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Design and Development of Automatic Selection Control System for Three-Phase Power Supply

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ABSTRACT
Reliable and uninterruptible power supply is crucial for mission-critical loads to function efficiently and optimally. However, in most developing countries, electric power supply is characterized by regular failures and when available, it is largely unreliable as the standard three phase power supply is most of the time unbalanced and the quality degraded by fluctuations. This project work involved the design and development of automatic three-phase power supply selector to guarantee uninterruptible and reliable power supply to critical infrastructure. The performance of the automated system was tested and the results showed that whenever there was voltage input or any combination of inputs from the threepower phases that served as reference inputs to the control system a voltageoutput is automatically produced to ensure reliable supply to mission critical loads.
Keywords: Three-Phase, Power Supply, Automatic Selector, Critical Infrastructure

I. INTRODUCTION

The need for reliable and uninterruptible power supply to critical infrastructure has become very critical in modern societies most of which have invested so much in the development of critical infrastructure such as aviation and communication systems, medical instrumentation, sensitive laboratory equipments etc. These mission-critical systems require reliable and uninterruptible power supply to function efficiently and optimally. However, in most developing countries, electric power supply is characterized by regular failures and when available, it is largely unreliable as the standard three phase power supply is most of the time unbalanced and the quality degraded by fluctuations. In addition, power demands have continued to grow exponentially and as a consequence, power lines are frequently over loaded, hence the need for load shedding.

1.1 Statement of Problem

As observed in practice, phase selection is manually done in three-phase power supply system in most developing countries and this process often leads to power supply interruption which is unhealthy to mission-critical systems. This necessitated the need for the development of an automatic phase selector for power system to enhance performance and reliability.

1.2 Aim and Objectives

In view of these obvious challenges, this project work is aimed at the design and development of automatic three-phase power supply selector to guarantee uninterruptible and reliable power supply to critical infrastructure. The objectives are to achieve:

i) The design an efficient and reliable automatic phase selector for three phase power system;
ii) Simulation of the system model;
iii) Implementation and realization of a reliable and affordable physical system with appropriate power electronics circuits;

II. LITERATURE REVIEW

This section presents the review of similar work done and highlighted different approaches that have been adopted to achieve automatic phase selection for three-phase power supply.

Kyereh, et al [1] reported that the ability to supply reliable power to consumer loads is a major aim of the utility company. Based on technological advancement, various theories have been implemented to design different kinds of means to attain automatic means of healthy phase selection in times of fault. Therefore, a real-time automatic phase selector was designed using logic gates and power electronic devices. Miniaturization of digital circuits and scalability of other electronic circuits are, therefore, recommended to improve upon the designs and development. Oduobuk, et al [2] reported that, the automatic phase changer was made from several electronic components which include; operational amplifiers, diodes, resistors, capacitors, Zenerdiodes, transformers, relays and fuses. Results obtained during the test showed that whenever the system senses a higher voltage across at least one of the three inputs, it then engages the load. The system was designed to handle low power load and not high power loads. Also, system reliability, compatibility, and durability in this work were not considered. Nweke et al [3] noted that the automatic three phase power system selector was designed and constructed to automatically switch over to the alternative phase that has current when there is power outage or extremely low current in the phase which the load is connected without the power being off. The selector links the load and the other phases and relay switches allowing the usage of the remaining phases where there is outage on the mains source without disturbing or interrupting the load. It maintains constant power supply to the load by automatically activating the phases when the need arises. This safeguards the electronics system from being damaged and burnout as a result of voltage instability, collapse, insistent outages which are paramount in under developed and developing countries. Bhise et al [4] observed that in many cases we have three phase supply where only single phase is used to run the equipment such as load of Operation Theater in hospitals, commercial Internet servers. By the use of proper relay logic, available phase can be automatically selected and avoid the short circuit condition between the different phases. This could be realized by using electrical component such as transformer, under voltage, overvoltage protection and relay switches.As reported by Lawal et al [5], the variation in voltage level per phase in a three phase supply circuit posed challenges in industrial power system. Hence, the need for the design of a system to check the availability of any live phase, and connects the load to the available live phase only. This feat was achieved with microcontroller (PIC16F628). Ofualagba, et al [6]proposed the design and construction of automatic phase selector and changeover switch for 3-phase power supply to provide a means of switching from one phase of AC mains to another in the case of failure in the existing phase. It also change over to generator if there is failure in all the three phases of the AC mains. The circuit also senses the restoration of any or all the three phases of the mains and changeover without any notice of power outage. The project was aimed at improving on the existing types of electromechanical device that has being in use over the years. The proposed system was realized by the use of 1- of - 4 analogue multiplexers (CD4052), analogue to digital converter (ADC0804), AT89C51 microcontroller and relay switches.

