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Implementation of the Designed Automatic Change over System for the Department of Physics, Chukwuemeka Odumegwu Ojukwu University, Uli.

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Abstract—**In this work, we constructed microcontroller-based automatic power changeover with artificial intelligence for auto switching from conventional source to alternative source and vice versa, in the event of power failure.This system has two major sensors; one for the public power supply and the other for the standby generator. The signal from the sensor goes through signal conditioning to be able to communicate with the controller. The microcontroller monitors the signals from both sensors, to ascertain when public power fails and when power from generator comes on line. Both scenarios are quickly reported to the user via SMS. When public power is restored, the automatic control system checks the voltage level to ensure that it is within the acceptable range (180V -230V), if it is, the control system quickly changes over power to the public power source and switches off the standby generator. If it is not within the acceptable range, the control system leaves the generator ON even though the public power is available. In this way, the building and appliance are protected from any fault in the public power supply source. This system therefore incorporates both the automatic control and the intelligent /feedback control.**

Index Terms—**About four key words or phrases in alphabetical order, separated by commas.**

I. Introduction

The need for steady source of power has called for alternative source of power especially in Nigeria where power failure is no surprise. The introduction of these alternative sources of supply bring forth the challenge of switching smoothly and timely between the mains supply and the alternative sources whenever there is power failure. There is also the need to reduce drudgery from switching between the two sources on the human side. Solving these challenges forms the focus of thi swork. The automatic power change-overs witch is a device that links the load and mains supply or the alternative supply together. This enables the use of either the mains supply or an alternative source when there is outage on the mains source. This can either come in with three phase or single phase. This device maintains constant power supplyto the load by automatically activating the generator when there is need. Reliable and secure uninterruptible power supply is the hope of all industrial operations, especially in most developing countries where population growth, industrialization and urbanization, [1,2] and improper planning by service providers and governments are the order of the day. Most manufacturing industries, firms and institutions such as hospitals and healthcare facilities, financial institutions, data centres and airports to mention but a few require constant power supply all year round. Power instability generally retards development in public and private sectors of any economy, [3,4,5]. Any instance of power failure could lead to prohibitive consequences ranging from loss of huge amounts of money to life casualties, [1]. The spate of frequent power outages without an effective back-up system is truly a disincentive to investors in any developing economy like Ghana, [3].Indeed, the ravages of power instability have equally necessitated automation of the switching system between national grid energy system and standby generators used as backup. In the last decade, different equipment and configurations have been used in order to cope with this problem, [1]. An automatic changeover system makes use of sensors and transducers to realize the changeover in a shorter time while eliminating human interference and its attendant errors, [5].

In the design of an automatic power changeover system with SMS feedback for critical application with zero tolerance for power outage, there must be three power sources of which two must be on always viz: public power source (PHCN), standby generator and a UPS or another standby generator. The text message system informs the user of the status of both public power supply and the generators. This system also monitors the restoration of the public power and changes over again to public power in order to save cost.

II. METHODOLOGY

The methodology adopted for the hardware development is the top-down design method. Here, we started by designing the system from the sensors, then the signal conditioning and analog to digital conversion subsystem, we went ahead to develop the control system, down to the output interfaces, where we connected our output devices and finally we added the final output elements as shown on Fig 1.

The sensors used here are a.c voltage sensing sensors for sensing both the generator a.c output and the public power supply a.c output. The signal conditioning subsystem involves the conversion of the analog signals gathered from the sensors to their equivalent digital signal which is what the control system needs to execute the required control. The control system typically is the AT89C52 microcontroller and the entire components needed to properly configure it for proper operations. The output interfaces involves all the

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circuit that converts the digital signal from the control system back to it equivalent analog signal for output devices requiring analog outputs, but it gives digital output to output devices that require digital outputs.

