An Intelligent Microcontroller-Based Smart Grid Changeover System

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ABSTRACT

This research work reviews the different methods used to design a changeover system. It addresses some of the earlier approaches being used, and proposes a more convenient, safe and cost-effective way of implementing a changeover when there is a power failure. Each of the earlier methods used has some drawbacks that makes it undesirable, some of which are time wastage, possibility of fire outbreak, generation of noise, frequent failures, product damage, high component count to mention but a few. In this research work we designed a system with microcontroller which is used to reduce the component count, improve the speed of the system as well as provide an uninterrupted power supply to a load, by automatically selecting a supply from any power source available. The system also has some desirable features like liquid crystal display (LCD) which makes the system user friendly, an alarm system for indicating generator failure and an automatic phase selector for selecting most appropriate phase, over-voltage and under-voltage level monitoring. From the results obtained after implementation and testing of the system which is documented in the report, it shows that the research can be imploded effectively in the power system especially for domestic consumers for changeover from one power supply to another if need be.
Keywords: Microcontroller, changeover, liquid crystal display, phase-selector, auto generator.

1. INTRODUCTION

1.1. Background to the Study

The demand for an uninterrupted power supply, most especially in areas where a mandated uninterrupted power supply is necessary, has called for an alternative source of power (Amuzuvi & Ado, 2015). Predominantly in Nigeria where power failure is customary, the initiation of these alternate sources of supply ushers in the challenge of switching timely and smoothly between the mains supply and the alternate sources when there is power failure (Emmanuel, 2014). Dependable and consistent power supply is the expectation of all residential, commercial and industrial operations, particularly in most developing countries where industrialization and urbanization are factors of high importance for its advancement (Dowuona, 2008). The circumstantial behind this research work was traced to the intense demand of the populace, industries, residential homes etc. for effective change of power supply switch for continuity of power supply without a noticeable interruption or delay in such process. Earlier to this time, such process was manually operated or not in use at all, the manual type are strenuous and time delayed, more level of involvement and expenses are always required to meet up with the time factors and effectiveness of this process of changeover.

These expenses and labor was not affordable for some individuals and industries. Regarded to this, solutions were suggested to improve the process, so the idea of changing the manual operated to automatic changeover was necessitated. Apparently, steady power supply is required in every sector of the Economy; Institutions, firms and manufacturing industries, aviation, data centers, financial institutions, hospitals etc. Generally, Power unsteadiness retards growth in public and private sectors of any economy (Jonathan & Kolo, 2007).

Any instance of power shortage can result to high-priced outcomes stretching from life casualties to loss of enormous sums of money. The series of recurrent power outages without an active back-up system is truly a deterrent to investors in any developing economy. Truly, the consequences of power instability have correspondingly compelled automation of the switching system. (Ilomuanya and Okpala, 2016).

The challenges and problems associated with changeover to alternative power source when there is failure in the main source makes this research work relevant and of great importance. To address the associated problems, we proposed of an intelligent microcontroller-based smart grid changeover system that will automatically switching between the main power supply and alternative energy source like generator or inverter. The proposed system will automatically senses the presence of power available in any of the sources connected to it but allow power to be fed to the load from the most preferred source as programmed in the microcontroller.

1.1. Statement Of The Problem

The available approach for switching from utility ac mains to an alternative source in case of power failure has some drawbacks which include time wastage, possibility of fire outbreak, generation of noise, frequent failures, product damage, high component count etc. The shortcoming mentioned are the problem that this research would addressed.

1.2. Aim And Objectives

The aim of this research work is to design and construct an intelligent microcontroller-based smart grid changeover system that could leads to the following objectives if implemented.

- Easy and convenient in switching from AC main and to alternative power such in case of power failure
- Enhancing safe and cost-effective way of implementing a changeover when there is a power failure.
- Enhancing speed to switch to an alternative source of supply when their power failure.

1.3. Significance Of The Study

Power failure is a very common occurrence in Nigeria hence there is need for a system to be incorporated to resolve the issue of power interruption and inconvenience that is associated to changeover from main AC to an alternative power source when there is power failure.

2. LITERATURE REVIEW

With technological advancement, maintaining power quality and a steady energy supply are the major requirements electricity consumers are demanding for. This is because when electrically powered and voltage-sensitive devices are temporary disrupted there is high tendency of scrambled data, a frozen mouse, interrupted communication system crashes, equipment failures etc. To avert power supply disruption, many commercial, industrial facilities, homes and companies must rely on power supply companies, generator sets (manually or automatically operated) or inverters.

