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MICROCONTROLLER-BASED AUTOMATIC SWITCHING SYSTEM [MASS]: DESIGN AND IMPLEMENTATION FOR DOMESTIC PURPOSE

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ABSTRACT

In most cases, emphasis is only made on industrial power supply switching leaving the domestic switching behind unmentioned. This paper presents the design and implementation of automatic and intelligent switching system modified from an industrial unit to meet the need of domestic demand. The simulation and experimental results demonstrate that the proposed system outperforms the traditional methodologies with a single phase (220Vac) power changeover control unit between the public supply and the domestic generating sets. The capacity of MASS is 100A since it was capable of switching 100-A contactors. The tolerable mains voltage level is 150Vac to 220Vac; corresponding to 8Vdc to 12Vdc for the potential divider network, thereby outputting 5Vdc to 7.33Vdc which the comparator conditions for the microcontroller to understand and interpret. The system was capable of monitoring the three lines of the public mains supply as well as the generator, to select the one that is live. So long as at least, one of the public mains lines is live, it selects it.Whenever there is a total outage on all the public mains lines, the system automatically starts the generator and loads the final circuit. At each condition, the system displays the individual status of the lines or generator on an LCD. The MASS method reduces the switching error to about 5% with increasing accuracy in switching of multiple power systems.

Keywords: Microcontroller-based system, Automatic, Switching System, Relay, Contactor and Domestic Purpose.

INTRODUCTION

As the society develops, there is need to domesticate the available household equipment. The better way of implementing this is to automatize the Switching System for home application. The short availability and sudden disappearance of energy from the public power supply leads to arcing and power surging on the domestic switching system. This is further buttressed by Mehta and Mehta (2011) when they argued that a heavy current usually flows through the contacts of a manual switching system and hence, rise in temperature. This design is aimed at introducing an intelligent device to handle the switching within some microseconds. This switching will occur without the domestic dweller noticing the sudden transfer from one power source to another except where delay is necessary for the purpose of saving the life of appliances. The reduction in human effort in a manual system of transferring energy from one source to another is termed automatic switching or changeover. The use of available household facilities in implementing the design of this nature makes the local dweller to see that the development in technology is not only meant for industrial use or paper work but can also be of benefit in domestic equipment operations.

STATEMENT OF TASK

The purpose of this paper is to design and implement a Microcontroller-based Automatic Switching System [MASS] for domestic purposes.The following serveas the objectivesof this design:

i. To design a system that will select the line with the highest voltage.
ii. To design a system that will offer an intelligent switching and protection.
iii. To design a system that will display the current source of power supply.
iv. Todesign a system that will automatically PUT-ON a generating set when there is public supply failure.

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THE RELATED CONCEPT OF MASS AND THE SIGNIFICANCE OF THE DESIGN

Automated power changeover has become very imperative in developing countries because of incessant power failure. Ahmed, et al (2006) observed that this automation is necessary as the rate of power failure is becoming predominantly high. They added that the manual system leads to waste of man-hour and introduction of technical problem to appliances and machines due to human error. Their system used operational amplifiers and other discrete electronic components but the design in this paper made use of microcontroller.

Recently, Bolajoko and Folorunso (2013) designed an automated lock system using keypad interfaced with a PIC microcontroller for the purpose of locking and opening a door. This system runs on software and opens and closes a lock just as the design of this paper. However it still requires human intervention on the keypad unlike this design which is fully automated.

In another design, Olatomiwa and Olufadi (2014) came up with an Automatic Transfer Switch (ATS). This system was capable of actually switching from public power supply source to generator and vice versa. However, it was basically for industrial use and it was not intelligent. It could attempt switching ON a generator but it could not determine whether the generator is unable to start due to lack of fuel, low battery or bad kick starter. The design in this paper is for domestic use and has the intelligent capability of sensing such a bad health condition of the generator and raising a flag to inform the generator owner that there appears to be a problem.Similarly, Christian (2012) designed a Smart Phase Change-over System. In the design, AT89C52 microcontroller by Atmega was used. The system was able to intelligently monitor the three lines of a three-phase power supply and pick the one that is live. It was basically designed for industrial use and concentrated on only phase selection. The design in this paper is a bit different from that one in the sense that it used a PIC microcontroller and in addition to selecting the live line among the three lines, it can also switch between public utility supply and generator. In their design, Ponnle and Omojoyegbe (2014) came up with an Under and Over Voltage Protection Device. This device was microcontroller-based and was capable of sensing an under voltage as well as over voltage condition. It made use of a potentiometer which served the purpose of a potential divider at the input terminal of the microcontroller. The output of the device was between 200V and 240V. Comparatively, their device did just part of the jobs the device in this paper can do. This design can sense the three lines of a public power supply and screen out lines that have voltage below 150V. It is only one that has voltage above 150V that can be transmitted to the final load.