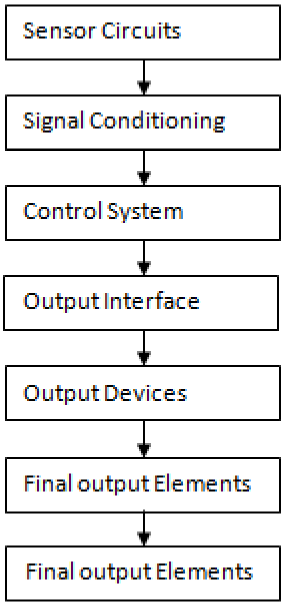

Fig. 1: The Block Diagram for Top Down Design Approach

The final output elements are those elements that execute the real world desired actions. A typical example is the relay which is an electromagnetic switche. They assist the control system in carrying out its decisions in the real world. In our proposed system the final output element here is the relay and the alarm system.

On the other hand, the methodology adopted for the software development is the pseudo coding and flow chart development. The desired action expected to be performed by the control system is carefully represent by our control algorithm also called pseudo codes and the flow chart. The software implementation controls the general operation of the system. In this work, we used assembly language.

III. SYSTEM DESIGN AND IMPLEMENTATION

A. *Power Supply design and Implementation*

In the design and implementation of power supply unit, we used the following components;

(1) 6V 4.5Ah rechargeable battery as the main source uninterrupted power to the system. This supplies the input voltage needed for the system. Back up battery wasalso used to make the system independent of external power sources (that is, generator or public power supply).

(2) A capacitor of 2200µf/35V was used to make sure voltage does not die off instantly from the system immediately power is removed.

(4) A 5V regulator that is 7805 voltage regulator. This generates the regulated voltage level required for the proper operation of the circuit.

(5) Power ON indicator (LED) and resistor which limits the voltage entering the LED. The backup batteries supply voltage level for the power supply unit. A voltage regulator (7805) is used to regulate the voltage output to get a 5V dc. The block diagram of power supply unit is as shown on Fig 2.

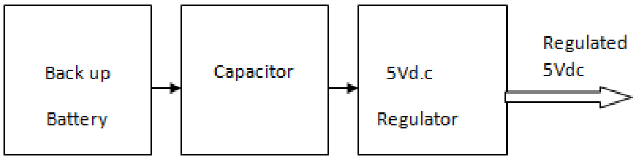

Fig. 2: Block diagram of the power Supply Unit

B. *Design Equations and Calculation of the Power Supply Unit*

The input voltage from the backup battery gives us a maximum of 8V and the capacitor could make the voltage going into the regulator to get up to 15V. This value is typical for the 7805 regulator, as the maximum required voltage input is about 25V. The 7805 voltage regulator is a three terminal IC used for voltage regulation. It is factory trimmed to provide a fixed output of 5 volts at 1A load current and has an on chip circuitry to prevent damage in the event of over heat or excessive load current. The chip simply shuts down, rather than burning out. The 7805 voltage regulator has the following characteristics.

(i) Input voltage range of 7 – 15 volts

(ii) Load regulation of 0.2 %

(iii) Load current of 132mA

To calculate for load resistor in the above circuit

$R_L \quad = \quad V_{max} / I_{max}$

$= \quad 15/ 132 \times 10 - 3 = 113 .64\Omega$

A standard resistor of 220Ω should be used.

The LED used as power indicator was biased using the following components as calculated below;

Imax = 16mA - 10mA (maximum required current for the LED used)

Voltage drop (Vd) = 0.6V

PD (max) = 15mW at 250C

R_1 is a limiting resistor that limits the amount of current flowing across the diode.

$R_1 \quad = (V_s - V_d)/ I_{max}$

Where Vs is source voltage

V_d is voltage drop

Imax is maximum current

$\therefore R_1 \quad = \quad (18 - 0.6 \quad x \quad 103)/16 \quad = \quad 1087.5\Omega \approx 1k\Omega$

A preferred value of 1kΩ was used as limiting resistor (R_1). This was chosen by experiment.

The Power supply unit is responsible for supplying the system's power requirements. It makes power available to the other units of the hardware system. The Power supply unit delivers 5V dc regulated supply at 1A each.

