit in a device. This unit is responsible for supplying the required voltage 12V to the relay circuit; 5V to the microcontroller, 5V to the LCD display. This includes the rectification stage which converts the AC supply to DC. The filtration stage which reduces the ripples from the DC signal and the voltage regulation stage which regulates the DC output voltage.

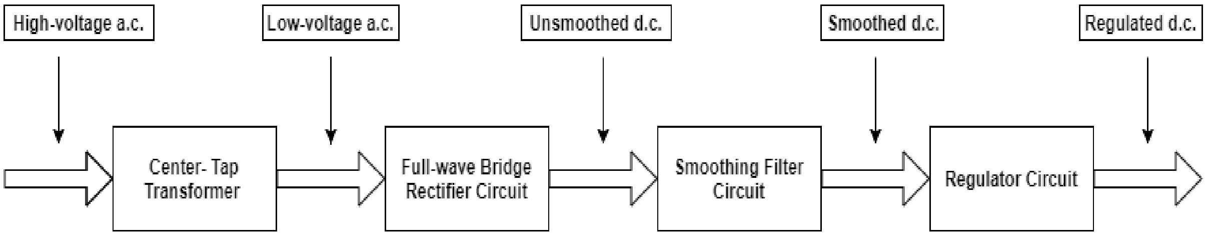


Figure 2. Block diagram of a regulated power supply

Transformer

A transformer is a static or stationary piece of device by means of which electric power in one circuit is transferred into electric power of the same frequency in another circuit. It can raise or lower the voltage in a circuit, but with a corresponding decrease or increase in current. The physical basis of transformer is the mutual inductance between two circuits linked by a common magnetic flux.

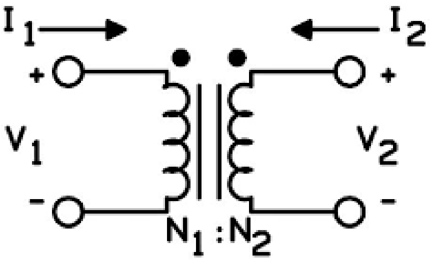


Figure 3. Schematic representation of transformer

Transformer Selection

The transformer is used to step down the AC input 220V to a lower voltage.
Primary voltage = 220V
Secondary voltage = 18V
Current rating = 500mA
Power rating, $P = IV = 18 \times 0.5 = 9W$

Rectifier Circuit

A rectifier is a device that converts AC voltage to a pulsating DC voltage with the use of diodes. The full wave bridge rectifier is employed in this study.
Secondary voltage of the transformer = 18V
Peak voltage $V_m = \sqrt{2} \ x \ 18 = 25.56V.$ Hence, for full wave,
Rectified d. c voltage $V_{dc} = 0.636V_m$ (2)
= 0.636 x 25.56 = 16.26V

The bridge rectifier delivers a pulsating dc, therefore

$$Ripple\ factor = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} \tag{3}$$

$$= \sqrt{\left(\frac{18}{16.26}\right)^2 - 1} \quad = 0.475$$

$$Efficiency = \frac{P_{dc}}{P_{rms}} x100\% \tag{4}$$

$$= \frac{16.26}{18} x100\% = 90.3\%$$

Filter Circuit

The filter circuit removes ripples and smoothens the signal. This can be actualises using a capacitor.

Selection of Filter Capacitor

Ripple factor = 0.475

Ripple voltage = $0.308\ V_m$ (5)

= 0.308 x 25. 56

= 7.872V

Ripple voltage ($⟦V⟧_{\downarrow}(rms)$) $= \frac{I_{dc}}{4\sqrt{3}\ f\ C}$ (6)

Therefore, $I_{dc} = 1A$ since it is the maximum output current of the LM7805 regulator.

The value of capacitor is $= \frac{1}{4\sqrt{3}\ x\ 50\ x\ 7.872} = 367\mu F$ (7)

Therefore, an electrolytic capacitor whose capacitance is about $470\mu F - 1000\mu F$ is required to filter the output DC from the bridge rectifier.

Charging Circuit

The charging circuit is used to charge the battery when it is low. The battery in this study is utilized as a constant source which supplies the microcontroller and the relay. The LM317 IC is used as the regulator for charging the battery.

$$V_{out} = 1.25\ x \left(1 + \frac{R_2}{R_1}\right) \quad (8)$$

Output voltage, V_{out} = 14 V

$R_1 = 100\Omega$

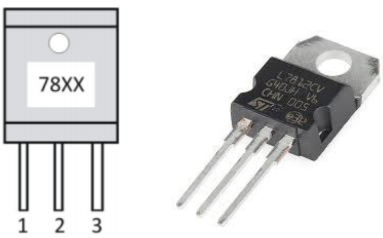
$R_2 = \frac{100}{1.25} V_{out} - 100$

$R_2 = \frac{100}{1.25}\ x\ 14 - 100$

$R_2 = 1K\Omega$

Voltage Regulator Circuit

A Voltage Regulator is a circuit designed primarily to maintain a constant voltage at a point irrespective of the input voltage to the regulator. The input voltage of the regulator must always be higher than the than the regulated output voltage. In this study, a 7800 series regulator will be used. It is a three (3) terminal device. The 7805 and 7812 regulator IC is selected, because the microcontroller will be powered by the 7805 regulator IC, while the 7812 regulator IC will produce 12V for the relay circuit.



