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Design and Construction of a GSM-Based Automatic Change-Over Switch with A Generator Control Mechanism

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ABSTRACT

This project is designed to automatically supply continuous power to a load through one of the two sources of supply that is available, the mains and generator. The two plugs represent the two sources. The plugs are connected to the two separate single-phase step-down transformers that steps down the input 230V or 240V to 12Vac. These 12Vac are rectified and regulated to 5Vdc which act as an input to the microcontroller. Once the microcontroller recognizes the presence of a given source, a relay module is switch ON to supply the load. In case mains is OFF, the system automatically triggers a relay to ON the generator that power the load and subsequently send an SMS to the user saying 'GENON'. As the mains is restored, the system sends an SMS to the user saying 'POWER RESTORED'. The user can decide to switch over to the mains or stay on the existing source by sending 'GENON' or 'STAYON' respectively. This project has proven to be of significant use to hospitals, industries and the military, among others.

Keywords: GSM, Switching, SMS, ATMEGA328P, Relay.

1.0 INTRODUCTION

Electricity is crucial for global economic development, but instability in developing countries necessitates alternative power sources like standby generators, wind, solar energy, and other renewables to meet energy demands for industrial, commercial, and domestic purposes (Herath et al., 2020).

This work addresses challenges in switching to alternative sources of supply, such as smooth and timely switching during interruptions or failures, and reducing human drudgery from switching between the two sources. It aims to eliminate these issues.

The GSM-Based Automatic Change-over switch automatically switches to an alternative power source (inverter or generator) during a power outage, and then back to the mains supply when power is restored. The switch allows users to switch between the mains supply and alternative source (Faried & Mohamed, 2018).

The system maintains constant power supply to the load by automatically switching ON the generator when the need arises. Since the user might not always be in need of the generator, provision has been made to prevent the generator from starting should an outage occur or a situation where the user might not want to switch to another source but remain on the available source (Basoene et al., 2022).

Despite the introduction of alternative power sources like generators, many developing countries still face challenges due to manual operation of these systems (James, 2019). Therefore, the need for an automatic changeover. Automation of power generation is required as the rate of power outages becomes predominantly high (Abdulkareem, 2021). If the processes of the changeover are manual, time is wasted; mal-operation and equipment damage can also result from overloading at the changeover. In order to eliminate downtime, an automatic changeover switch is required (Onah & Kpochi, 2020).

Home automation offers convenience, power management, and cost efficiency through remote control of appliances. Advancements in mobile phones enable the development of applications for remote management and control of devices. Different approaches, such as DTMF, SMS, and GPRS, can be used to create remote management systems, making life easier. Mobile phones are gradually replacing personal computers in various applications (Smith et al., 2018).

Home automation systems are becoming increasingly sophisticated, enabling smart homes with centralized control over lighting, entertainment, security, telecommunications, heating, and air conditioning (Maraneetharan, E ;Selvakumar, 2019).

These systems record usage, prepare shopping lists, and automatically order replacements. They enable users to control security lights, heat water, and stream live videos from anywhere. Home automation systems range from remote TVs to automated air conditioning systems, making them essential for managing busy lives (Abereola, 2017). Mobile phones offer an additional advantage in work by alerting users about available supply sources and allowing them to act on system needs.

Manual switching systems are vulnerable to human errors and user preferences, necessitating the use of an efficient automatic control system.

Hence, this project focuses on the design and construction of GSM based automatic change over switch with generator switching mechanism.

2.0 LITERATURE REVIEW

Some of the literatures that are related to the work are reviewed and discussed as shown below.

Smith et al., (2018) focuses on design and Construction of An Automatic Change over Switch with Option Of GSM-Based Remote Control Using Graphic User Interface (GUI). Three power sources were considered: public, inverter, and backup generators. Power supply was ensured through wireless change-over using a GSM Module and MATLAB GUI interface.

Ezema et al., (2012) worked on Design of Automatic Change-Over Switch with Generator Control Mechanism. The system aims to automatically switch on and off the generator during mains power failure, restoring power to the mains supply and simultaneously switching off the generator. It uses contactors, timer, and relay components to detect power restoration and ensure continuous electricity supply.

