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Design and Implementation of Automatic Transfer Switch for Power System Management

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Abstract

Power system management is such that electrical power never goes off in the facility for a definite period of time. The operation of the system is such that when power goes off, the system will automatically detect it, sends information to its module. This module will send signals to a generator for it to start and send its power status (weather it started or not), back to the module and the module, the module checks the availability of this power and if it finds suitable, it will send signals to an automated change over switch that will switch over source of power supply from mains power to generator power. The generator is controlled by two relays which are in turn receiving signals from the microcontroller via resistors and transistors, these relays are connected directly into the kick-starter of the generator, one is connected to the terminal that starts the generator while the other is connected to the terminal that stops it, the changeover circuits are built using electromechanical contactors which are in turn controlled by the microcontroller. A reliable circuit was developed and implemented to switch the power source automatically from the public mains to the generator and vice versa, ensuring uninterrupted power supply.

1. Introduction

In contemporary industrial and domestic environments, reliable and continuous power supply is essential for maintaining operational stability and everyday convenience. Power interruptions, whether due to grid failures, surges, or fluctuations, pose significant challenges, potentially leading to operational downtime in industries and disruptions in domestic routines. Addressing these challenges requires an efficient and automated power supply solution that can seamlessly transition from a primary power source to a backup generator without manual intervention [1-2].

Epileptic power supply has become a norm in this part of the world. Blackout spanning to hours and days and sometimes even into weeks and months is not an unusual occurrence. To this effect, individuals, establishment and cooperate bodies have resort to the use of alternative source of power supply in other to ensure constant power supply to their establishment as a break in power supply can adversely affect the growth of business and hinder the comfort of personal life [3-5].
[6], established that the cost and depredation associated with breakdown vary from one application to the other, and in some cases, the user has little choice but to ensure that a stand-by unit is available to takeover on event of failure of primary system.

Power management systems are essential for maintaining power continuity in the event of failures or interruptions in the primary power source. These systems automatically switch to an alternative power source, such as a generator, to prevent downtime and maintain operational stability. They consist of several key components, including an automatic transfer switch (ATS), a generator, and control mechanisms. Power management systems are designed to ensure a continuous power supply and protect against power disruptions. According to [6], power management systems can be broadly categorized into manual, semi-automated, and fully automated systems.

Early power management systems relied heavily on manual intervention, with operators needing to manually start generators during power outages. Over time, technological advancements have led to the development of more sophisticated systems that automate these processes, significantly improving reliability and reducing response times [7].

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Fully automated systems, the focus of this thesis, are capable of detecting power failures and switching to backup generators without human intervention, offering significant advantages in terms of reliability and efficiency [10]. A notable example is the use of fully automated systems in data centers, where uninterrupted power is crucial. Data centers often deploy advanced power management systems to handle outages without affecting operations. For instance, the deployment of Automatic Transfer Switch (ATS) and generator systems in a major data center demonstrated significant improvements in uptime and reliability [11]. Benefits of this system include enhanced reliability, reduced human error, and minimal downtime.

2. Methodology

2.1 Design Methodology

The full system can be represented using blocks diagram, where each block contains a section of the complete work is shown in figure 1.