MATERIALS AND METHOD

The materials used in this design include 220V/12V step down transformer, 1N4007 diode, 7812 and 7805 voltage regulators, 1000μF/63V capacitor, LM324 operational amplifier, resistors, preset resistor, TIP41 transistors, PIC16F877A microcontroller, 2x16 LCD, 5-V relay, 100-A contactor, buzzer and crystal oscillator.

These materials were connected in such a way that they form various sections of the entire circuit of the design. Below is the block diagram representation of the design.

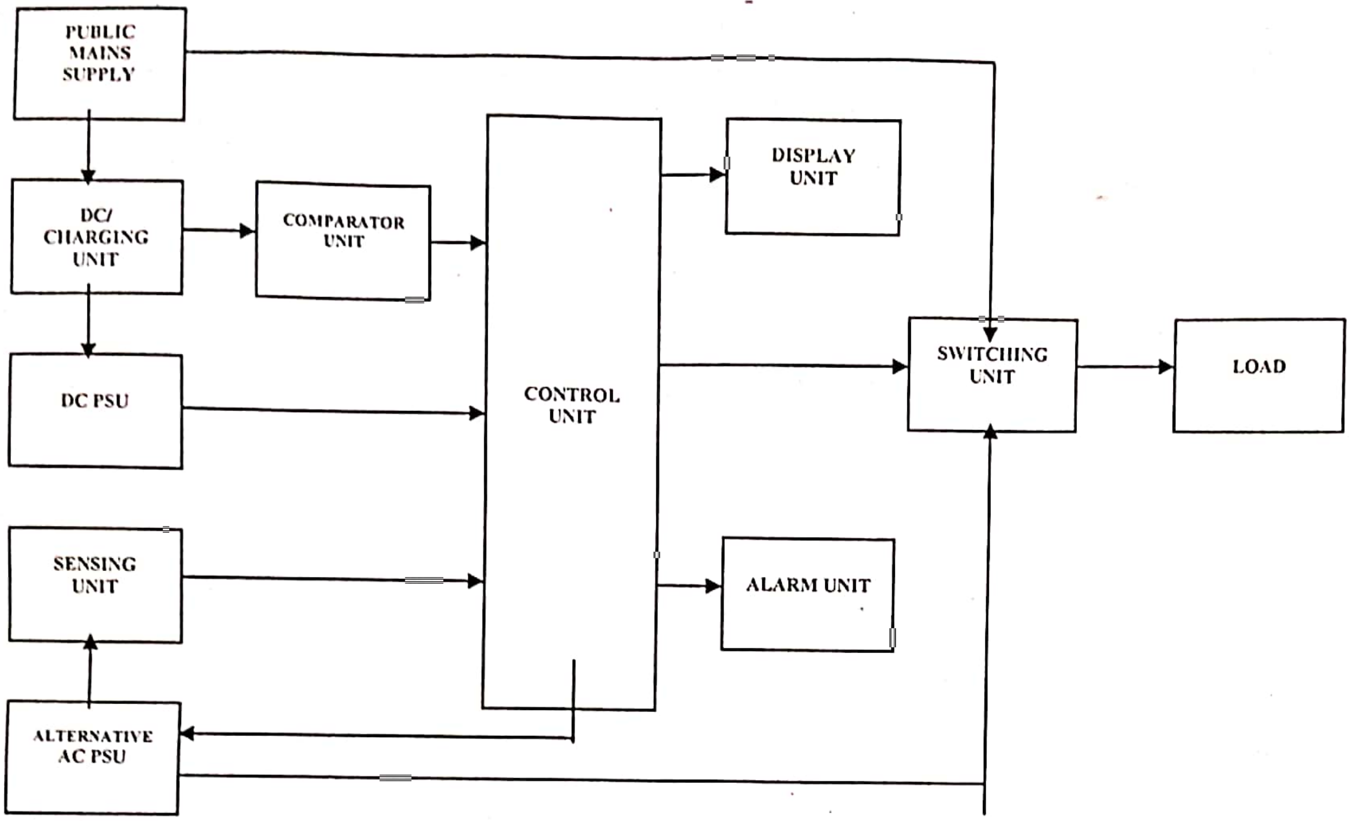

Figure 1: Block diagram of Microcontroller-based Automatic Switching System (MASS)

The block diagram in figure 1 shows the different sub units of the Microcontroller-based Switching System (MASS). The component parts of each sub unit are seen in details in the circuit diagram of figure 2.

Circuit Diagram

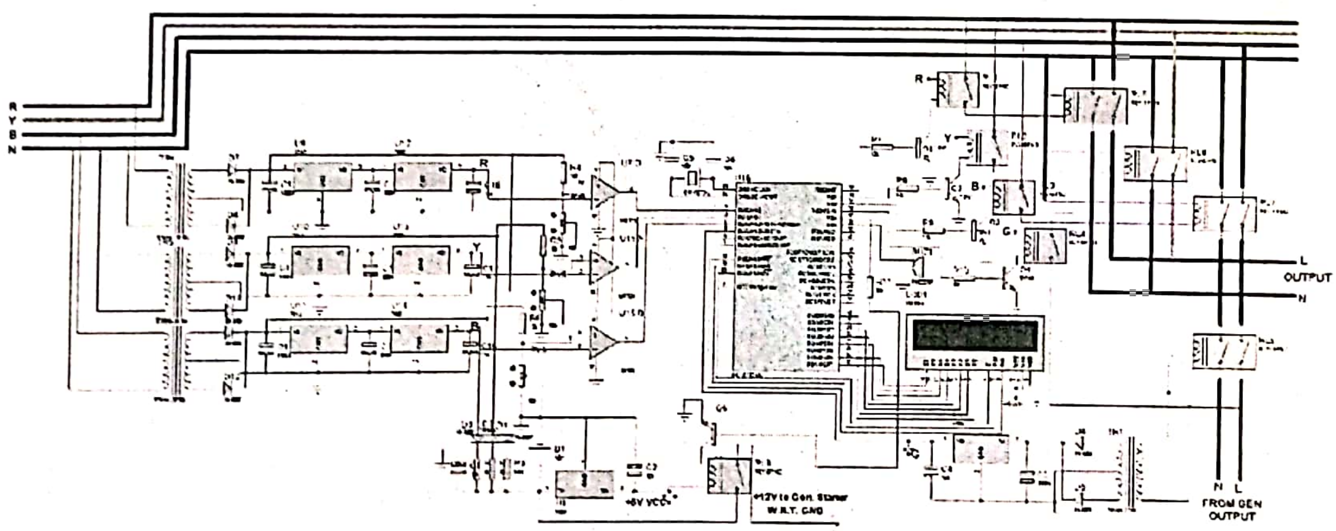

Figure 2: Circuit diagram of Microcontroller-based Automatic Switching System (MASS)

From the block diagram in figure 1 and schematic diagram in figure 2, the three lines from the public power supply are stepped down and rectified so that they can pass through the array of comparators and be fed to the microcontroller which serves as the control unit. The charging unit charges the generator battery whenever the public power supply is ON. The DC power supply unit is the generator battery which is regulated to 5V. It is the power supply source of the microcontroller and other auxiliary components. The comparator checks for any of the lines that is live or that has voltage from 150V and above and selects it. Any line that is dead or that has voltage below 150V is screened out. This information is then fed to the microcontroller which follows the logical design in the program embedded in it, to select the corresponding relay. The relay so selected, further activates a contactor which selects the mains line that supplies power to the final load. The program used in this design is C programing language.
On the other hand, if all the three lines from the public power supply are dead, the microcontroller activates a relay that triggers the generator ON, to supply power to the final load. If the system tries starting the generator for five times without success, it triggers an alarm to alert the owner that there is a problem starting the generator.
Furthermore, every state the circuit finds itself, it will display it on the LCD. This includes, the line(s) that are live; whether it is the generator or public power that is supplying and whether the generator is ON or inoperative.