Ayindesaburabiodun, (2018) worked on Implementation of GSM Based Automatic Change over System for Electric Generators. The system aims to automatically switch on and off the generator in case of power failure, send SMS alerting the user, and switch to the mains supply once restored. It uses a GSM module, relay, and PIC16FN77 components. A sensor detects power failure and the generator output control turns on or off based on the message. The system performs as expected.

Keshinro et al., (2016) worked on Design and Development of SMS Based Generator Start /Stop System. The author developed an integrated SMS alert and remote-control system for a generator, allowing users to control the generator remotely. The system can be activated or stopped from anywhere, even when the owner is away. The SMS unit is mounted inside the generator housing and sends an SMS to a predetermined phone number when power fails. The system allows for efficient problem-solving and secure use without interference.

3.0 METHODOLOGY

3.1 Materials

This work utilizes various components such as relay, capacitor, resistor, GSM module, transformer, Atmega 323p microcontroller, diode, LED, LCD, voltage regulator, and bridge rectifier.

1. Relay: Relays are electromechanical devices actuated by electrical current, used in various industries like telephone exchanges, digital computers, and automation systems. They protect electric power systems from trouble and regulate power generation and distribution. Relays are also used in home appliances like refrigerators, washing machines, and dishwashers. They can be electrical or mechanical in input and output.

Figure 1: Diagram of a Relay switch

Figure 2: GSM module (SIM900)

2. GSM Module: The GSM Module is interfaced with microcontroller Atmega328p. GSM Module have a SIM card, it sends an SMS to user, as when it is programmed.

GSM is a global mobile communication modem developed in 1970 by Bell Laboratories. It operates at 850MHz, 900MHz, 1800MHz, and 1900MHz frequency bands and uses time division multiple access (TDMA) technique for communication. GSM can carry 64 kbps to 120 Mbps of data rates and has various cell sizes, including macro, micro, pico, and umbrella cells, with varying coverage areas.

The SIM900A Modem is a Dual Band GSM/GPRS based SIMCOM modem, operating on frequencies 900/ 1800 MHz. It can search these bands automatically and can be configured via AT commands. It features an internal TCP/IP stack for internet connectivity.

3. Atmega 328p Microcontroller: A microcontroller is a cost-effective, self-sufficient, integrated circuit used to control electronic devices. It consists of a central processing unit, input/output interfaces, peripherals, RAM, ROM, EEPROM, and a clock generator. This reduces the number of chips and wiring needed for equivalent systems using separate chips.

ATMEGA328P is a popular 8-bit microcontroller from Microchip, renowned for its high performance and low power, primarily used in ARDUINO boards due to its AVR RISC architecture.

Figure 3: ATMEGA 328P

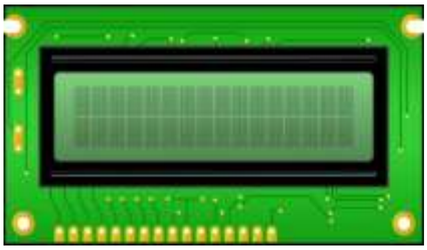

Figure 4: LCD (16×2)

4. Liquid Crystal Display: LCD Jhd162a is a flat panel electronic visual display using liquid crystals for light modulation. It operates on two polarizing sheets with a liquid crystal solution, blocking out light with an electric current. It operates in temperatures ranging from -10°C to 60°C and has over 50000 hours of operation.

LCD in 4-Bit uses 4 lines of data bus instead of 8 lines, splinting data in nibbles. Successful interface with 4 Pins saves 4 lines for other purposes.

5. Step-Down Transformer: This project utilized a step-down transformer to convert AC electricity from high to low voltages, ensuring safety and minimal power loss.