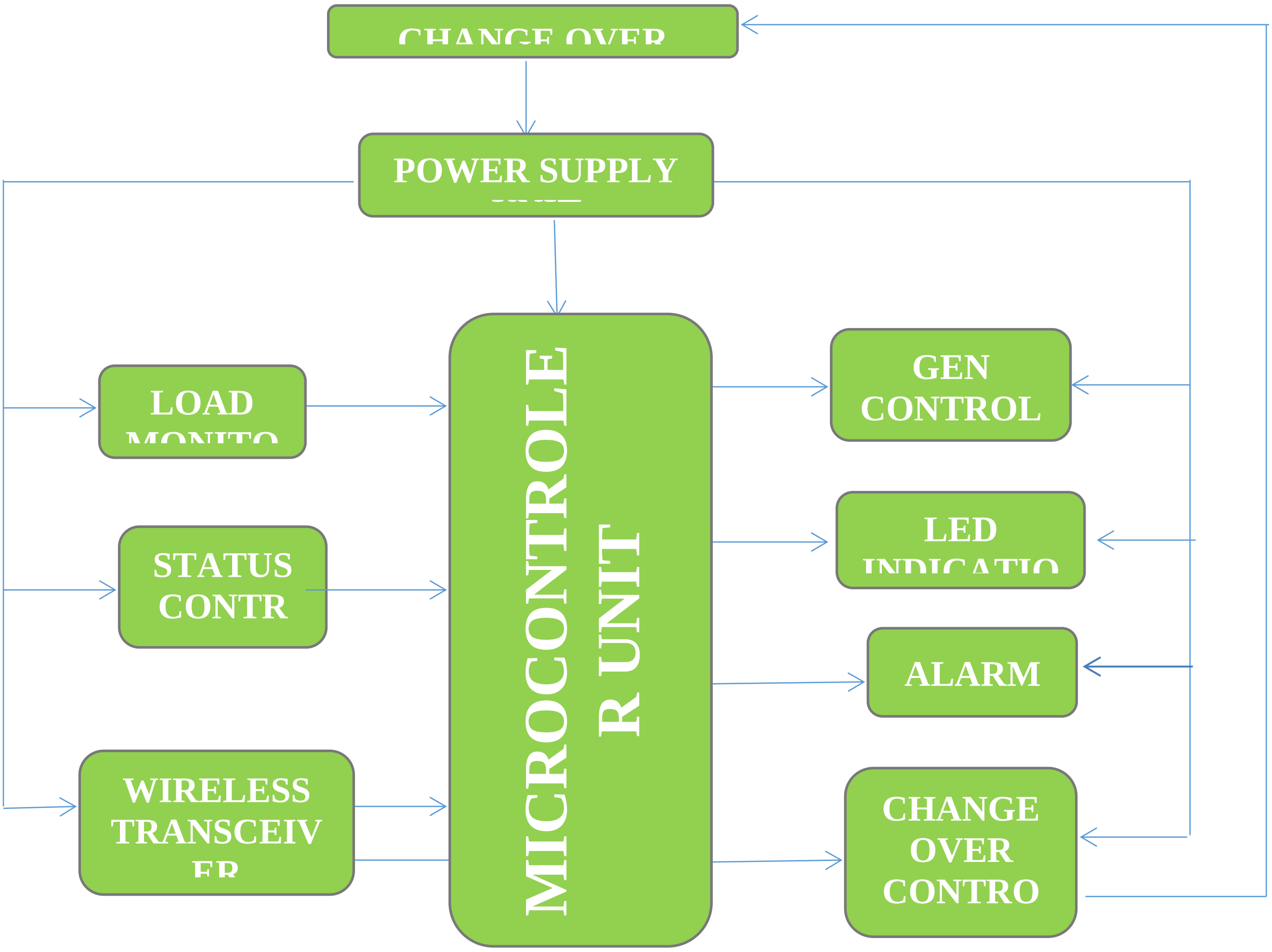

Figure 1: The block diagram of power management system

2.2 Power Supply Unit

This is the unit that supplies power to the whole system. The system requires 5V dc for its operation. The power for the system is obtained from a dual source which includes a 220vac source and a 12vdc battery source. The circuit diagram is as shown in figure 2.