1 = input, 2 = common, 3 = output

Figure 4. 78xx series voltage regulator

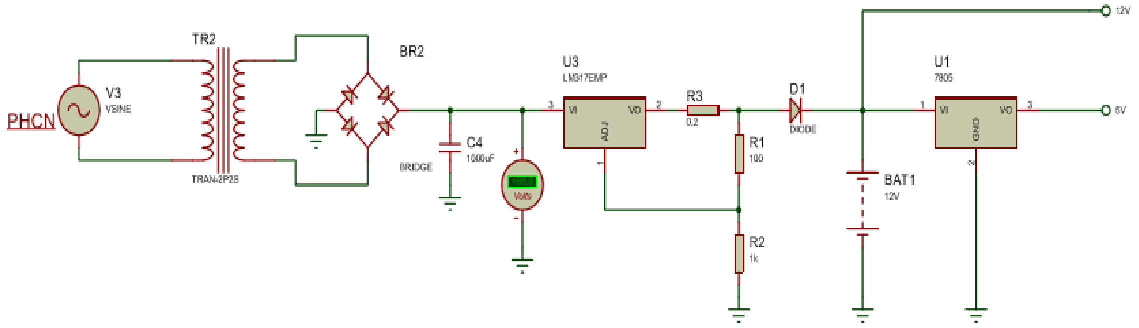


Figure 5. Complete schematic representation of power supply

Component Used

Transformer (220/18v)
Bridge rectifier
Capacitor (1000 μf)
7805 voltage regulator
7812 voltage regulator
Battery
LM317
Diode
Resistor

The AC Voltage Sensor Unit

A voltage sensor is a device or circuit that detects voltage in a wire and generates a signal proportional to that voltage. This unit is to comprise of three sensing circuit each of which contains a bridge rectifier, a voltage divider circuit. The ac sensor gives high or low to the microcontroller.

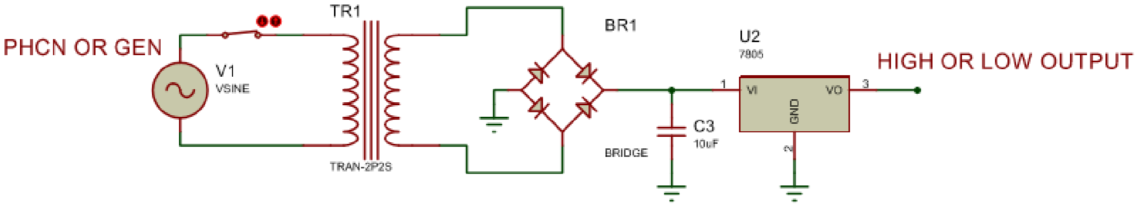


Figure 6. AC voltage sensor

Component Used

Transformer (220/12V 0.5A)
Bridge rectifier
Capacitor (1000μf)
7805 voltage regulator

Microcontroller

Microcomputer is a small computer on a single integrated circuit, it consist of the processor core, memory, the input and output peripherals. Microcontrollers can decode written instruction and convert them to an electrical signal. A microcontroller's processor will vary by application. Options range from the simple 4-bit, 8-bit or 16-bit processors to more complex 32-bit or 64-bit processors. In terms of memory, microcontrollers can use random access memory (RAM), flash memory, EPROM or EEPROM. Generally, microcontrollers are designed to be readily usable without additional computing components because they are designed with sufficient on board memory as well as offering pins for general I/O operations, so they can directly interface with sensors and other components. They various microcontrollers which include the ATMEGA, PIC, ARDUINO e.tc

PIC Microcontroller

The Peripheral Interface Controller is a family of microcontrollers made by Microchip technology The PIC is the sole component which makes this ATS truly automatic and intelligent. The PIC has a constant 5V DC supply which keeps it functioning there are many PICs available in the market ranging from Pic16F84 to pic 16C84. In this study, the PIC 16F877A is utilized .The PIC microcontroller is implemented with some complimentary component whose choice is based on manufacturer on the datasheet. For this work, the components include a crystal oscillator of rating 8MHz, a 10k pull-up resistor and two stabilizing capacitor.

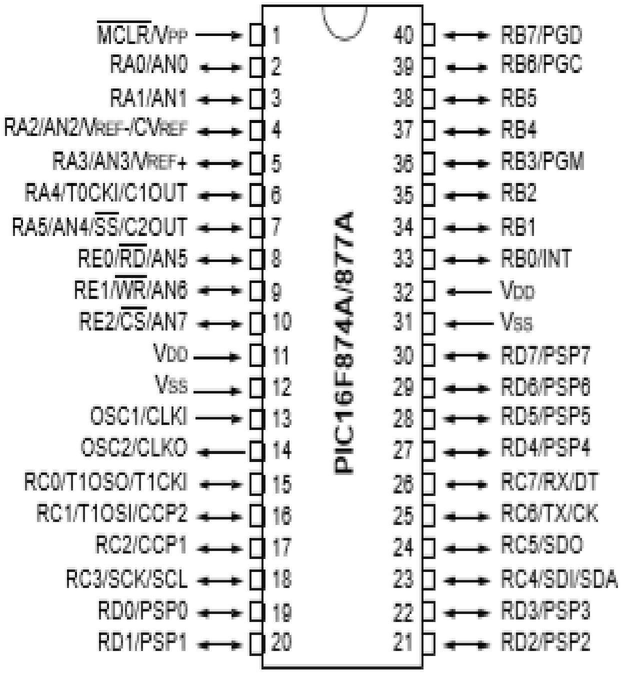


Figure 7. PIC microcontroller (PIC16F877A)

Relay Switching Unit

This unit switch between the different relay circuits receives instruction from the microcontroller on where to switch to. The switching unit comprises of the relay driver IC and relay circuit. The ULN2003 is use as a relay driver IC which is made up of seven open collector Darlington pairs having common emitter which shows ULN2003 has a capability of handling seven different relays at the same time.