As a result of the growing complexity of electrical systems, it becomes imperative to give attention to power supply reliability and stability, (Hurst, 2001). Over the years many approaches have been adopted in configuring changeover systems through various switching devices. A switch is a device for changing the course for flow of a circuit, the prototypical model is a mechanical device, which can be disconnected from one course and connected to another (Smeaton & Ubert, 1998). A switch can be classified according to the arrangement of their contact. Some contacts are normally open until closed by operation of switching, while others are normally closed and opened by the switch action. A switch with both type of contact is called a changeover (Paul & Winfield, 2008; Emmanuel, 2014).

Automatic change over switch works in such a way that when there is a power failure from the main supply, there is no need for a human intervention to change from the mains to the generator as the change-over switch does this automatically upon sensing power supply from the generator. Also, when the main supply is restored, the changeover switch senses the power input and transfers the load back to the mains supply, therefore making the process faster (Mbaocha, 2012).

3. MATERIAL METHODS AND DESIGN

3.1. Materials

The materials to be used in the development of the system are highlighted and discussed here.

Microcontroller PIC16F877: PIC16F877 is one of the most advanced microcontrollers from Microchip. It is a self-contained system with peripherals, memory and processor unit that can be used as an embedded system, designed for automatically controlled electronic applications.

LED: Light emitting diodes are diode designed to emit light whenever a voltage source is applied. They are usually connected in circuits as indicators. The output of the controller is connected to LEDs to indicate a specified ongoing operation.

MECHANICAL RELAYS: Mechanical relays are electromagnetic devices that can turn on or turn off the power supplied to another device. They are triggered by alternating its input so as to achieve a desired output. They exist as normally closed and the normally open (Paul and Winfield, 2008**).** When current runs through the input and energizes the coil, it creates a small magnetic field which either pulls the arm of the switch away from the other contact of the switch, or pushes it down to close the switch. Recently, electromagnetic relays (EMRs) have been used with other components to implement automatic changeover. Such component can be logic gates, transistors, opt-coupler, microcontroller, etc. Most of these components make use of 5 volts (Weedy, 1972).

Liquid Crystal Display (LCD): A liquid-crystal display (LCD) is a flat panel display, electronic visual display, which uses the light modulating properties of liquid crystals. LCDs come in 1 Line, 2 Lines or 4 Lines, those with only 1 controller support 80 characters, whereas LCDs supporting more than 80 characters make use of 2 HD44780 controllers. Most LCDs with 1 controller has 14 Pins and LCDs with 2 controllers has 16 Pins

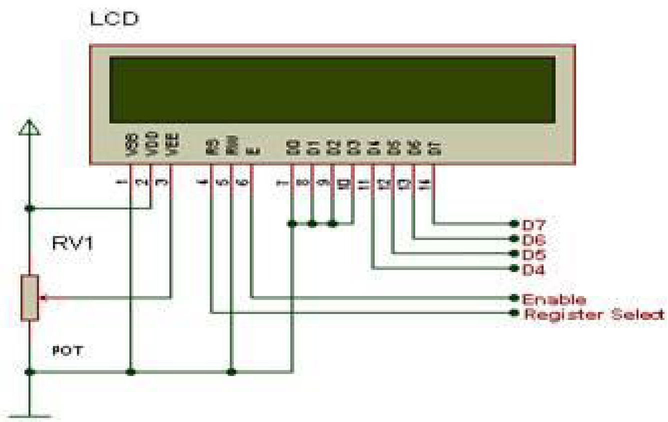

Figure 1: Character LCD type LM016L

3.2. DESIGN

The basic hardware design is discussed here. The hardware designs include the block diagram development, the circuit design. The hardware is the components of the system that is responsible for it physical operations. Figure 2 is the symbolical representation of each module that is combined to form the system. Each module of the block performs a specific function and the combined modules perform the overall operation of the changing over process.