Figure 5: Typical transformer

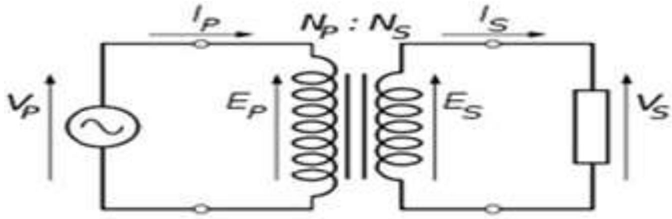

Figure 6: An ideal transformer

In this case, the step-down transformer reduces 230VAC to approximately 12VAC depending on the turn's ratio.

$Turns\ Ratio = \frac{V_P}{V_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$

Where Vp = primary voltage, Vs = secondary voltage, Np = number of turns on the primary, Ns = number of turns on the secondary Ip is primary current, Is = secondary current

6. Voltage regulator LM7805: The LM7805/LM7805A, a three-terminal positive regulator, was utilized in this project, providing a fixed output voltage of 5V, with internal current limiting up to 1A.

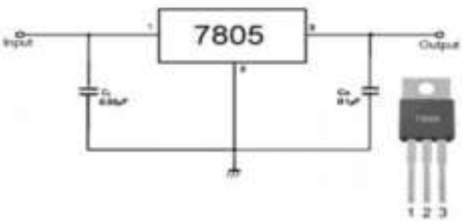

Figure 7: Voltage regulator (LM7805)

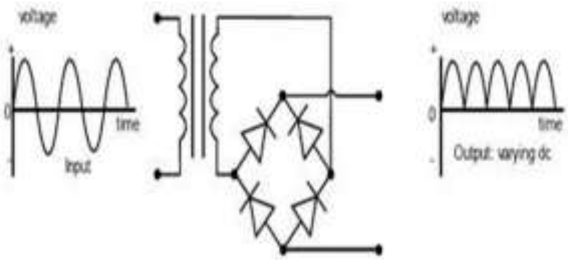

Figure 8: Full wave rectification

7. Bridge Rectifier: The bridge rectifier converts alternating current (AC) to direct current (DC) using a transformer output. It offers stability and full wave rectification, with only two diodes conducting in positive half cycle and two in negative half cycle.

8. Filters: This project employs a capacitive filter to smooth the DC output of a rectifier, ensuring constant output if mains voltage and load remain constant.

Figure 9: Resultant full wave form

Figure 10: Capacitor

A capacitor is a passive electronic component with two conductors separated by a dielectric, used to smooth power supply output and block direct current in electronic circuits, particularly on wide, flat, parallel, narrowly separated conductors.

9. Light Emitting Diodes (LEDs): LEDs are silicon-based semiconductor devices that emit photons when current passes through a diode, releasing energy in the form of light when forward biased.

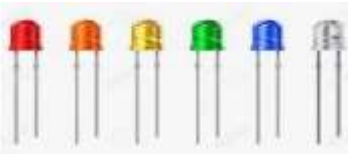

Figure LEDs

11:

Figure 12: Diode (IN4007) Figure 13: Resistors

10. Diodes (IN4007): The project utilized diodes, specifically IN4007, to convert AC to DC, with their maximum forward current, reverse voltage, and forward voltage capacity.

11. Resistors: A resistor is a two terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law; V = IR

Where; V = applied voltage across the terminals of a resistor, I = current flow through the resistor in direct proportion to the applied voltage, R = Resistance

3.2 Methods

3.2.1 Block Diagram

The complete system block diagram is as shown below;