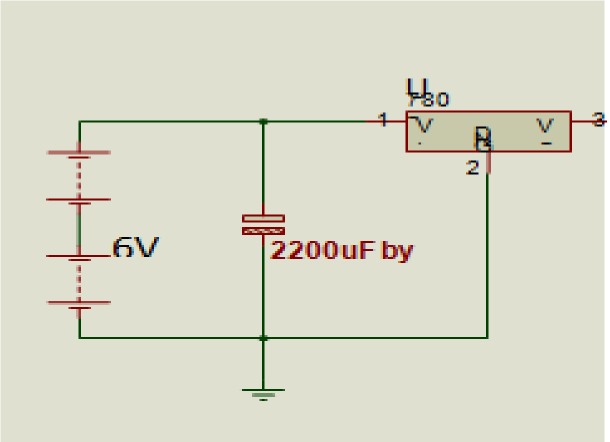

Fig 3: The Power Supply Unit.

IV. The Control System Implementation

The control section is responsible for carrying out the desired controls via the output bits of the AT89C52 microcontroller. It is also responsible for sending a feedback to the user when public power is restored. The control section consists of an AT89C52 Microcontroller, 11.0592MHz crystal oscillator, resistors, capacitors e.t.c. The additional components besides the microcontroller are used to configure the controller for proper operation. The microcontroller is programmed according to the already designed control algorithm using assembly language program for 8051 microcontroller series. The controller executes the required action as it receives the corresponding input digital signals from the input interface.

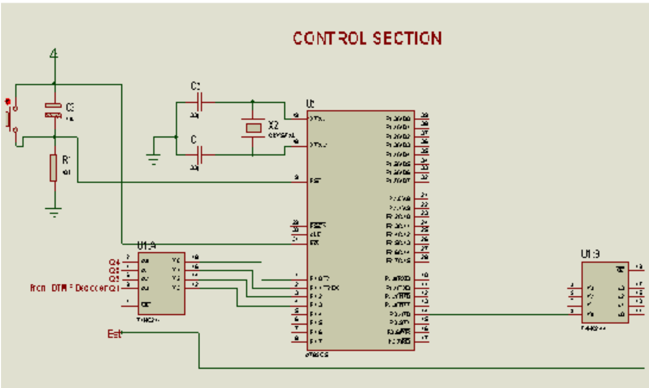

Fig. 4: The Schematic implementation of the Control Section

V. Design of Output Interface /Relay Driver Unit (Generator Starter/ Changeover Unit)

The output interface section is also the generator starter/ power change over unit and it consists of a proper arrangement of resistors, transistors and the 12V 10A relay. The design was done in such a way that the output bits of the microcontroller drives the BC337 transistors directly, which in turn drives the relay. The two relays are responsible for the power changeover and the starting of the standby generator.

Calculations for the choice of components were made using the component specifications from datasheets as shown below:

Table 1: An Extract from transistor datasheet

Transistor number and type	Collector to base voltage (Vcb)	Collector to emitter voltage (Vce)	Maximum Collector Current (I_C)	Maximum power dissipation (W)	Current Gain (hfE or β)
BC337 NPN	75	75	0.6A	0.500	200

From Table 1, the maximum collector current for BC337 Ic = 0.6A and β=200

But $I_C = \beta I_B$

$I_B = I_C/\beta = 0.6/200 = 0.003A$ or 3mA

Also from the microcontroller's Datasheet, the maximum output current of each of the bits is 10mA. But we need we need a resistor R1 to limit the current getting to the base of our transistor to about 2mA.

The internal pull up resistance of the Microcontroller Rp can be calculated using ohms law.

V=I*Rp , Therefore Rp =V/I

But I = 10mA (10 x10-3A), V=5V

Rp = (5 x1000)/10 = 500Ω

This is the internal pull up resistor Rp.

We must connect our current limiting resistor R1 in series with Rp

I_b= 3mA max. But let chose I_b= 2mA

I_b= V/RT where RT is the effective resistance in series.