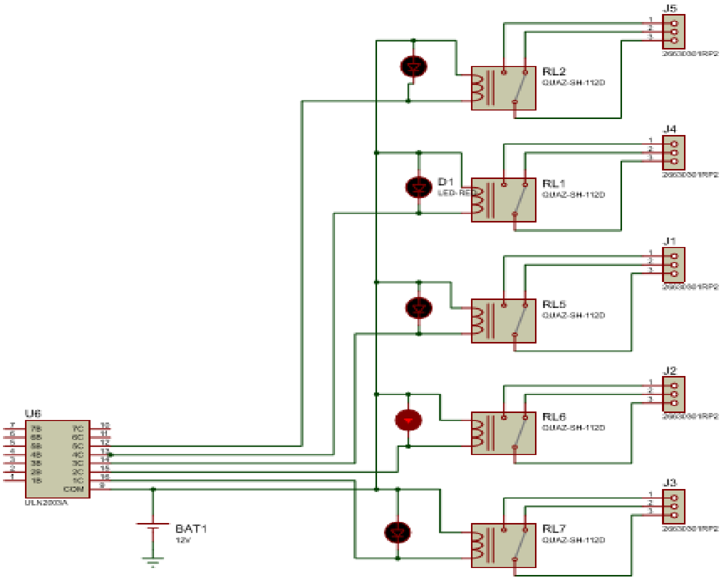


Figure 8. Relay driver circuit

Relay

The main operation of this device is to make or break contact with the help of a signal without any human involvement in order to switch it ON or OFF. On the output side you have three pins: common (COM), normally open (NO) and normally closed (NC). In this study, a 12V relay is utilized.

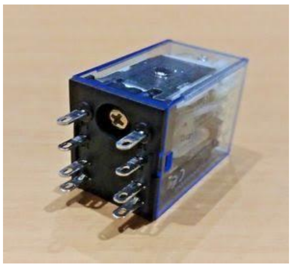


Figure 9. Relay

Generator Start and Stop Function

This is the circuit that switches the generator off when it senses the presence of power from the mains (PHCN) and start the generator when power from the PHCN is interrupted. It employs the switching action of ULN2003 and relay. Relay3 and Relay 4 receives signal from the relay driver and send signal to the start and stop function of the generator. The device is design to excite the start function of the generator for five seconds.

Overload Protection Unit

A circuit overload occurs when the amount of current flowing through the circuit exceeds the rating of the protective devices. This study is specified for 5Kva with an ampacity rating of 21.7A. A circuit breaker is utilized as the protective device.

Figure 10. Circuit breaker

LCD Display

This is a flat panel, electro–visual display on video display that uses the light modulating properties of liquid crystals. This circuit is responsible for interfacing information to the user. The LCD tells the user what is going on in his building in terms of the condition of the AC input, the load consumption, and possible reasons for blackout in case the user was shut out due to faults observed by the system.