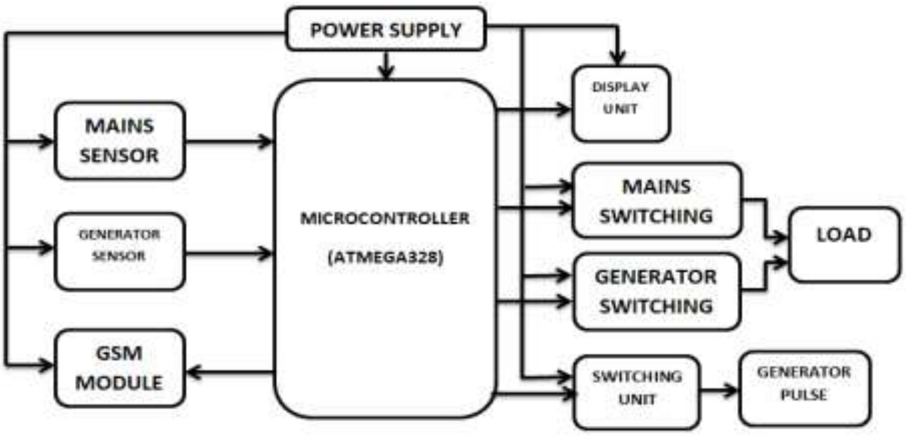

Figure 14: Complete System Block Diagram

3.2.2 Design

3.2.2.1 Power supply design

The voltages required for powering the various integrated circuit components for the implementation include 12V, 5V and 4.2V.

The central power supply schematic from where the required 12V, 5V and 4.2V will be harnessed from is shown in Figure 15. It will consist of the step-down transformer, the bridge rectifier and a filtering capacitor.

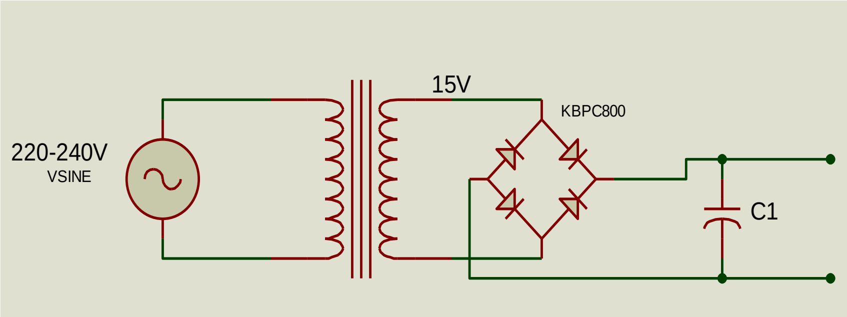

Figure 15: Central Power Supply

3.2.2.2 Filtering capacitor design

The peak voltage $= V_{peak} = V_s \times \sqrt{2}$

V_s =R.M.S value of the transformer secondary winding = 15V

$V_{peak} = \sqrt{2} \times 15 = 21.21V$

The DC value of the rectified voltage is given by

$$V_{dc} = \frac{2}{\pi} V_{peak} = \frac{2}{\pi} \times 21.21 = 13.50V$$

Maximum load current is given by $I_m = \sqrt{2} \times I_{R.M.S} = \sqrt{2} \times 2 = 2.83A$

$I_{R.M.S} = 2A =$ Transformer secondary output current

Average load current $I_{dc} = \frac{2}{\pi} I_m = \frac{2}{\pi} \times 2.83 = 1.80A$

It is preferable to use a filtering capacitor that will hold the peak ripple voltage at approximately 1%

$V_{ripple} = 0.01 \times V_{dc} = 0.01 \times 13.50 = 0.135V$

The shunt capacitor value C_1 is obtained from the relation given by

$$C_1 = \frac{I_{dc}}{F \times V_{ripple} \times 4\sqrt{3}} = \frac{1.80}{50 \times 0.135 \times 4\sqrt{3}} = \frac{1.8}{46.77} = 0.0384862 = 38486.2\mu F$$

From the E series for capacitors available for commercial purchase, the rated capacitance for C_1 is not available. Hence, available capacitors will be parallel to make up for the rating of C_1.

3.2.2.3 Design of 5V sower supply

This power supply will be used to power the microcontroller, the LCD, the temperature sensor and the buzzer alarm. A 5V constant voltage regulator called LM7805 was used to deliver the required 5V. The capacitor C3 of Figure 16 is suitably chosen as 100µf and used for post filtering purposes