RT = Rp + R1 (resistances in series)

RT = 500Ω + R1

$2 \times 10^{-3}A = 5V/(500\Omega + R1)$

2*(500Ω + R1) = 5 x103

(500Ω + R1) = 2.5 x103 =2500 Ω

R1 = 2500-500 = 2000 Ω =2k Ω

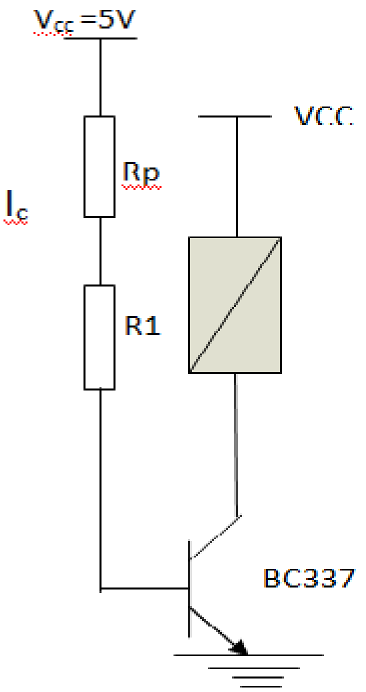

Fig:6

Experimentally, we discovered that 2KΩ was perfect in biasing the transistor. The block diagram of the resulting unit is as shown below:

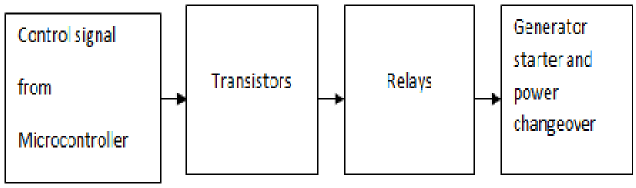

Fig 7: Block Diagram of the Output Unit

The freewheel diodes incorporated in the design is used to eliminate or minimize kick-backs and protect the transistor from flashing because of these kick-backs.

VI. The Output Interface Implementation

The output interface is responsible for executing the desired control. As it receives instructions from the output bits it executes desired actions, which could be starting the generator and changing over to generator line or vice versa. The output interface is made up of the following components; resistors, transistors (BC337) and relays (6V by 10A).

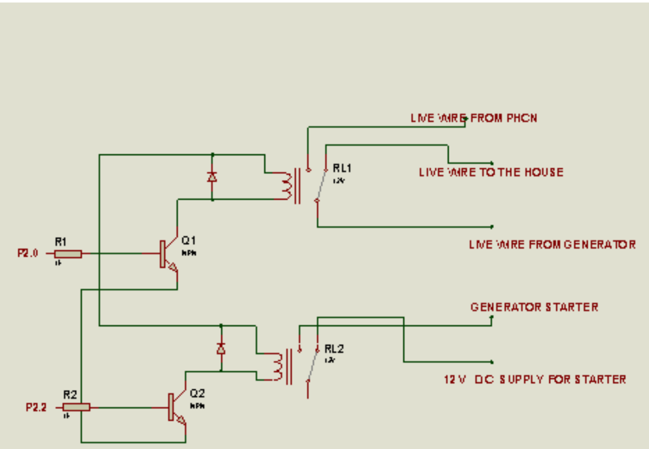

Fig 8: The Schematic Implementation Feedback Section

VII. The Feedback Unit Design and Implementation.

The feedback for the system was achieved by text messaging. This is made possible by sending clock pulses to dedicated switches of a mobile phone which sends the text messages to the desired designated phone number. The calculations of the feedback circuit are similar to that of the output interface because the same type of transistor and opto-coupler were used. Therefore we will use a 10kΩ pull up resistor to source for enough current since we are using port 1 and 1kΩ to bias the BC377 transistor.

In addition, feedback unit was implemented by switching the GSM keypad switches responsible for sending a text message to the designated remote GSM. This switching was achieved by using a pull up resistor of 1kΩ, BC337 transistor and 4N35 opto-coupler. The opto-coupler here is purely acting as a switch to control the key pad switches. The controller achieves the feedback by simply sending clock pulse to the designated bits at specified intervals. The schematic diagram for the feedback circuit is as shown in Fig 9 below.