Table 2. LCD specification

Parameter	Value
Supply voltage for LCD	4.7V -5.3V
Supply current	300mA

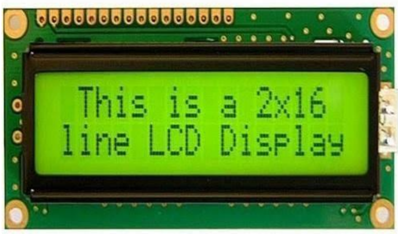


Figure 11. LCD Display

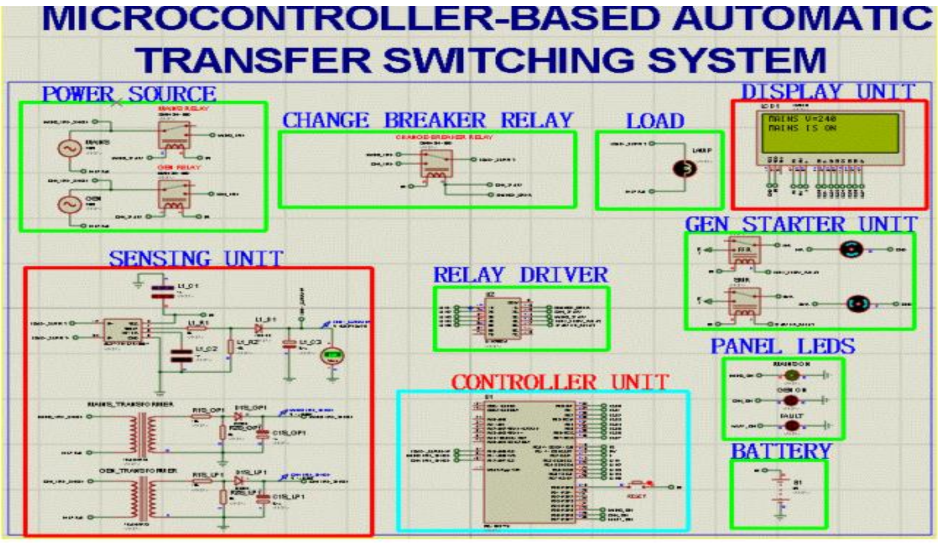


Figure 12. Overview of the entire unit

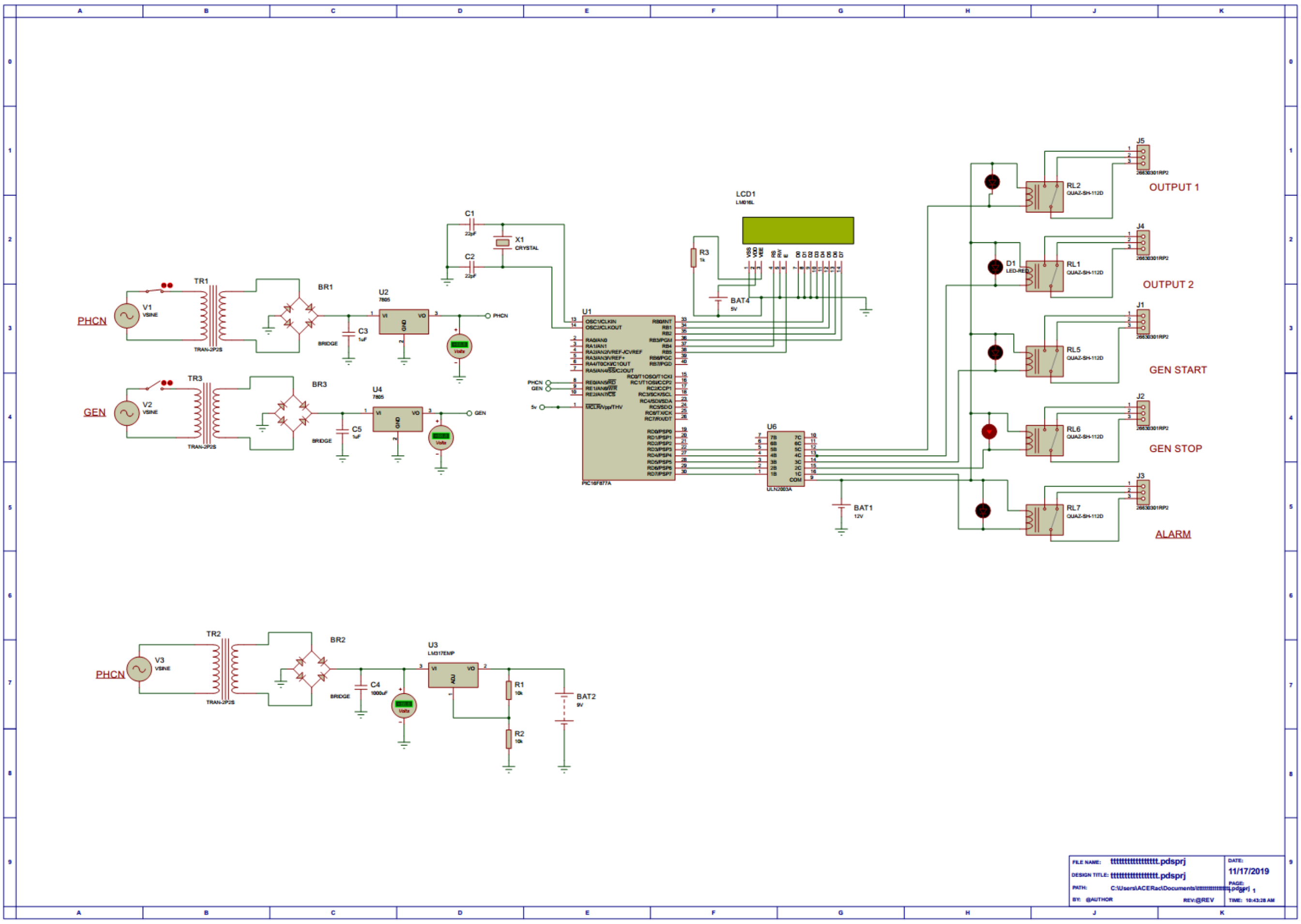


Figure 13. Circuit Diagram

Firmware Design

Firmware is a software program or set of instructions programmed on a hardware device. In this study, the PIC Microcontroller is utilized. The controller will be program using embedded C Language using a Mikro C for PIC IDE. After compiling the program, the HEX (machine) code is generated which is transferred to the MPLAB for easy transfer of the program to the microcontroller hardware via a programmer.

MikroC for PIC

MikroC is a powerful, feature rich development tool for PIC micros. It is designed to provide the consumer with the easiest possible solution for developing applications for embedded systems, without compromising performance or control. MikroC provides a successful match featuring highly advanced IDE, ANSI compliant complier, broad set of hardware libraries and comprehensive documentations.

MPLAB

MPLAB is a window package that makes writing and developing a program easier. It could best be described as developing environment for a standard program language that is intended for programming a PC. Some operation which were done from the instruction line with a large number of parameters until the discovery of IDE "Integrated Development Environment are now made easier by using the MPLAB.

PIC Programmer

A PIC programmer is a circuit which interface the pc to the microcontroller using the PC's parallel, serial or USB port. It can write data to the microcontroller and read it back for verification. The PIC programmer translates digital logic levels from the PC to suitable logic levels for the microcontroller.