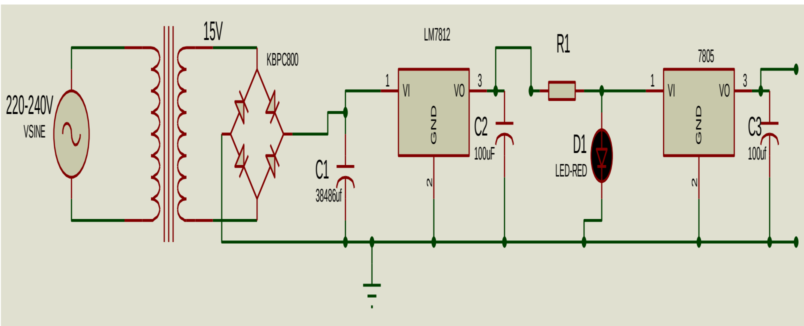

Figure 16: 5V Power Supply Circuit.

3.2.2.4 Design of 12V power supply

The 12V power supply will be derived from the central power supply shown in Figure 17. A 12V constant voltage regulator called LM7812 was used to deliver the required 12V

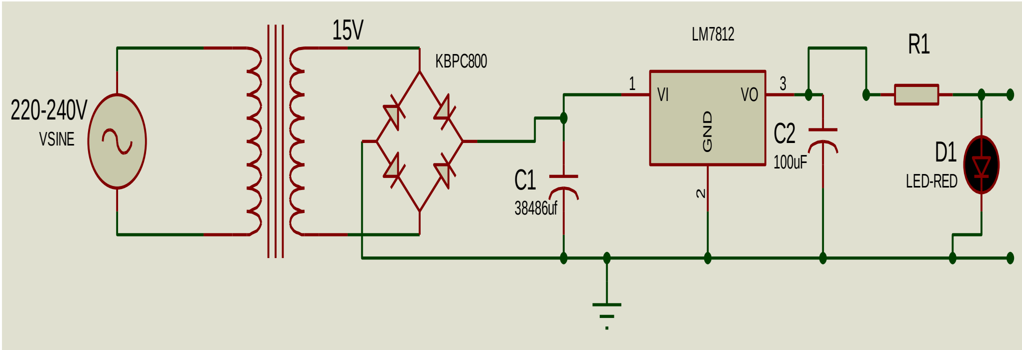

Figure 17: 12V Power Supply Circuit

The capacitor C_2 is used for post filtering after regulation, its value is suitably chosen as 100µf. The protection resistor rating for the red LED is designed using the KVL relation around closed loop between C_2, R_1 and D_1 of Figure 17 as follows

$$V = V_D + I_D R_1$$

Where V = source voltage of the red LED = 12V, V_D = voltage consumed by the LED from its data sheet specification = $2V$, I_D = Current consumed by the LED from its data sheet specification = $20mA$

$$R_1 = \frac{V - V_D}{I_D} = \frac{12 - 2}{20mA} = \frac{10}{20} = 500\ ohms$$

But 510-ohm resistor was used in the implementation since 500 ohms resistor was not available

3.2.2.5 Design of 4.2V power pupply

The 4.2V power supply was used to power the GSM module and will be shouldered by LM317 variable voltage regulator.

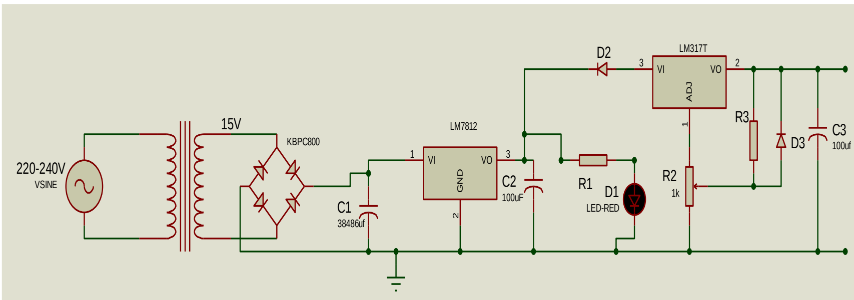

Figure 18: 4.2v Power Supply Circuit

Using the formula for maximum output voltage ($V_{o\,max}$) required from the LM317 adjustable voltage regulator, the ratings of resistor R_2 of Fig. 3.0.3 can be determined.