III. METHODS AND MATERIALS

The methodologies adopted in this work are divided into three sections, namely:

i) Design of system components with block diagram;
ii) Simulation of system model using Circuit Wizard simulation software;
iii) Realization of physical system with electronic circuits as well as testing and validation

3.1 System Design Block Diagram

The design of the system is depicted by the block diagram shown in fig 3.1 below:

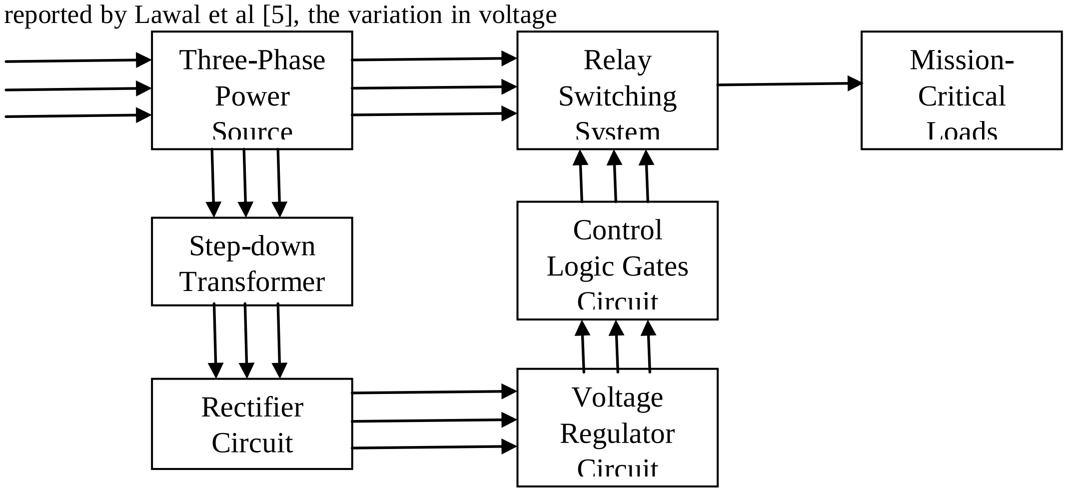

Figure 3.1: Block Diagram of Automatic Phase Selector Control for Three-Phase Power Supply to Mission Critical Loads

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The system takes 3-phase inputs and these are fed in to step-down transformers which function as ac-ac converter to step the 3-phase ac inputs from 240 volts to 12 volts. The rectifier circuits convert the 12 V ac signal to 12 V dc signal which was in turn employed to energize the power electronic circuit and control logic gate circuit after it has been regulated by the regulator circuit. The control logic gate circuit monitors the state (ON or OFF) of the three-phase and actuates the relay switching system appropriately. The logic circuit operation is autonomous as it actuates on the relay switch with power on the input phase and when there are more than one phase with power supply, it ensures that only one phase supplies power to the load. The relay switches are actuators which are controlled automatically by the control logic gates. The control system guarantees uninterruptible power supply to the mission critical loads whenever there is power in at least one of the 3-phase inputs.

3.2 System Circuit Design

This system circuit was simulated using Circuit Wizard simulation software. This is shown in Figure 3.2.