Design

The three lines of the public supply were stepped down using a 220V/12V, 1000mA, 50Hz centre-tap transformers. The current on each of themwas rectified using full wave method. The diodes used were 1N4007 all through, each of which drops 0.7V.

Total voltage drop $= 0 \cdot 7 + 0 \cdot 7 = 1 \cdot 4V$

Voltage after rectification $= 12 - 1 \cdot 4 = 10 \cdot 6V$

However, the capacitor, $C_1$is an electrolytic capacitor. It compensates for the voltage drop to still make it up to 12V. It also filters the ripples present at that point to make it a smooth direct current.

To get the voltage value of the capacitor to use at that point, the method below was used:

$$V_c = V_o + \frac{V_o}{2}$$

$$V_c = 12 + \frac{12}{2}$$

$$\therefore V_c = 18V$$

This implies that the capacitor that should be used there must be of voltage value, 18V and above.

To get the capacitance value of the capacitor, the method below was used:

$$I_m = I_{rms}\sqrt{2} = 1000 \times 10^{-3}\sqrt{2} = 1 \cdot 41A$$

$$V_m = V_{rms}\sqrt{2} = 12\sqrt{2} = 16 \cdot 97V$$

Where $I_m$and $V_m$are maximum current and maximum voltage respectively.

$$I_{dc} = \frac{2I_m}{\pi} = \frac{2 \times 1 \cdot 41}{3 \cdot 142} = 0 \cdot 9A$$

$$V_{dc} = \frac{2V_m}{\pi} = \frac{2 \times 16 \cdot 97}{3 \cdot 142} = 10 \cdot 80V$$

Again, $V_{dc} = V_m - \frac{I_{dc}}{4fc}$

$$C = \frac{I_{dc}}{4f(V_m - V_{dc})} = \frac{0 \cdot 9}{4 \times 50(16 \cdot 97 - 10 \cdot 80)} = \frac{0 \cdot 9}{1234} = 0 \cdot 000729F = 729\mu F$$

(Formulae adapted from Adejumobi et al, 2011)

Therefore, the preferred chosen value is 1000µF/63V electrolytic capacitor.

Two dc voltage regulators were used in each case. They are 7812 and 7805. Both of them are positive voltage regulators hence the first two numbers, 78. The former supplies fixed +12V (hence the last two numbers, 12) and the latter supplies fixed +5V (hence the last two numbers, 05).

The potential divider networks before the comparators were employed to reduce the voltage supplied to the non-inverting input of the op-amp while the inverting input was fixed at5V.

First of all, $220V_{ac}$from the mains gives $12V_{dc}$ entering the potential divider network. The design is such that below $150V_{ac}$ the system would consider the mains line as dead.

Therefore $150V_{ac}$ would give $\frac{12 \times 150}{220} = 8 \cdot 18V_{dc}$

This $8.18V_{dc}$ needs to be stepped down to 5V at the potential divider point, to cancel the fixed 5V that is entering the inverting input of the comparator. The method below was employed:

$R_1 = 10K, R_2 =$ unknown, expected output voltage $V_o = 5V$ and input voltage $V_i = 8 \cdot 18V$

$$V_o = \frac{V_i R_2}{R_1 + R_2}$$

$$5 = \frac{8 \cdot 18 R_2}{10000 + R_2}$$

$$R_2 = 15723.27\Omega$$

Since 15723.27Ω is not a standard resistance value in the market, a 50KΩ preset resistor was used to select the value. Therefore, at mains voltage of $150V_{ac}$ and below, the output of the comparator becomes 0V but at above 150Vac, the output would be +5V because the power supply voltage to the op-amp IC is +5V. This +5V is then seen by the microcontroller as logic 1.

Supposing the mains voltage is $220V_{ac}$ the output voltage from the potential divider network would be

$$V_o = \frac{V_i R_2}{R_1 + R_2}$$

$$= \frac{12 \times 15723 \cdot 27}{10000 + 15723 \cdot 27}$$

$= 7 \cdot 33V$, which is above 5V.