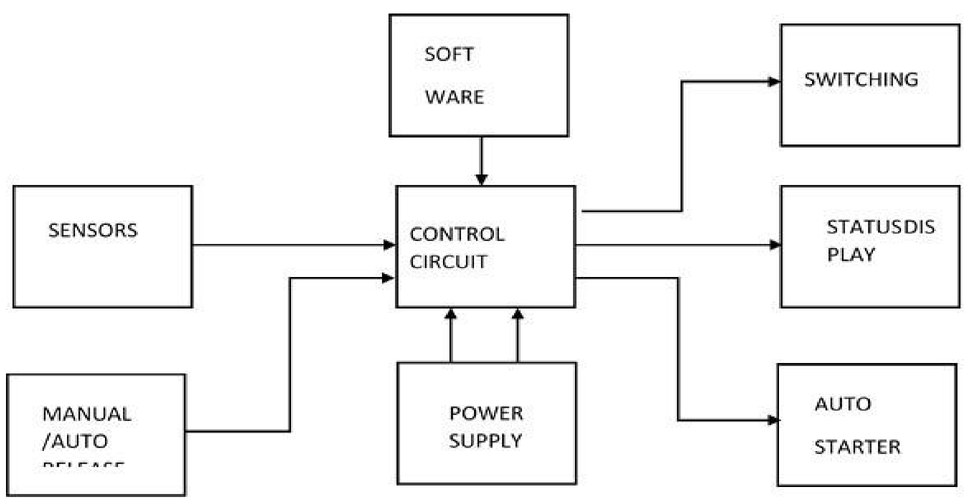

Figure 2. Block diagram of the system

Power Supply Circuit: The power unit provides dc supply to all the electronic components of the circuit. The system is to run on 12V and 5V supply. The power unit block is subdivided into the transformation, the rectification and the smoothing and the regulation sections. Description of components of the power circuitry is as follows:

- **Transformation:** It is composed of a step-down transformer (240/12V ac, 50Hz). The needed voltages are 5V dc, and 12V dc. However, due to low power consumption of the whole circuit, the minimum available rated transformer was adopted for the work. The transformer is specified as 240/12V, 50Hz, 300mA. The 300mA is the primary current.

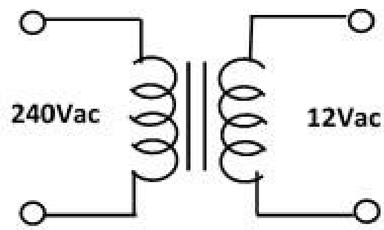

Figure 3. Transformer Circuit

- **Rectification:** The bridge type rectification (full wave, 4 diodes bridge rectification) will be used in this research work. The choice of rectification types include: the peak value of the applied voltage and the maximum load current

Smoothing: smoothing is will be done by connection of capacitor in parallel to the output of the rectified circuit to removes the ac ripples. The value of this capacitor is determined by considering the load current as calculated below.

The ripple frequency is 100Hz, and the charging time, $t=1f⁄=1100⁄=10ms$
Charging voltage on the capacitor is given by $Vcap=QC=ItC$

Where Q is the charge on capacitor, C is the capacitance, I is the load current, and t is the charging time $=(1\times0.01)C=(1\times10-2)C\ Average\ output\ voltage=Vpeak-Vcap=(2Vpeak)\pi⁄=(2\times16.97)\pi⁄$

$\boldsymbol{Note}:V=Vrms\sqrt{}2=12\sqrt{}2=16.97v$
$\therefore16.97-(1\times10-2)C=(2\times16.97)\pi=10.8$
$\therefore C=(1\times10-2)(16.97-10.8)=(1\times10-2)6.17=1620.8\mu F$

- **Regulation section:** This section makes use of the 7805 regulator IC which regulates for 5V. A low value capacitor (say 470µF) is incorporated at the output of the regulator to remove any instantaneous ripple because of variation, or sudden change in the load applied to it.

Supply Sensors Circuit: This is responsible for the detection of various sources of power. It is a diode-transistor opto-isolator circuit. The diode end senses the power source while the transistor end is coupled to switch the input of the microcontroller circuit. The sensor circuit is not directly connected to the power source but connected via a small dc power supply circuit.

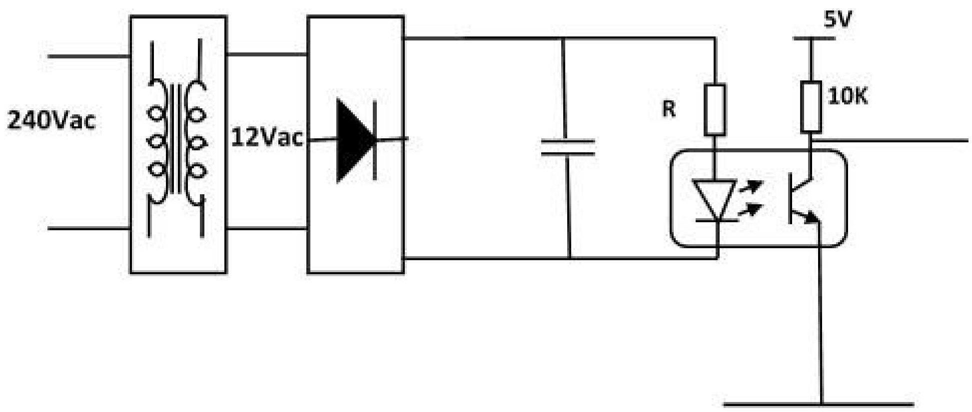

Figure 4. Sensor Circuit

Manual/Auto Release Circuit: This is introduced to enable or disable the auto-generator at will. Push buttons are used to implement these functions. 10kΩ pull up resistors will be connected from VCC to the push buttons to aid the initialization of the microcontroller.