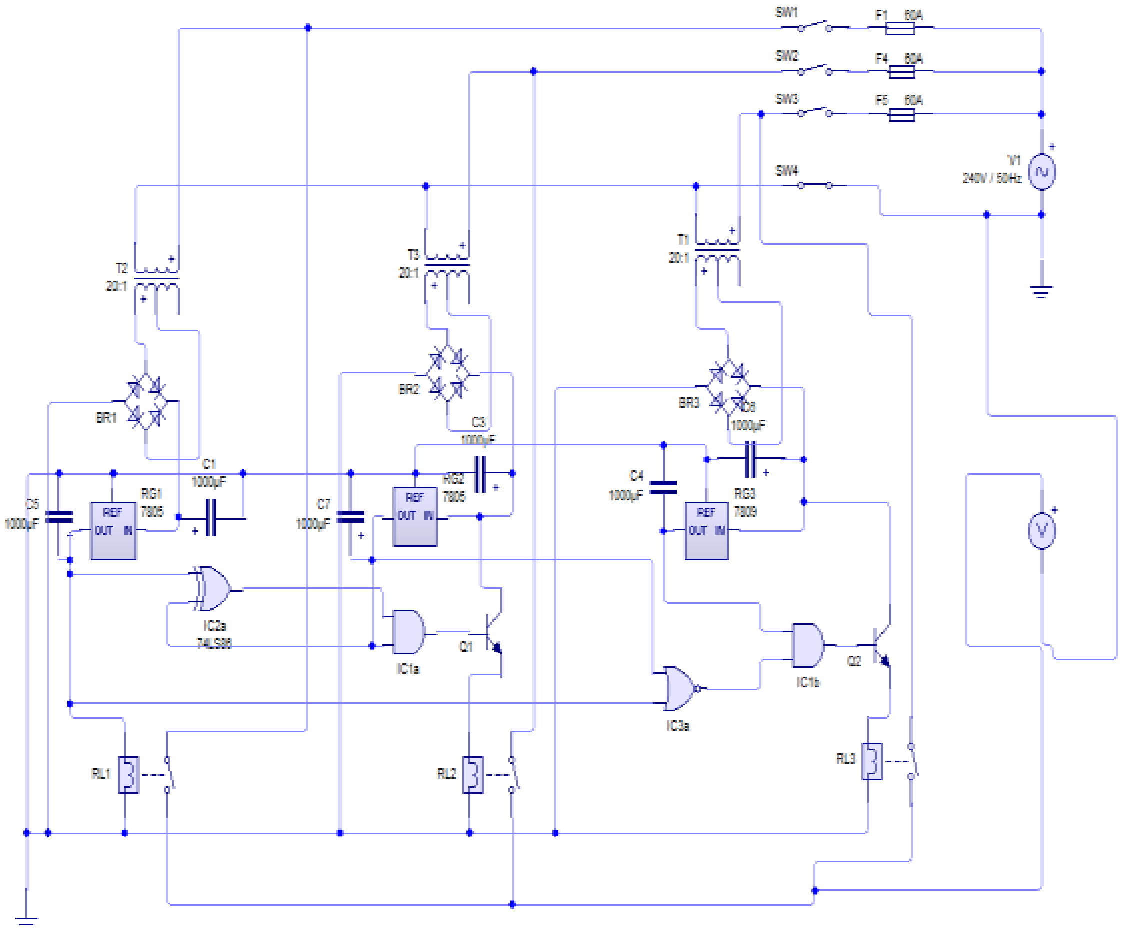

Figure 3.2:Circuitsimulation ofautomatic three-phase selector system

The simulation of the automatic phase selector for 3-phase power system was done by circuit wizard. The simulation of the system was accomplished by a constant and detailed study of the constituent components. This involved the study of their characteristics in isolation, and when connected together with some other components. The method employ in this design was based on the visualization of the three phases. The design considered the six possibilities;

i) When the R, Y and B phase has no input supply
ii) When the R phase has input supply but the Y and B has noinput supply
iii) When the R and Y has input supply but not the B phase
iv) When the R and B Phase has input supply but not the Y phase.
v) When the Y and B phase has input supply but not the R phase