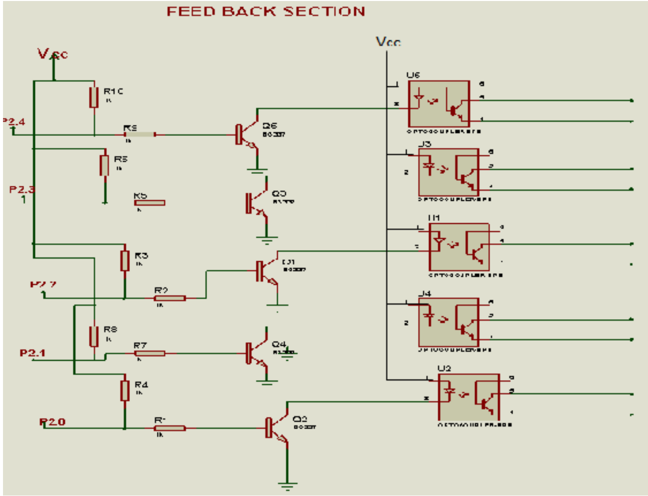

Fig 9: The Schematic Implementation Output Interface Section

VIII. AC Sensor Unit Design and Implementation

This unit consists of the following components;

(1) A 12-0-12V by 220V, 500mA step-down transformer. It steps down the 220V a.c from public power supply source to 12Va.c.

2) A bridge rectifier which rectifies the already stepped down a.c voltage to d.c voltage.

(3) A filter capacitor of 2200µf/35V filters the rectified d.c voltage to remove the a.c ripples existing in the rectified d.c voltage. This capacitor was chosen by careful calculation and experiments.

(4) A 5V regulator that is 7805 voltage regulator. These generate the regulated 5 V needed to control the transistor which informs the control unit of the presence or absence of public power.

The 220V-240V/50Hz input is supplied into the transformer; it then passes through a rectifier that converts it to a DC voltage. The rectifier is made up of four diodes connected in bridge form. Smoothening of the dc voltage is carried out by the capacitor. Voltage regulator (7805) is used to regulate the voltage outputs to get a 5V dc required to implement our AC sensor. Shown below is the block diagram of the A.C sensing unit.

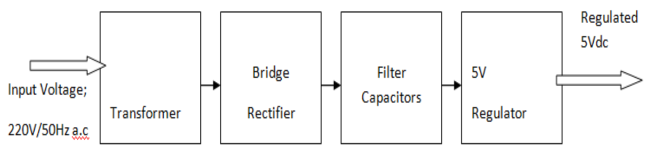

Fig 10: Block diagram of the AC sensor unit

IX. Design Equations and Calculation of the AC Sensor Unit.

For the bridge rectifier circuit above, four IN4001 diode was used with the following characteristics.

- Max peak reverse voltage PRV (max) = 50v
- Forward voltage drop (VD) = 1.6v at 1A
- Reverse leakage current = 50µA
- Max load current IL(max) = 32mA

Output voltage V_{out} = Vac√2

Since output voltage Vac from the transformer is 15volts

$\therefore V_{out} = 12*\sqrt{2} = 21.213$ v

Load voltage (V d.c) = 2 V /π......................................(1)

Therefore, from equation 1

V d.c = 2 x 21.213/ 3.14= 13.502 V

A capacitor is selected whose capacitance can produce a ripple of about 10% of the dc load voltage

So, 10% of 13.502V = 1.3502 volts

$\therefore$Ripple voltage (Vrip) = $I_L$max/ F_{rip} x C …………… (2)

Where Frip = 50Hz

I_L(max) = 32 mA

C = Capacitor

For full wave, Frip 2xf = 100Hz

From equation 2

C = IL max /Vrip x Frip

$\therefore$C = 0.32/1.3502 x100 = 2304μf

But by experiment using oscilloscope, a standard capacitor of 2200μF will be discovered satisfactory, with a maximum Breakdown voltage of 35V.

The LED used as power indicator was biased using the following components as calculated below;

Imax = 12mA - 10mA

Voltage drop (V_d) = 0.6v

PD (max) = 15mW at 250C

R_1 is a limiting resistor that limits the amount of current flowing across the diode.