$$V_{o\,max} = V_{ref}\left(1 + \frac{R_2}{R_3}\right) \text{ --- } 3$$

$V_{ref} = LM317$ Reference voltage $= 1.25V$

Since there is need an output of 4.2V from LM317, then $V_{o\,max}$ will be equated to the required output voltage. Setting R_3 as 220 ohms, then equation 2 becomes

$$1.25 \times \left(1 + \frac{R_2}{220}\right) = 4.2 = 1.25 + \frac{1.250R_2}{220}$$

$924 = 275 + 1.250R_2$ or $924 - 275 = 649 = 1.25R_2$

$\frac{649}{1.25} = R_2 = 519.2$ $R_2 = 519.2$ Ohms

Since from the E- series for four color band resistors available commercially shown in Table.4, we can't get an exact rating of a resistor with 519.2Ω value that will correlate with our expectant voltage output from the LM317, we then resorted to using a variable resistor of Ohmic value 1k Ohms for R_2.

3.2.2.6 Design of LCD constant voltage dividers

The voltage divider configuration made up of R7 and R8 are required to supply an output voltage of 0.5V (in accordance to the data sheet) to the LCD for powering the background light contrast.

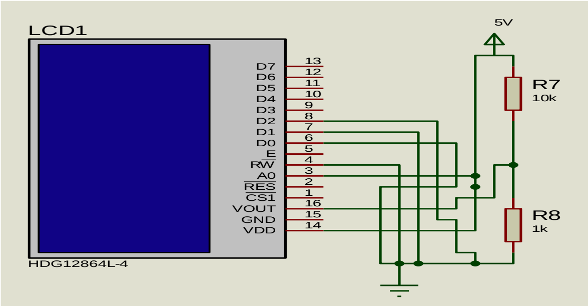

Figure 19: LCD circuitry with Constant Dividers

$$V_{OUT} = \frac{R_8}{R_8 + R_7} \times V_{CC} = 0.5 = \frac{1000}{1000 + R_7} \times 5$$

Note, $R_8$was set as 1000 Ohms for convenience in calculating R_7

$$5000 = 500 + 0.5R_7$$

$$5000 - 500 = 0.5R_7 = 4500$$

$$R_7 = \frac{4500}{0.5} = 9000\ Ohms$$

3.2.2.7 Design of microcontroller oscillatory circuit

This unit is responsible for determining the frequency of operation of the microcontroller. The choice of ratings for the capacitors shown in Figure 20 will be based on the design. The crystal oscillator chosen determines the range of selection for C_2 and C_3.

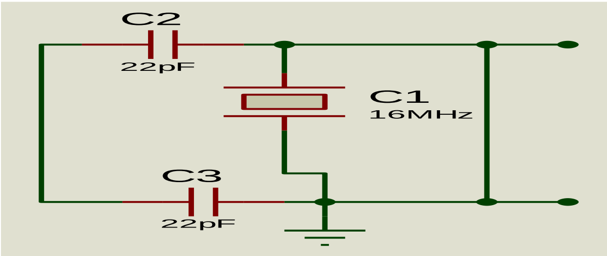

Figure 20: Oscillatory Circuitry for Microcontroller.

A 16MHz high speed crystal oscillator was used as C_1 and the rating of C_2 and C_3 were chosen in accordance to the ranges available with reference to the value of C_1.

Internal frequency of operation of the microcontroller and period of machine cycle needed to execute an instruction is computed below

$$F_{internal} = \frac{F_{Quartz}}{2} = \frac{16MHz}{2} = 8MHz$$

$$T = \frac{1}{F_{Internal}} = \frac{1}{8} = 0.125\mu s$$

$F_{internal}$ = Internal clock frequency of microcontroller, T = Period or machine cycle for executing an instruction, F_{quartz} = Frequency of crystal quartz