In this circumstance, the output of the comparator is logic 1 (i.e., 5V).

The outputs of the three comparators are then fed into the RA0, RA1 and RA2 pins of the microcontroller for sensing. Meanwhile, diodes D_1, D_2 and D_3 were used to form an OR gate from the three mains lines to charge the generator battery if any of the lines is live. This battery is the power supply unit of the microcontroller and other auxiliary components that work with it. It was regulated to +5V through a 7805 dc voltage regulator, since the microcontroller uses +5V.

Pins RB0, RB1 and RB2 of the microcontroller were connected to the bases of power transistors through limiting resistors to bias any of them that is selected as the case may be. The collector terminal of each of the transistors is connected to one mains line through a 5V relay. This line is used to energize a 100-A contactor which finally selects the line that is to be delivered to the final load.

The LCD was connected to PORTD and PORTE of the microcontroller according to the declaration of the header file used. It displays which mains lines are live; whether public supply or generator is supplying and when the generator has failed to operate.

The logical design of this work is a program written in C language. It directs the microcontroller on which pin to select at each point in time depending on the condition that is fulfilled at the public mains supply or generator.

According to the program, when the three lines of the public supply mains all fail, the microcontroller would send current to start the generator. This attempt is made for a maximum of five times and if the generator still fails to start, it would stop attempting to start the generator. Immediately it triggers an alarm which will blow for one minute and also write GENERATOR INOPERATIVE on the LCD.