R_1 = (V_s - V_d) / Imax

Where Vs is source voltage

Vd is voltage drop

Imax is maximum current

$\therefore R_1 = (13.5 - 0.6 \quad x \quad 10^3)/12 = 1075\Omega$

A preferred value of 1kΩ was used as limiting resistor (R_1).

The 7805 voltage regulator is a three terminal IC voltage. It is factory trimmed to provide a fixed output of 5 volts. It can deliver up to 1A load current and has an on chip circuitry to prevent damage in the event of over heat or excessive load current. The chip simply shuts down, rather that blowing out. The 7805 and 7812 voltage regulators have the following characteristics.

(i) Input voltage range of 7 – 25 volts

(ii) Load regulation of 0.2 %

(iii) Load current of 132mA

To calculate for load resistor in the above circuit

R_L = V_{max}/I_{max}

= 25/132 x 10 – 3 = 189 .4Ω

A standard resistor of 220Ω can be used or ignored.

The following components were selected after design calculation for the schematic implementation;

(1) A 12-0-12 V by 220V, 500mA step down transformer.

(2) A bridge rectifier, which delivers up to 3A.

(3) A filter capacitor of 2200μF by 35V

(4)5V voltage regulator able to deliver a maximum current of 1A.

(5) A limiting resistor of 1K which limits the current going into the base of the NPN transistor, which was used for final sensing.

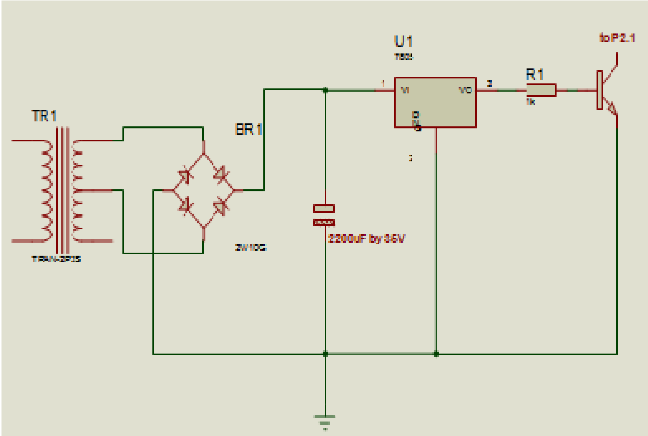

Fig 11: A.C. Sensing Unit

X. Software Subsystem Implementation

Various implementations of design steps ensured that software system was properly integrated with my hardware. This resulted into software codes that are working properly. These steps are;

(1) Initialization and Port/ bits assignments

(2) Writing of the main or control program

(3) Writing of required subroutines

(4) Assembling the Assembly language codes

(5) Programming the HEX file of the assembled assembly language codes

(6) Test Running the Program Controller inside the Hardware.

I assigned all my output bits and feedback bit and initialized them to state zero.

XI. Writing of the Main Program

The main program for the system was written using the control algorithm realized during the design stage. The program is written with the instruction set 8051series of microcontroller. The main program needs some subprograms to run, these subprograms are called subroutines. Example of a subprogram is the delay subroutine. The main program often calls the subroutine, which executes and returns back to the main program after execution. Appendix B shows the relationship between the main program and the subroutines.

XII. Project Packaging

The mechanical drawing of my project package is as shown below;

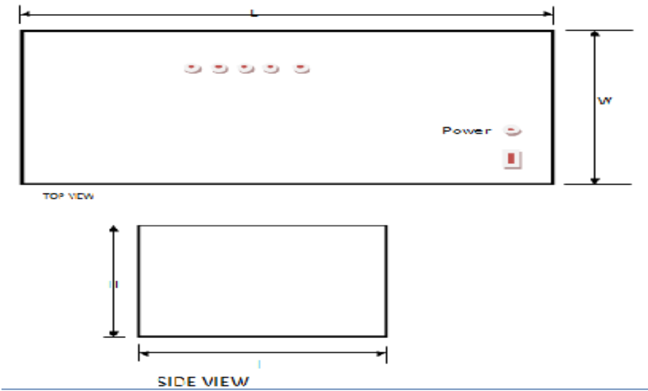

Fig.12: Mechanical Drawing of the Project Casing

XIII. HARDWARE TESTING

The resulting prototype was tested as follows.