Figure 14. PIC microcontroller

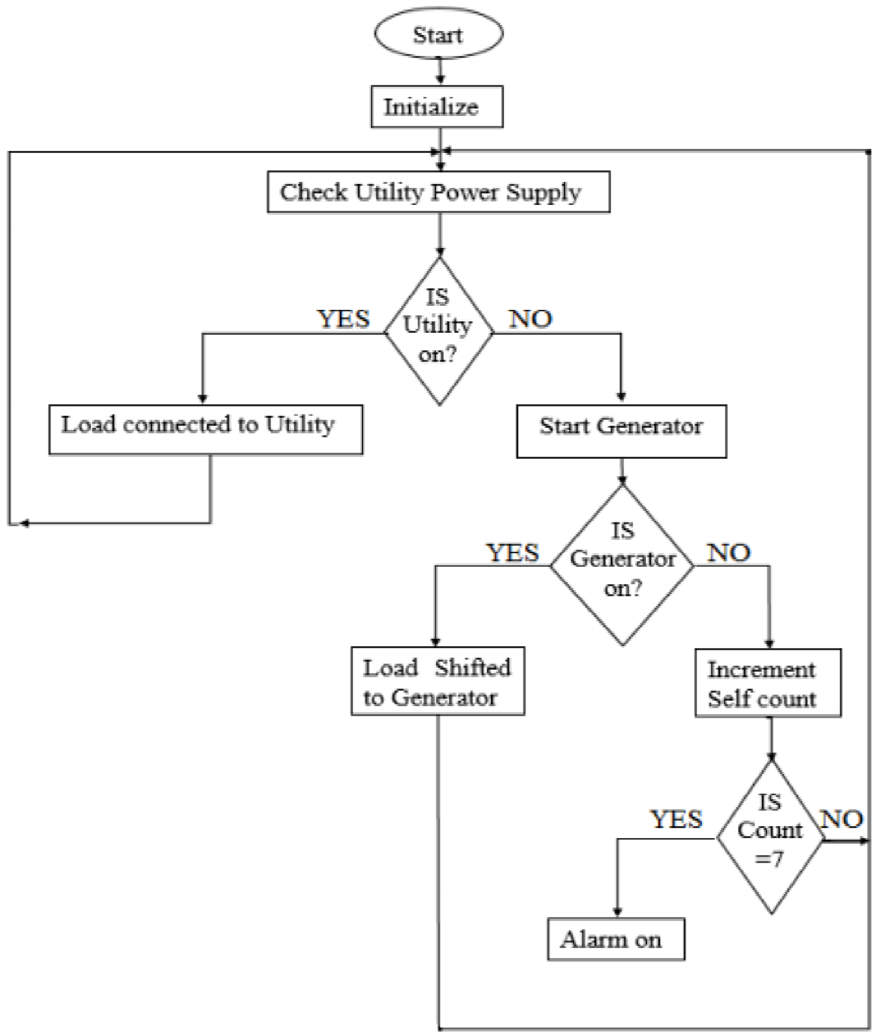


Figure 15. Flow Chart for Firmware Development

Simulation

The simulation of the electronic circuit of the study was done using software called proteus. The results are based on the system flow chart developed, the corresponding hardware programming and the simulation outcome. The programming of the hardware was done using MikroC for PIC software. The proposed circuit was successfully simulated using the proteus design suite software. This was done to ascertain the workability of the proposed design. The results indicated that, the ATS responded appropriately to power outages overload condition.

The connection was properly made by linking the appropriate components in each unit to produce the general circuit for the design. After the connection, the circuit was simulated and the result displayed in an oscilloscope as well as in the form of bode plot as shown on the test results.

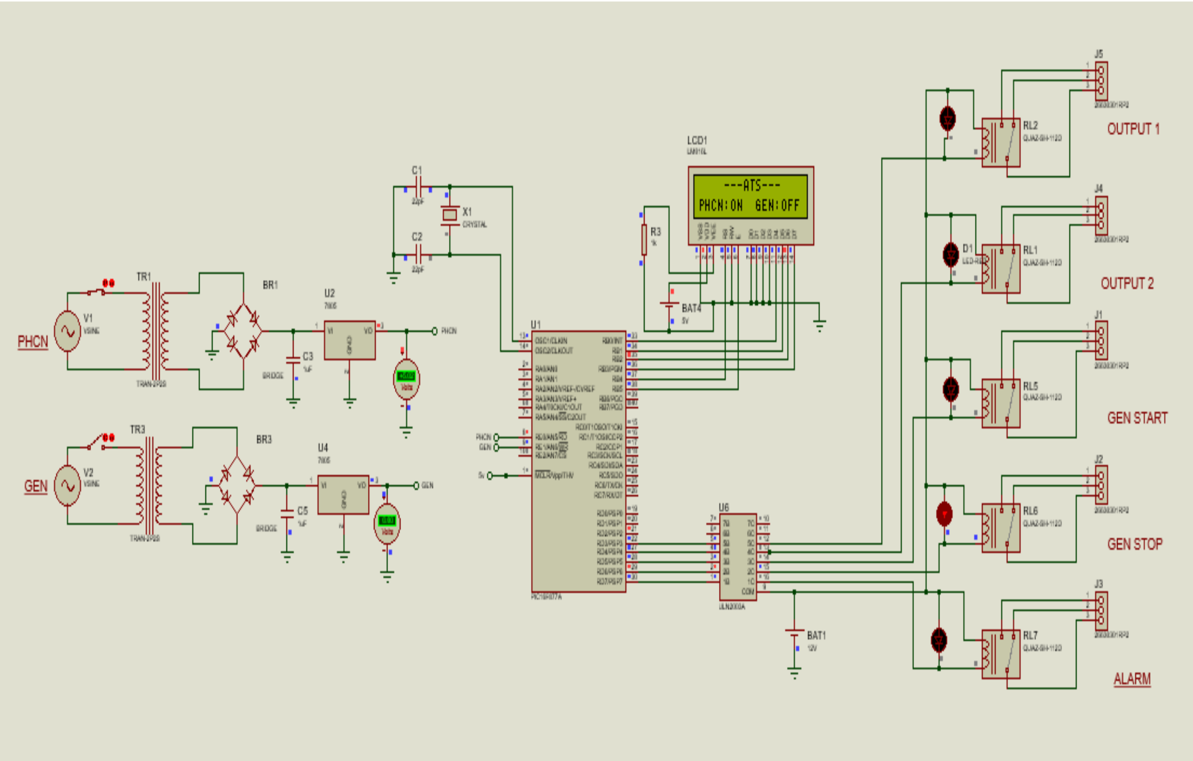


Figure 16. Circuit simulation

Programming the Microcontroller

The controller will be program using embedded C Language using a Mikro C for PIC IDE. After compiling the program, the HEX (machine) code is generated which is transferred to the MPLAB for easy transfer of the program to the microcontroller hardware via a programmer. The code is shown in appendix A.