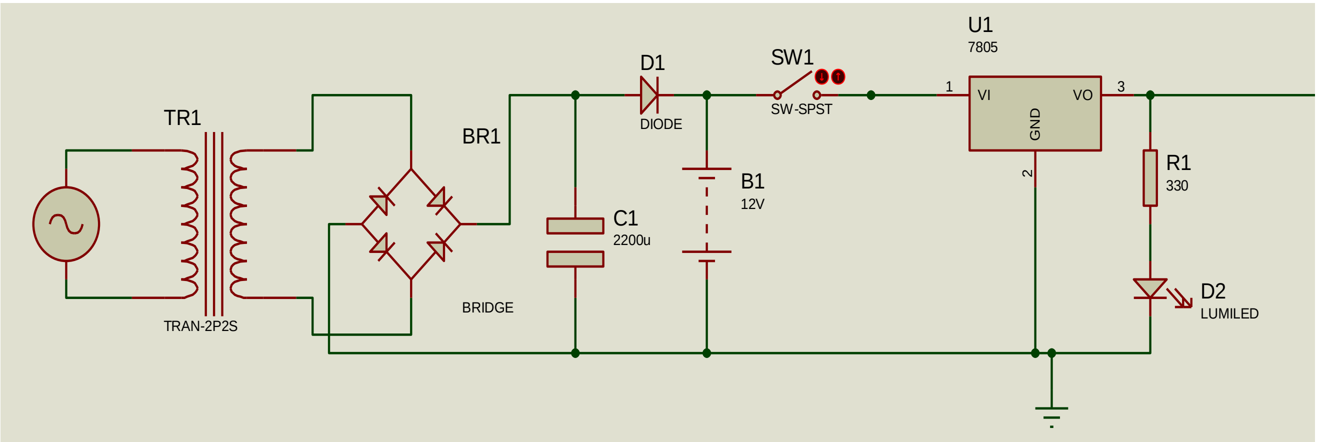

Figure 2 the diagram of a Power Supply Unit

TRI: This is the step down transformer. A transformer voltage of 12Vac or above is required. The current should be enough to supply the requirement of the circuit.
The transformer (T1) chosen is
12Vac@300mA.
D1-D4: These are the rectifier circuit. The diodes chosen must have a peak inverse voltage (PIV) that must be able to withstand twice the peak voltage (V_P) of the transformers output and a forward current (D_c) of 1.5 times the output current of the transformer.

2.3 Load Power Monitor Unit

This is the main circuit that monitors the availability of power in the various nodes of testing. It checks power available from the generator, power available from the public mains supply and power available to the load. The circuit diagram is as shown in figure 3.

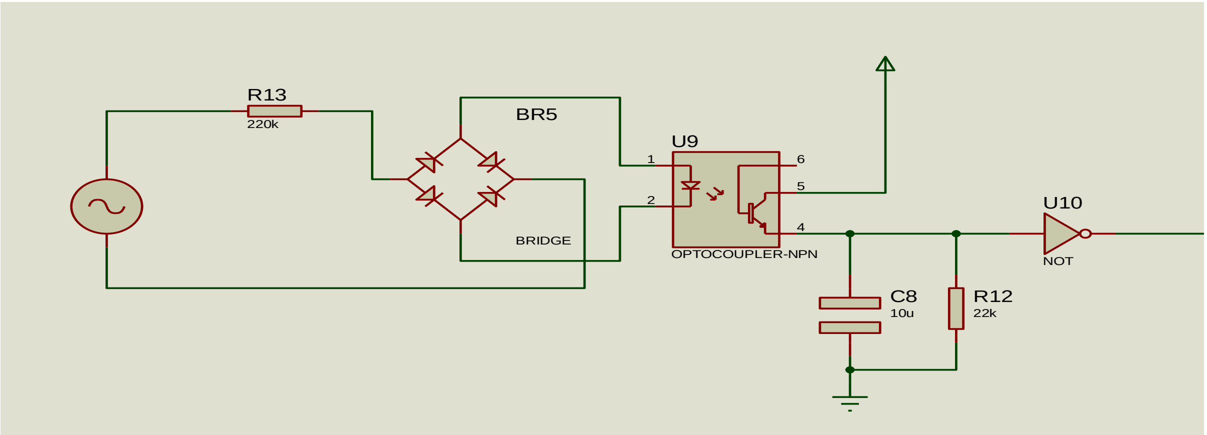

Figure 3 the diagram of a Load Power Monitor Unit

This is a circuit that uses an optocoupler to link between the supplied power and the control circuit. It takes in an analogue input voltage of about 220V ac and produces a digital output of HIGH or LOW. when power is available, it presents a LOW output and when power is unavailable, it presents a HIGH output.