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vi) When the B phase has input supply but not the R and B phase.
vii) When all the Phases of R,Y and B hasinput supply

This gave rise to a truth table shown in Table 1.0

Table 1.0. Truth Table of the 3-Phase possible outcomes

R	Y	B	Connection to load
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

The "1" state of the logic is a 5V delivered through the Output of the Voltage regulator which represent the "ON" state while the "0" state indicate any voltage of 0V or any voltage less than 5V which represent the "OFF" state.
The truth Table of the analysis is shown below:

RED (R)	Yellow (Y)	Blue (B)	OUTPUT
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

3.3 Circuit Components Analysis and Calculations

The components values are as determined below

i) Fuses

In selecting the cutout fuses, we consider the total load of the building. If we assume that the load consumption would amount to 10kw[7], the supply voltage is 240v, then from the relationship:

$P = IV\cos\Theta$

$10,000 = I \times 240 \times 0.8$

$I = 10,000/240x0.8 = 52,0833A$

By this calculation, we can choose a fuse of **60A**

ii) Determination of the Transformer

Expected input voltage= 240V
Needed output voltage= 12V
From the relation Np/Ns=Vp/Vs = 240V/12V
This gives the ratio of the primary to Secondary winding used in the circuit to **20:1**

iii) Diode

Peak inverse voltage = 2 x Vrms
2x12=24V

iv) Capacitors

The capacitor value was calculated by considering the ripple voltage as low as 0.1v and a load current of 10mA= 0.01A

From the relation $Q=It = CV_{rp}$

Where V_{rp} = Ripple voltage

also, t = T/2 for a full wave rectifier = 1/2F

Therefore: $C= I/2FV_{rp}$

C= 0.01/2x50x0.1
= 0.001F
= 1000µF

v) Transistors

From the expression $I_c/I_b=\beta$

Where I_c is Collector current, I_b is the Base current and β is the gain

β is set to 30

To find the collector current, we derive it from the formula below

$I_c = V_c/R$

Where I_c is collector current, V_c is the Collector voltage which is supplied from the 12v DC; the output of rectified voltage which is 12V, R is the coil resistance of the relay which is 400Ω

$I_c = V_c/R = 12/400 = 0.03A$

The design considers the transistor gain of 30.

Therefore, from the relation $I_c/I_b=\beta$

$I_b = I_c/\beta = 0.03/30 = 0.001A = 1mA$

To ensure that the base current is sufficient to bias the transistor, we multiply it by 2.

This implies that I_b will be 2mA. This is the Current sufficient to bias the Transistor.

IV. RESULTS AND DISCUSSIONS

From the performance test of the system, output results were obtained for different combinations of input phases and tabulated as shown in Table 4.1.

Table 4.1: Input Combinations and Output Results

Input combination	Output Range	
R	222V	240V
Y	222V	240V
B	222V	240V
YB	222V	240V
RB	222V	240V
RY	222V	240V
RYB	222v	240V
Zero	0V	

This table show a range of output Voltage of 222V-240V with the combinations of R, Y, B, YB, RB, RY, RYB Where when the phase inputs are zero, the output obtained is zero.

V. CONCLUSION AND RECOMMENDATIONS

In conclusion, a design, simulation and construction of an automated input selection for 3-phase power system was carried out to realize an uninterrupted power supply to critical infrastructure. The performance of the automated system was tested and the results showed that whenever there was voltage input in any of the 3 phases or a combination of the phases an output corresponding to the input is produced. This process takes place automatically according to the design. This project is an improvement of the existing types of electromechanical device that has been in use over the years. Hence this has been achieved by the use of logic gates, voltage Regulator and relays in a simplified circuit.

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