Construction

The Construction of the study is done based on the components layout, the circuit is constructed firstly on a breadboard before soldering. Various tests were carried out both on the discrete component and integrated circuit to ensure they are functioning properly. Also, Continuity test and coil resistance test were carried out on the components (Relay, Transformer) to ensure they are functioning properly. All connections were implemented with the help of the circuit diagram to ensure that it works perfectly before mounting them on the panel. The connections are done according to the circuit diagram presented in Figure 13.

Testing and Results

The circuit diagram of the Automatic Transfer switch was designed to select between two available sources of power giving preference to one out of the two sources. In this case, preference was given to the mains supply.

Power-on Test

Power-on test was performed to check whether the voltage at different terminals is according to the requirements or not. A multimeter was switched to voltage mode to test for the voltages at different junctions. This test was performed without the microcontroller to avoid damage to the microcontroller due to any excessive voltages. The output of the transformer was checked and measured and the required 18V AC voltage was obtained, which was then applied to the power supply circuit and the terminal voltages of DC voltage at positive, negative terminals, AC1 and AC2 of the bridge rectifier were measured respectively. This voltage was then applied to the filter capacitor, and the voltage at the anode terminal and cathode of the capacitor was measured. Then this voltage was applied to the voltage regulator. This experiment was carried out to measure the output voltage at different stages. The multimeter was used to implement this test. The results obtained are shown in Table 3.

Table 3. Power supply testing result

Test	**Voltmeter**
Secondary transformer voltage	18V
Voltage at bridge rectifier	18.6
Voltage after capacitor	19.2V
Output voltage	13.8V
Battery voltage	12V
Voltage supplied to the microcontroller	5V

Transfer Switching Testing Result

The experiment was carried out to verify the capability of the designed system to switch over the supply source of the load from the power utility to the generator, and vice-versa. A light bulb was used as the load. The result obtained are shown in Table 4.

Table 4. Transfer switching testing result

Status of the utility power	**Status of the generator**	**Relay conditions**		**Load condition**
		R1	**R2**	
ON	OFF	OFF	OFF	ON
OFF	ON	ON	ON	ON

When there was a service interruption of the power utility, the load would be supplied from the generator through relays R1 and R2.

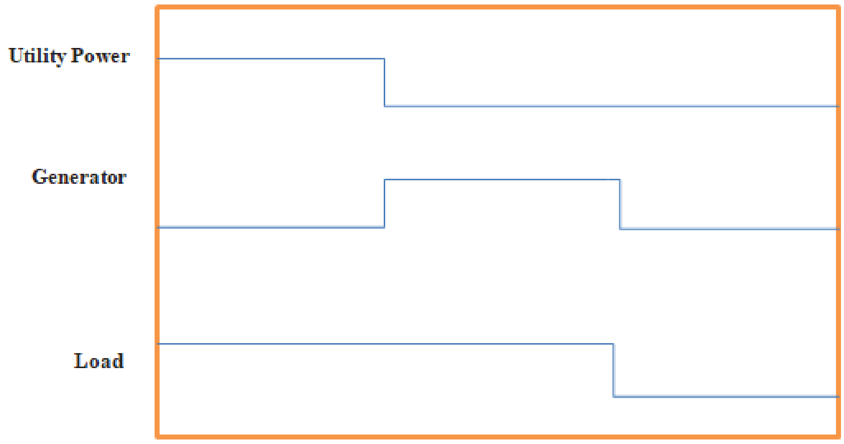


Figure 17. Digital oscilloscope transfer between utility and generator

Genset Start/Stop Testing Result

The purpose of the experiment was to examine whether the designed ATS could turn on/off the genet as desired. The starting time was counted from the moment of utility power interruption, whereas the stopping time of the genet was counted from the moment of utility power recovery. A light bulb was used as the load. Testing result is shown in Table 5.

Table 5. Generator start stop testing result

Status of the Utility power	Relay conditions				Generator condition	Load condition	Time (seconds)
	R1	R2	R3	R4			
ON	OFF	OFF	OFF	ON	OFF	ON	-
OFF	OFF	OFF	OFF	OFF	OFF	OFF	0
OFF	OFF	OFF	OFF	OFF	OFF	OFF	3
OFF	OFF	OFF	ON	OFF	ON	OFF	5
OFF	ON	ON	ON	OFF	ON	ON	6

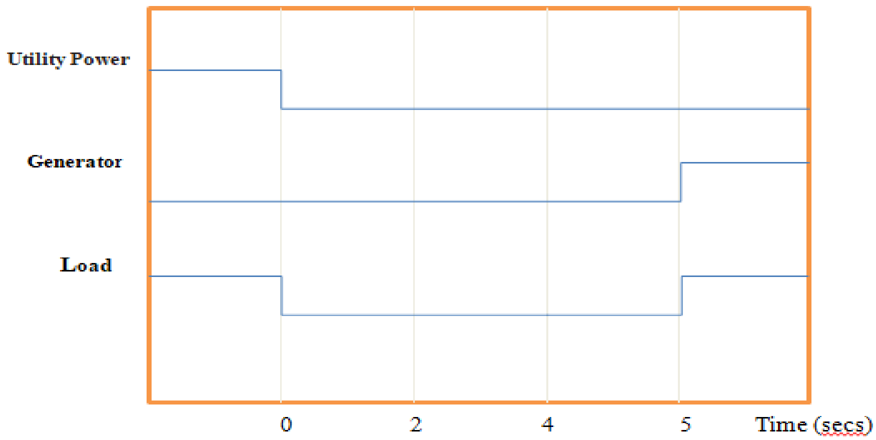


Figure 18. Digital oscilloscope showing generator start function with respect to time

Alarm Test

The alarm is expected to make a sound for 5secs whenever the PHCN is OFF and the system tries GEN and refuses to ON after 10secs with a tolerance of ±1 second as designed.