Procedural Flow Chart

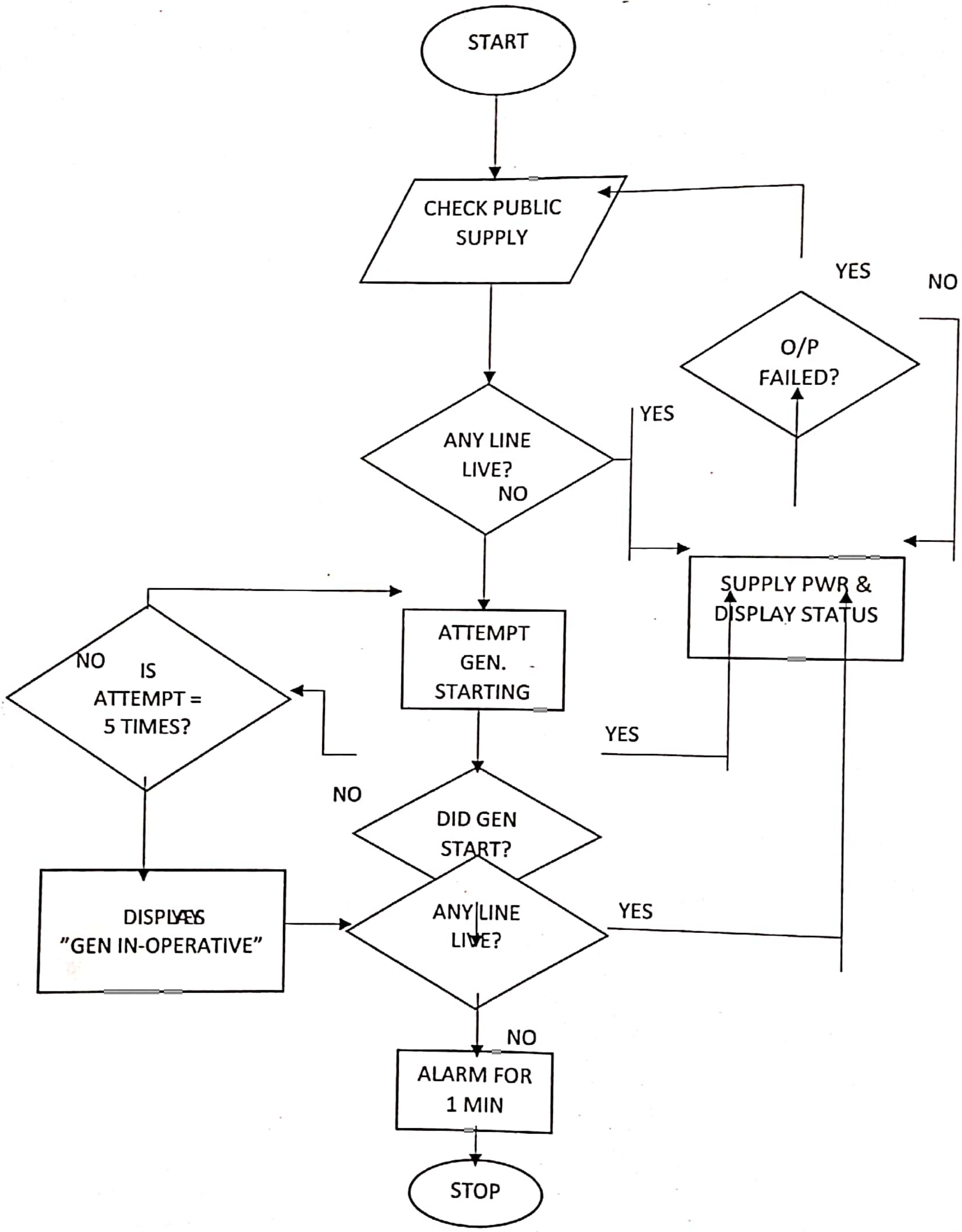

Figure 3: Flow chart of Microcontroller-based Automatic Switching System (MASS)

PRINCIPLE OF OPERATION AND IMPLEMENTATION

The entire physical design of MASS is built around the microcontroller PIC16F877A. This is the controlling unit of the system. However, this unit depends on the voltage conditioning that takes place from the mains to the potential divider network. Table 1 shows the different voltage levels obtained before reaching the microcontroller. It receives input from the comparators and with the help of the source code written in C language and compiled into the microcontroller, switches the supply to the load correspondingly as shown in table 2.

However, if there is no supply on the public mains, the microcontroller kick-starts the generator by setting pin RB4 high and if the generator starts up, it sends a signal to pin RA3 which in turn sets pin RB3 high and the generator is selected to supply the load through contactor RL8.

If the first attempt to start the generator fails, the controller keeps trying until up to five times and then stops trying. Instantly it blows alarm; displays GENERATOR INOPERATIVE and keeps on checking for availability of the public supply. This is done logically as shown in the program below.

The power supply unit for the system is partly derived from the generator battery which is also being charged when any of the lines in the public supply is live.

The logical implementation code for Microcontroller-based Automatic Switching System (MASS) using C programming language is thus:

```
#include <pic.h>
#include "lcd.h"
#define _XTAL_FREQ 4000000
char a=0;
void choose();
void pick();
void choose(){
if(RA0==1&&RA1==0&&RA2==0){RB4=0; RB1=0; RB2=0; RB3=0; RB5=0; __delay_ms(100); RB0=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINE 1 LIVE");}
if(RA0==0&&RA1==1&&RA2==0){RB4=0; RB0=0; RB2=0; RB3=0; RB5=0; __delay_ms(100); RB1=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINE 2 LIVE");}
if(RA0==0&&RA1==0&&RA2==1){RB4=0; RB0=0; RB1=0; RB3=0; RB5=0; __delay_ms(100); RB2=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINE 3 LIVE");}
if(RA0==1&&RA1==1&&RA2==0){RB4=0; RB1=0; RB2=0; RB3=0; RB5=0; __delay_ms(100); RB0=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINES 1 & 2 LIVE");}
if(RA0==1&&RA1==0&&RA2==1){RB4=0; RB1=0; RB2=0; RB3=0; RB5=0; __delay_ms(100); RB0=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINES 1 & 3 LIVE");}
if(RA0==0&&RA1==1&&RA2==1){RB4=0; RB0=0; RB2=0; RB3=0; RB5=0; __delay_ms(100); RB1=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINES 2 & 3 LIVE");}
if(RA0==1&&RA1==1&&RA2==1){RB4=0; RB0=0; RB1=0; RB3=0; RB5=0; __delay_ms(100); RB2=1;
goto_row(1); send_string("PUBLIC SUPPLY"); goto_row(2); send_string("LINES 1,2,3 LIVE");}
```

```
}
void pick(){
while(1){
jump:
if(RA0==1||RA1==1||RA2==1){break;}
if(RA3==1){goto jump;}
if(RA0==0&&RA1==0&&RA2==0){RB0=0; RB1=0; RB2=0;
for(a=0;a<5;a++){RB3=1; __delay_ms(3000); RB3=0;
if(RA3==1){RB3=0; RB5=0; __delay_ms(5000); RB4=1; send_string("GENERATOR ON");break;}}
if(RA3==0){RB3=0; goto_row(1); send_string("GENERATOR");
goto_row(2); send_string("INOPERATIVE"); RB5=1; __delay_ms(60000); RB5=0;}
loop:
if(RA3==0&&a=5){
if(RA0==1||RA1==1||RA2==1){goto jump;}
goto loop;}
}
}
void main(){
PORTB=0b00000000;
TRISA=0b00001111;
TRISB=0b00000000;
lcd_init();
while(1){
choose();
pick();
}
}
```