R13: this is a current limiting resistor for the LED inside the optocoupler. The value can be calculated from the basic ohms law formula
V = IR……………………………………………………(1)
Where
V= 220V
I = 1mA (safe operating current of the LED inside the optocoupler)
$R = \frac{V}{I}$
$R = \frac{220}{1 \times 10^{-3}}\Omega$
R = 220,000Ω

R12 and C8: these are snubber circuit components for the output of the optocoupler. R12 is an emitter resistor while C8 is a bypass capacitor. From experiments, the values that were used are as follows
R12 = 22kΩ
C8 = 10μF

2.4 Microcontroller Unit

The microcontroller unit circuit is the heart of the project. This is where the program for the control part of the project is written and burned using assembly language and a universal programmer, respectively. The circuit diagram is as shown in figure 4,

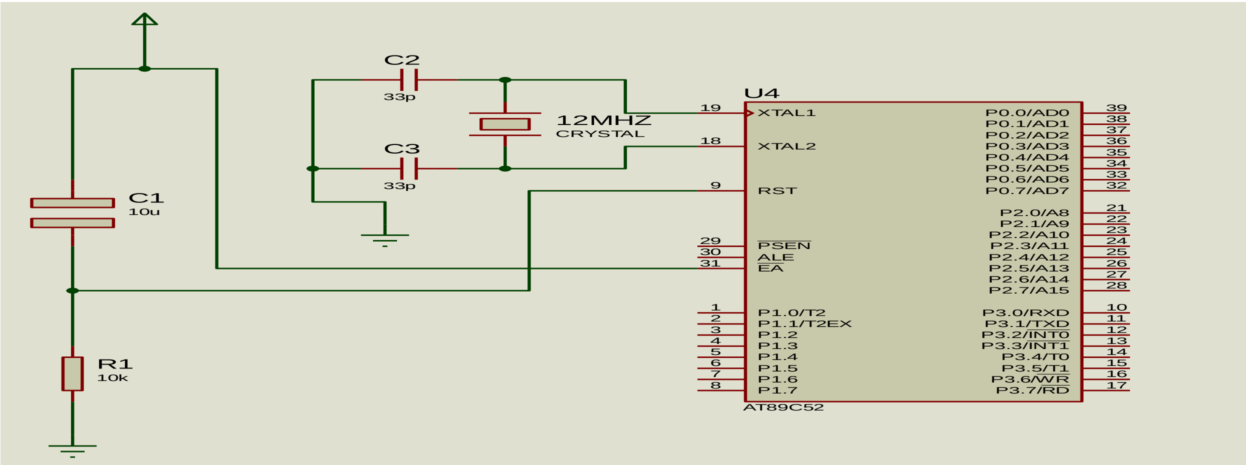

Figure 4 the circuit diagram for the microcontroller unit

The 8052 microcontroller hardware circuit is usually a very flexible one and all the surrounding components are given a recommended range of values, by the datasheet but the actual values can be chosen by the programmer.

The ranges of values given for the 8052 microcontroller hardware are as follows

1. Reset capacitor: 4.7μF - 10μF
2. Reset resistor: 8.2KΩ - 15 KΩ
3. Crystal oscillator: 4MHz - 32MHz
4. Crystal capacitors: 27pF - 47pF