3.2.2.8 Switching unit

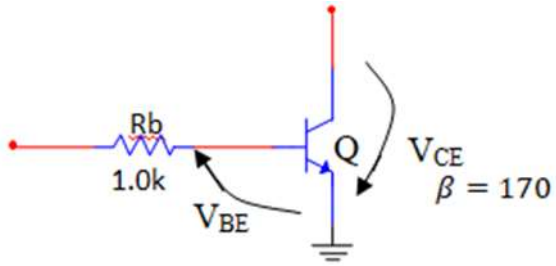

Figure 21: Switching Unit

$V_{cc} = 5v$ The input V_{in} can be express as $V_{in} = V_{be(on)} + I_{b(eos)} \times R_b$

$R_b = \frac{V_{in} - V_{be(on)}}{I_{b(eos)}}$ But $I_{b(eos)} = \frac{I_{C(sat)}}{\beta}$

$$I_{b(eos)} = \frac{1.2mA}{170} = 7.1\mu A$$

$\therefore\ R_b = \frac{12-0.7}{7.1\mu A} = 161Kohms$ $R_b \approx 160Kohms$

The diode placed across the relay is commutative diode to protect the circuit from back Emf.

3.3 Principle of Operation

The project basically supplies continuous power to a load in automated mode through one of the two sources of supply that are: mains grid, and generator when any one of them is available.

Two power supplies connected to two different socket outlets are used for the two respective sources. The outputs of these power supplies are connected to the Atmega 328P microcontroller and they act as sensors to the analog input to the microcontroller. When a socket outlet is turn on, a 240Vac is step down to 12Vac which is rectified and regulated to 5Vdc. This regulated voltage act as an input to the microcontroller. Once there is an input of 5Vdc to the analog terminal of the microcontroller, a relay switch is turn ON to supply the load with an AC voltage. Lamps rate 10W were used as a load for demonstration purpose which draws power from any of the available supplies.

The system allows users to select sources based on available options via SMS. If mains supply goes off, the system automatically turns on the generator, supplying the load. If mains supply returns, the system sends an SMS, allowing users to choose within a specified time frame.

3.3.1 Circuit Diagram

The complete circuit diagram is shown below;

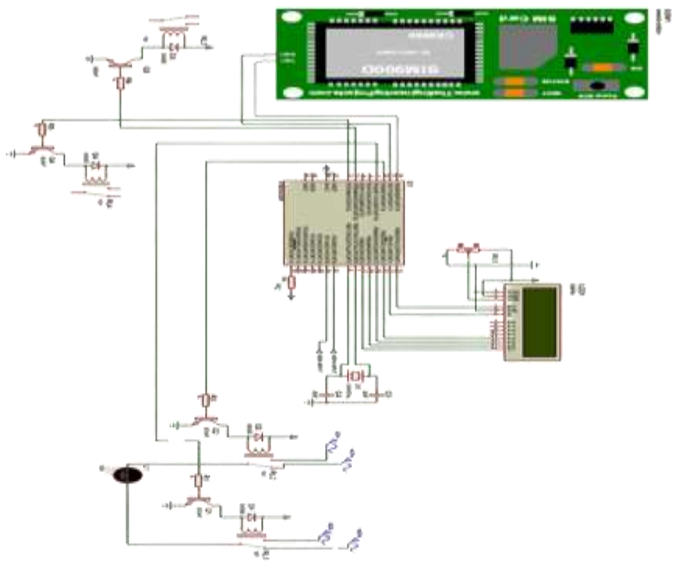

Figure 22: Circuit Diagram

4.0 TESTS, RESULTS AND DISCUSSION

4.1 Tests

4.1.1 Continuity Test

Continuity test was carried out to check if there was current flow in the project circuitry and was aimed at finding circuit open paths in the circuitry after completing soldering and configuration. A multimeter was used to perform continuity test on the electric circuit by measuring electric current flow, as follows;

i. A multimeter was kept in buzzer mode.

ii. The ground terminal of the circuit is connected to the ground terminal of the multimeter and the live of the multimeter to Vcc, to test for current flow.

iii. Finally, terminals are connected across the path that needs to be checked and there is continuity in the path, a beep sound was produced by the multimeter.