RESULT AND DISCUSSION

Table 1: Voltage divider variation with mains supply

Mains (V)	V_i (V)	V_o (V)
220	12.00	7.33
210	11.45	7.00
200	10.91	6.67
190	10.36	6.33
180	9.82	6.00
170	9.27	5.67
160	8.73	5.33
150	8.18	5.00
140	7.64	4.67
130	7.09	4.33
120	6.55	4.00

Table 2: Status of various line voltage levels

R (V)	Y (V)	B (V)	Comparator 1	Comparator 2	Comparator 3	Relays	Contactors	Output
220	0 or <150	0 or <150	High	Low	Low	RL1	RL5	RED
0 or <150	220	0 or <150	Low	High	Low	RL2	RL6	Yellow
0 or <150	0 or <150	220	Low	Low	High	RL3	RL7	Blue
220	220	0 or <150	High	High	Low	RL1	RL5	RED
220	0 or <150	220	High	Low	High	RL1	RL5	RED
0 or <150	220	220	Low	High	High	RL2	RL6	Yellow
220	220	220	High	High	High	RL3	RL7	Blue
0 or <150	0 or <150	0 or <150	Low	Low	Low	RL4	RL8	Gen.

Table 1 above shows the various voltages got from voltage conditioning. The mains refers to the voltage from the three lines. Vi is the stepped down input voltage from the various lines (R,Y, B) to the potential divider network whereas Vo is the output voltage from the potential divider network, which is the input voltage to the comparator. The variation of the mains voltage from 220Vac to 120Vac resulted in $12V_{dc}$ to $6.55V_{dc}$ for V_i. Consequently, this led to the variation from $7.33V_{dc}$ to $4.00V_{dc}$ for Vo. According to design specification it would be seen that above mains voltage of 150Vac, the voltage entering the non-inverting input terminal of the comparator is above $5V_{dc}$. This implies that the resultant output voltage being fed to the control unit is 5V (i.e. logic 1). However, from mains voltage of 150Vac and below, the input voltage to the non-inverting input terminal of the comparator falls to $5V_{dc}$ and less. This leads to a resultant output voltage of 0V (i.e. logic 0) being fed into the control unit.

In table 2, the various possible conditions of the voltage levels of the public mains lines are shown. The corresponding states of the outputs of the comparator are also shown, as well as the relays and contactors that are selected in each condition. Moreover, the mains line that is selected for each condition is also shown on the last column as output. This line selection is purely done by the microcontroller in compliance with the specifications in the program. However, when all the public mains lines are dead, the generator is started and selected to supply. This is the condition shown on the last row of the table.

CONCLUSION

A Microcontroller-based Automatic Switching System was thus realized by this procedure. It was able to meet the domestic demand of switching between public supply and generator; as well as selecting the live line among the three lines of the public supply. Its capacity is 100A since it is capable of switching 100-A contactors. The tolerable mains voltage level is 150Vac to 220Vac; $8V_{dc}$ to $12V_{dc}$ for the potential divider network; thereby outputting $5V_{dc}$ to $7.33V_{dc}$ which the comparator conditions for the microcontroller to understand. The system is capable of monitoring the three lines of the public mains supply as well as the generator, to select the one that is live. So long as at least, one of the public mains lines is live, it selects it. However, once there is total outage on all the public mains lines, the system automatically starts the generator and loads the final circuit. Moreover, in each condition the system displays the individual status of the lines or generator (as the case may be) on an LCD.

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