Microcontroller Circuit: The microcontroller unit is built around the PIC 16F877 chip. PIC16F877 is an 8-bit microcontroller with 368 bytes of RAM and many other extra peripherals like ADC; the microcontroller processes the sensors outputs to control the output. The outputs include the auto-generator starter, and its changeover relay, the manual changeover, the mains changeover, the indicators and the LCD display. The microcontroller also houses the software code which is the brain of the whole circuit that determines the operations of the microcontroller.

Auto-Gen Starter Circuit: The auto-gen starter is responsible for the automatic starting of the generator. Though controlled by the microcontroller, it is composed of two relay circuits whose contacts are closed and opened to initiate the starting of the generator. The software is written to first close relay one which make contact for two cable that gets the generator ready and then the relay two that makes the contact for the third cable that starts the generator. The auto-ON sensor senses that the generator had picked and this causes the microcontroller to break the contact of the relay two which in turn breaks the third wire of the starter to keep the generator in running mode. This starting is designed to be done between three to five seconds after which if the generator is not started, a retry is made for additional four times and if the generator does not pick after the fourth additional time, the auto-start is terminated and the system switches to manual generator, where it remains unless mains is restored or a release switch is pressed.

Switching Circuit: The switching circuit is responsible for the actual changing over from one of supply to the other. The operation involved the sensing of available supply, or supplies, determination of sequence of supply priority, and the eventual switching of the load to the set priority. The microcontroller does a great deal of job in this respect as it is the one responsible for the operation.

4. IMPLEMENTATION AND TESTING

The system was implemented as discussed in section 3. The design was then simulated using Proteus 8.0 simulator. Some of the hardware that are not available on the simulator are represented with alternatives that best can best exhibit the behavior of the hardware, e.g. switching actions are replaced with LED displays. The result of the simulation is shown in figure 3. The components was then soldered on a Vero board and the constructed system was put to test. The tests also include those carried out in the simulation. Three separate supplies were applied to the system and the supplies were alternatively switched ON and OFF and the response of the system was noted and the results was tabulated as in table 1.