4.1.2 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, note that, 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 12V AC voltage was obtained, which was then applied to the power supply circuit and the terminal voltages of 12.00V and 0.00V, DC voltage at positive, negative terminals. AC1 and AC2 of the bridge rectifier were measured respectively. This voltage was then applied to the 2200uF capacitor, and the voltage at the anode terminal and cathode of the capacitor was 12.00V and 0.00V respectively. Then this voltage was applied to the voltage regulator LM7805, i.e., an input of 12VDC and output of 4.96VDC were obtained according to the requirements. The 5V DC voltage was then given to the 7th pin and ground to 8th pin of the microcontroller.

4.1.3 Operational Testing

The functionality of the complete construction was tested by connecting it to generator, mains and the load. The connections were made to the appropriate points of the generator. When mains was switched OFF, the system started the generator, sends an SMS to the user indicating “GENON” and at the same time switched over the load. As mains was restored, then the system sends an SMS to the user as “POWER RESTORED, waiting for command”. The user can decide to send an SMS using “STAYON” to allow him continue using the generator or stay mute without responding and after a while, the system automatically switched OFF the generator and switch over the load to the mains supply. The system repeats itself over and over again.

4.2 Results

The system, consisting of 10 ports, was tested for its performance using a circuit diagram, switch, and transformer. The device connected to the mains, generator, load, and generator parts, with the generator and mains power being connected to the input and load respectively.

Table 1: Summary of the performance evaluation of the system

Activity	**Input**		**Output**
	Mains	**Generator**	**Load (Bulb)**
Switch	ON	OFF	Glow
	OFF	ON	Glow

The result is summarized as provided in the table above. Taking the switch to the ON position implies the flow of main power, while taking the switch to the OFF position implies the outage of main power.

4.2.1 DC power supply

Table 2: showing results of DC power supply circuit and microcontroller

Output of the bridge rectifier	**Input into the voltage regulator**	**Output of voltage regulator**	**Input into the microcontroller (Vcc)**
11.7Vdc	10.2Vdc	4.96Vdc	4.96Vdc

4.4 Discussion

This project was implemented, tested section by section and integrated before testing the entire system. The inputs from the two sources were given to the microcontroller and the output of the microcontroller is given to the relay which controls and maintains continuous power supply to the load.

Finally, the system status of the available sources is sent as an SMS to the user and as well being displayed on the LCD.

5.0 CONCLUSION

A single-phase automatic change over switch having a generator switching mechanism has successfully been constructed and tested. It worked averagely due to issues experienced with the programming. It was implemented according to specification and was constructed with low-cost materials that were readily available in our local market. The changeover process takes place almost instantaneously.

In-depth knowledge of programming should be deployed in working with such system to avoid failure or damage to the existing installation. This project can further be modified or enhanced using IOT, other sources like solar can also be incorporated.

Table 3: Bill of Engineering Measurement and Evaluation

S/N	**Item Description**	**Type**	**Qty**	**Unit Price**	**Total Cost**
1	Microcontroller	Atmega328P	1	2000	2000
2	GSM	SIM900A	1	1500	1500
3	Contactor	100A	1	3000	3000
4	Light Emitting Diodes	RED	5	50	250
5	Voltage Regulator	7805	4	100	400
6	Diodes		8	100	800
7	Capacitor		5	250	1250
8	LCD Module		1	2000	2000
9	Screws		10	100	1000
10	Transformer	240Vac/12Vac	1	2500	2500
11	Relays (single unit)	10A, 230Vac	3	700	2100
12	Relay module	10A, 230Vac	1	700	700
13	ATMEGA 328P socket	28pins	1	500	500
14	Strip board (big size)	14 × 9 cm	1	1000	1000
15	Strip board (small size)	4 × 6 cm	1	1000	1000
16	Jumper wires		10	100	1000
17	Soldering lead		1	500	500
18	Electrical cables		2	200	400
19	Lamp holder		1	200	200
20	Bulbs	10w	1	500	500
21	Resistors	330 Ω	10	50	500
22	Supply Cables		5	300	1500
23	Arduino UNO		1	5000	5000
24	Casing		1	4000	4000
25	Miscellaneous		1	1500	1500
Total					35100 ($35)

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