Table 6. Alarm test

Utility Power	Generator condition	Time (seconds)	Relay conditions					Load Condition	Buzzer
			R1	R2	R3	R4	R5		
ON	OFF	-	OFF	OFF	OFF	OFF	OFF	ON	OFF
OFF	OFF	0	OFF	OFF	OFF	OFF	OFF	OFF	OFF
OFF	OFF	3	OFF	OFF	OFF	OFF	OFF	OFF	OFF
OFF	OFF	5	OFF	OFF	OFF	OFF	OFF	OFF	OFF
OFF	OFF	7	OFF	OFF	ON	OFF	OFF	OFF	OFF
OFF	OFF	10	ON	ON	ON	OFF	ON	OFF	ON

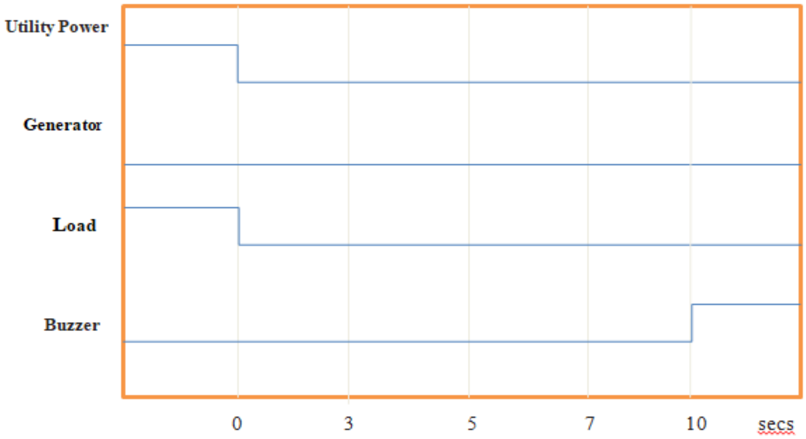


Figure 19. Digital oscilloscope showing situation when generator fails to start with respect to time

LCD Test

The LCD display is expected to display all state and condition of the system. The LCD display shows when PHCN and GEN is either ON or OFF.

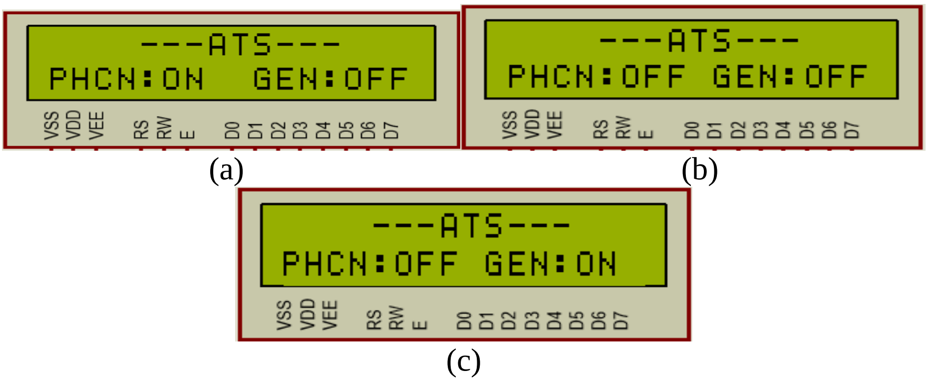


Figure 20. The LCD display showing the status of the power sources (a) when the utility power is ON and the generator is OFF; (b) when the utility power is OFF at time t < 5 secs; (c) generator is ON at time t >5 secs

Overload Protection Test

Beyond a load of 5kW, for the above configured system, the system trips the output off. This function is very critical as it controls what load can be plugged to a certain output. This is a protective unit as it saves the electrical installation from electrical stress. Figure 21 shows the screen display when an overload occurs on the system.

Table 7. Different load connected to the output and overload condition

Load	Power consumption (kW)	Circuit breaker
Two filament bulb, two fan, and a television set	0.42	ON
Six filament bulb, five fan, two television set and a pressing iron	2.26	ON
Two pressing iron, one cooker unit and a refrigerator	6.25	OFF
Three air conditional unit, bore hole pump and a pressing iron	8.1	OFF

Figure 21. The LCD display showing that the system is overloaded

Performance Evaluation

In order to test for the performance of the system, The Red LED indicate the status of the utility power supply, Green LED indicate the status of the generator. The power switch is used to ON/OFF the system.

Table 8. Performance Evaluation

Status of utility power	Generator condition	Relay RI	Relay R2	LED (Red)	LED (Green)	Observation
ON	OFF	OFF	OFF	ON	OFF	Mains is available and it supplies power to the load
OFF	ON	ON	ON	OFF	ON	Mains is out, and the generator starts in 5s which supply power to the load
OFF	OFF	ON	ON	OFF	OFF	Mains is out, and the generator refuse to starts in 5s, hence no supply to the load

Conclusion

A Microcontroller Based Automatic Transfer switch with generator starting/shut down facility has been designed to help man reduce the stress and loss of time associated with the starting and shutting down of the alternative sources of supply (generator). After the implementation of the design, various tests were carried out and the results obtained demonstrated that the automatic transfer switch achieved its design and construction purpose. The system worked according to specification by monitoring power failure and overload thereby switch between the two power supply sources according to the set priority and also automatically switches on the generator and switches it off. This device operates without human intervention hence the sluggishness of manual operation is eliminated and production downtime reduced to the barest minimum thereby reducing production losses and costs.