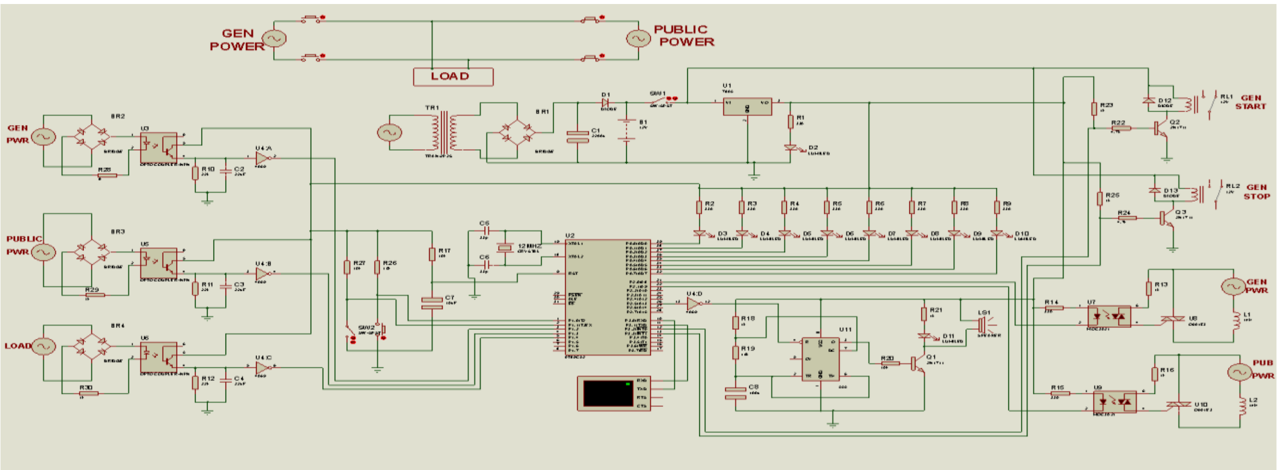

Figure 5 the Complete Circuit Diagram

3. Results and Discussion

3.1 Mode of Operation

The mode of operation of the semi/fully automated power monitoring system is such that when it is installed in an establishment, the user has the prerogative to determine its mode of working. It is a system that has the ability to completely or partially monitor and control the power to an establishment by monitoring the power supplied to the establishment from the public mains. When power goes off from the mains, the system will automatically sound an alarm to inform the user that power is off, then it will automatically turn on a generator and change over source of power supply to the establishment from public mains to generator.

Conversely, when power is restored on the public mains, the system will detect this restored power, automatically change over the source of power supply from the generator, back to the public mains and automatically switch off the generator. These operations are always done when the user selects the fully automated mode. However, when the user sets the system in the semi-automatic mode its function is quite different. The generator will not automatically turn on when power fails but will wait for the user to send either a wireless command or he pushes a button. When this is done, the system will turn on the generator automatically and change over, while still monitoring the restoration of the power to the public mains and switching back to the public mains and turning off the generator.

This feat is possible by the use of a programmed microcontroller whose program is written to respond to sensors connected to the power supply from the public mains, generator and the load power. Also the microcontroller responds to signals from a wireless transceiver and inputs from push buttons that are used to select when to turn on the generator manually and when to set the system in the automatic mode. The microcontroller also sends signals to a group of Light Emitting Diodes which serves as the user interface with the system and informs the user on the activities going on in the system.

The generator is controlled by two relays which are in turn receiving signals from the microcontroller via resistors and transistors. These relays are connected directly into the kick-starter of the generator. One is connected to the terminal that starts the generator while the other is connected to the terminal that stops it. The changeover circuits is built using electromechanical contactors which are in turn controlled by the microcontroller using optotriac that drives Triacs that controls the coil of the contactors. The contacts of the contactor are connected to the power supplied from the mains and the generator in such a way that there will not be a bridge in the two power sources in the event that both powers are present at the same time.

The system has two major sources of forms by which they alert the user when an event occurs and these are by the use of an alarm of the use of a bank of LEDs. The alarm is designed on a multivibrator integrated circuit, a 555 timer, which is connected in the Astable mode and calculated for a frequency of one hertz. This mode will enable the IC to produce a pulsating sound of one-second apart. The second form by which the system uses, (the bank of LEDs), will visually indicate to the user, the current mode and current status of the system.

A mobile app is written and burned into a phone and it communicates with the hardware via wireless media [12 – 14]. The wireless media that was chosen is Bluetooth. The blue tooth module (HC-05) is connected to the microcontroller using UART protocol by which signals are sent to the microcontroller by the user. With this connectivity, the user can set the system to fully or partial automatic mode.

The fully system is powered using a dual mode type of power supply, a 12volts dc battery rated 7amps/hour and also shares power to the load. When the load is powered, the system is automatically powered and when the load is down, the backup rechargeable batty, tales over the supply of power. That way, the system is fully provided with uninterruptible power supply at all times.
This section presents the results of the survey of the water utility of Hall 3. The results are presented in form of water supply network diagrams and tables of nodes, pipe sections, pumps, reservoirs, valves and tanks properties.

4. Conclusions

The developed system enables the automatic starting and stopping of a generator using both wired and wireless communication. This feature ensures convenience and operational efficiency, the system effectively detects the presence or absence of electrical power from the public supply and sends a report to the central control unit, enabling real-time monitoring, a reliable circuit was implemented to switch the power source automatically from the public mains to the generator and vice versa, ensuring uninterrupted power supply.

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