Table 2: Hardware Test Plans

S/N	TEST PLAN	EXPECTED TEST RESULT	ACTUAL TEST RESULT
1	Continuity test on the Vero board	There should be no bridging.	There was no bridging.
2	Power supply voltage	5Vdc at 1A.	4.95V at 1A.
3	DTMF Decoder outputs	High=5V at 2.5mA	High = 4.95V at 1.6mA
4	Output relay response	Reliable	Reliable
5	Feedback speed	Very Fast	Fairly fast
6	Controller Output port	High= 5V at 10mA	High=4.95V at 10mA
7	Feedback response	Reliable	Reliable

(a) After wiring the system, we conducted a continuity test to ensure that there were no shorts circuits or open circuits.

(b) The wired hardware without the ICs was powered to ensure that the voltage levels required at different points were accurately supplied.

(c) The DTMF Decoder for the input interface was slotted into the hardware and tested with its outputs connected to LEDs and it was working perfectly.

(d) The output interface was also tested by supplying it with it's require voltage level manually, and it was perfectly working.

(e) The feedback interface was also tested by manually feeding it with its required voltage level and it was working properly.

(f) The control system was also tested by running a test program with the control unit, and it was working properly. All the different units of the system responded perfectly to individual test. The whole system was now brought together and tested and it worked perfectly.

XIV. SOFTWARE SUBSYSTEM TESTING

We did our software testing using an electronic PC simulator/ CAD tool called Protus ISIS. We reproduced exactly a sample of our hardware with the simulator. Then we loaded the HEX file from the assembly language mnemonics into the AT89C52 in the simulator and simulated. We discovered that the software was working almost perfectly. The only malfunction was that some actions were executing too fast, so we adjusted our delay subroutines until we came up with what we wanted. When the HEX file was now tested on the developed hardware prototype the system was working perfectly.

XV. PROBLEMS ENCOUNTERED AND SOLUTIONS

In the cause of the development of this prototype, some problems were encountered. The problems we encountered and how we solved them are as tabulated in Table 3 below:

Table 3: Problems encountered in the cause of the project and solutions.

PROBLEM	SOLUTION
(a) The Control Section was not Oscillating.	I went through my wiring and discovered and corrected some open circuits I discovered.
(b) The DTMF inputs to the Controller grounded my input ports.	The introduction of an octal buffer line driver with a non-inverting inputs(74HC244) solved the problem
(c)The feedback section was not integrated properly with the control system.	A pull resistor of 1kΩ solved this problem

XVI. CONCLUSION

We have successfully constructed microcontroller-based automatic power changeover with artificial intelligence for auto switching from conventional source to alternative source and vice versa, in the event of power failure.This system has two major sensors; one for the public power supply and the other for the standby generator. The signal from the sensor goes through signal conditioning to be able to communicate with the controller. The microcontroller monitors the signals from both sensors, to ascertain when public power fails and when power from generator comes on line. Both scenarios are quickly reported to the user via SMS. When public power is restored, the automatic control system checks the voltage level to ensure that it is within the acceptable range (180V -230V) before it quickly changes over power to the public power source and switches off the standby generator. If it is not within the acceptable range, the control system leaves the generator ON even though the public power is available. In this way, the building and appliance are protected from any fault in the public power supply source. This system therefore incorporates both the automatic control and the intelligent /feedback control.

XVII. RECOMMENDATIONS

The automatic changeover system with feedback performs optimally if the recommended operating conditions are observed by users. The following are the recommended conditions for optimum performance.

- power supply 12-18V dc
- maximum operating temperature +500C
- minimum operating temperatures 9oC
- maximum load 120watts
- minimum DTMF signal +1dB
- (each tone of composite signal) 869mvrms

Exceeding any of these values may cause a permanent damage to either the chips in particular or the entire system as a whole. Because of the problems encountered during the project design and construction, the following recommendation should also be put in place in order to achieve a result oriented design.

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