References

Abiodun, A. S., Kayode, O. O., Nsukhoridem, B. E., & Roseline, A. F. (2018). Design and Construction of a Single Phase Automatic Change Over Switch. *IOSR Journal of Engineering (IOSRJEN)*, *8*(1), 1–5.

Adedokun, G., Oladosu, J., Amuge, R., & Baruwa, A. (2016). Development of an intelligent automatic transfer switch for single phase electrical loads. *Annals of the Faculty of Engineering Hunedoara*, *14*(1), 61.

Adoghe, A. U., & Odigwe, I. A. (2009). Automatic transfer and controller system for standby power generator. *Advanced Materials Research*, *62–64*, 187–193. https://doi.org/10.4028/www.scientific.net/amr.62-64.187

Adoghe, A. U., Olowoleni, J. O., Ademola, A., Omadoye, A. O., Agbetuyi, A. F., Orovwode, H. E., & Awosope, C. O. (2015). Construction and Operation of an Electronic Automatic Transfer Switch (Ats). *Global Journal of Energy Technology Research Updates*, *2*(1), 01–05. https://doi.org/10.15377/2409-5818.2014.02.01.1

Agbetuyi, A. F., Adewale, A. A., Ogunluyi, J. O., & Ogunleye, D. S. (2011). Design and Construction of an Automatic Transfer Switch for a Single Phase Power Generator. *International Journal of Scientific and Engineering Research*, *2*(May), 1–8.

Amadi, A. K., Umeogamba, A. I., Ogbuka, C. U., Nwosu, C. M., Chinaeke-ogbuka, I. M., Odo, M. C., & Ajibo, A. C. (2019). A 5kva Automatic Transfer Switch With Overload , Short Circuit Protection And Generator Stop Functions. *2019 IEEE 1st International Conference on Mechatronics, Automation and Cyber-Physical Computer System*, *March*, 105–110.

Amuzuvi, C. K., & Addo, E. (2015). A Microcontroller-Based Automatic Transfer Switching System for a Standby Electric Generator. *Ghana Mining Journal*, *15*(1), 85–92.

Ananth, D., Jogarao, G., Sirisha, K., Kumar, B., & Sai Kumar. G, K. A. (2019). Automatic Power Supply Control to Ensure No Break Power. *International Journal of Scientific Research in Science, Engineering and Technology*, *6*(March 2019), 249–255. https://doi.org/10.32628/ijsrset196254

C, E. J., V, E. C., & V, O. O. (2018). Single phase microcontroller-based automatic. *International Journal of Electronics, Communication & Instrumentation Engineering Research and Development (IJECIERD)*, *8*(1), 7–16.

Ehiabhili John, C., Ezeh Chioma, V., & Orji Onyeka, V. (2018). Single phase microcontroller-based automatic. *International Journal of Electronics, Communication & Instrumentation Engineering Research and Development (IJECIERD)*, *8*(1), 7–16.

Eshovo, M. O., & Salawu, A. (2017). Single-Phase Automatic Changeover Switch for Low. *FUW Trends in Science & Technology Journal*, *2*(1), 223–226.

Ezema, L. S. (2019). Design of automatic change over switch with generator control design of automatic change over switch with. *Academic Research International*, *3*(July), 125–130.

Ilomuanya, T., & Okpala, U. (2016). Implementation of the Designed Automatic Change over System for the Department of Physics, Chukwuemeka Odumegwu Ojukwu University, Uli. *International Journal of New Technology and Research*, *2*(4), 263534.

KASSIM, J. A. (2011). *Design and construction of an LDR based 3-phase automatic switch*. Bayero University Kano.

Khan, S. S., Nasim, S., & Ali, F. (2015). Switching of Generator using PLC with SCADA and Implementation of ATS with GSM Alerts. *Journal of Electronics and Communication Engineering Research*, *2*, 30–34.

Kolo, J. G. (2007). Design and Construction of an Automatic Power Changeover Switch. *AU Journal of Technicial Report*, *11*(2), 1–6.

Olatomiwa, L., & Olufadi, R. (2014). Design and development of a low cost automatic transfer switch (ATS) with an over-voltage protection. *Journal of Multidisciplinary Engineering Science and Technology*, *1*(4), 190–196.

Onipede, B., Joseph, S., & Odiba, O. (2017). Developing an Automatic Switch for Home or Industrial Power Supply Changeover. *British Journal of Applied Science & Technology*, *21*(4), 1–7. https://doi.org/10.9734/bjast/2017/32785

Osaretin, C. A., & Ibhadode, E. (2016). Design and Implementation of Automatic Changeover Switch (with Step Loading) for Renewable Energy Systems. *Int. J. Renew. Energ & Environ*, *2*(May), 179–192.

Roy, A. A., Newton, F., & Solomon, I. (2014). Design and Implementation of a 3-Phase Automatic Power Change-over Switch. *American Journal Of Engineering Research*, *3*(9), 7–14.

Sohail, S., Nasim, S., & Ali, F. (2015). Switching of Generator using PLC with SCADA and Implementation of ATS with GSM Alerts Switching of Generator using PLC with SCADA and Implementation of ATS with GSM Alerts. *Switching of Generator Using PLC with SCADA and Implementation of ATS with GSM Alerts*, *2*(September), 30–34.

Sotelo-Valer, F., Huamán-Sayán, L., & Mamani-Arroyo, E. (2020). Design and Implementation of an Automatic Coffee Dryer. *ACM International Conference Proceeding Series*, *9*(7), 69–73. https://doi.org/10.1145/3429536.3429548

Suryawanshi, A. A., Diwani, T. M., Khot, S. P., Bhoi, R. M., Chougule, R. J., & Bilkar, R. A. (2019). Automatic Changeover System using PLC. *International Journal of Engineering Science and Computing*, *9*(3), 20888–20891. http://ijesc.org/