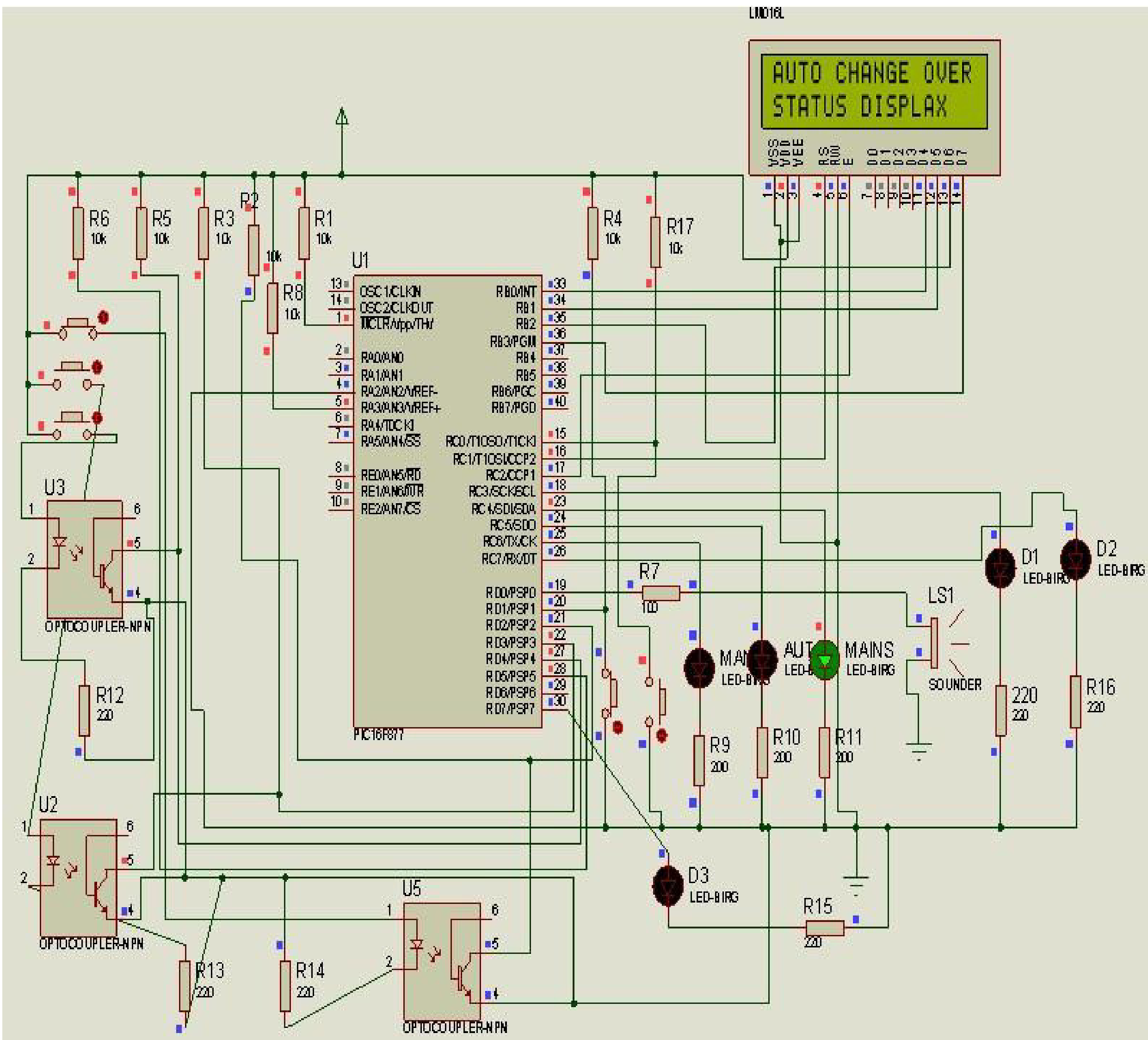

Figure 5. Simulation of the Design

Table 1: Test Result

TES	SUPPLIES STATUS					RESPONSES				
	AUTO DISAB	MANUAL	MAINS	AUTO -	MA - UAI	MAII RELA	AUTO - RELAY	MAN RELA	STATU DISP -	STARTER STATU
1	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	ON, OFF, OFF	DEACTIVATED
2	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF, ON, OI	ACTIVATED AND DEACTIVATED AFTER 5 TRIALS
3	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF, OFF, O	AFTER A RELEASE BUTTON PRESS - ONCE AND DEACTIVATED
4	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF, ON, OF	DEACTIVATED
5	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON, OF ,OFF	DEACTIVATED
6	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON, OF ,OFF	DEACTIVATED
7	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	ON, OF ,OFF	DEACTIVATED
8	ON	OFF	INITIAL ON, LAT -	ON	ON	INIT ON LATE OFF	OFF	INITI OFF LATE ON	OFF, ON.OF	DEACTIVATED
9	OFF	ON	INITIAL ON, LAT -	ON	OFF	INIT ON LATE OFF	INITIAL OFF LATER ON	OFF	OFF, OFF ON	ACTIVATED ONCE AND DEACTIVATED
10	ON	ON	ON	ON	ON	ON	OFF	OFF	ON, OF ,OFF	DEACTIVATED
11	ON	ON	OFF	ON	ON	ON	OFF	OFF	OFF, O ,OFF	DEACTIVATED

5. RESULT ANALYSIS

The tests show the operation of the system with the three supplies connected to the system. Major challenge in the test is the generator starter circuit which is to be disengaged immediately the auto generator is started so that damage is not done to the kick starter of the generator. The solution provided in this work is for the starter to stop its action after five seconds of starting the auto generator. Looking at the results of the testing, is shows the ability of the system to disable some of its functions when it not needed. However, other tests showed how the main takes the priority over the other alternative supplies that is the inverter, followed by the auto generator and finally the manual. In case of a failure of the auto-gen, provision is made for five trials before the section is shut down for the next priority.

6. CONCLUSION AND RECOMENDATION

An intelligent microcontroller-based smart grid changeover is a system capable of switching between alternative sources when there is no power in the priority source. The system has been designed to automatically switching between power source at high speed hence reduces stress associated with manual changeover. The system was tested with the three supplies connected to it, and it was observed that the proposed system met the aim and objectives of the design.

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