Design and Implementation of a Three-Phase Automatic Changeover Switch Using CAD Electrical Simulation

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ABSTRACT—*The advantages of using an automatic changeover switch, which involves switching power from one source to another, is enormous. An automatic change-over switch system ensures acontinuous power supply to load in case the mains supply is faulty. Manual power switching from one source to another takes time and may delay some processes, rendering it disadvantageous. In this project, we designed and implemented a three-phase automatic changeover switch system for Ashesi University to ensure an uninterrupted power supply to the institution's electrical infrastructure. The ECG is the system's primary power source, with a generator set as an alternate power supply in the event of ECG power failure. When the ECG power source fails, the system automatically switches to the generator setwithin a specified time limit and then returns to the ECG power supply when it becomes available. The system was designed using a combination of contactors, relays, timers, starters, and switches. This project has a substantial impact since it assures that Ashesi University's electrical infrastructure has an uninterrupted power supply, eliminating the risk of data loss, service disruption, and life endangerment.*

KEYWORDS: *Generator, Relay, Change-over switch, Power Supply, timer, starter.*

INTRODUCTION

As one of the higher learning institutions in Ghana, power failure in an institution like Ashesi University directly has a negative impact on its operations by interrupting teaching and learning activities. Ghana's power supply infrastructure has been a major challenge, with frequent power outages experienced nationwide. The Electricity Company of Ghana (ECG) is the primary power supplier in Ghana. Still, due to its unreliability, many institutions and individuals have installed generators as an alternative power source, should ECG fail. Unfortunately, manually switching between power sources during a power outage can be tedious and time-consuming. As a result, this project seeks to solve this problem by designing a three-phase automatic changeover switch to suit the needs of Ashesi University. Although implementation of an automatic changeover switch is beneficial, the use of manual changeovers has several disadvantages, including time wastage, the potential for human error, the risk of damaging electrical equipment when power is abruptly switched and human safety. These problems highlight the need for an automated changeover switch, providing a seamless transition between power sources dependent on human intervention. To build the three-phase automatic changeover switch, contactors, relays, timers, and switches will be used to provide a dependable and efficient switching method between power sources. The circuitry was designed by using the standard ratings from the Electricity Company of Ghana. The system automatically switches the generator on within 5 seconds when the mains go off and turns the generator off when the mains are restored. Completing this project will ensure that the university has a dependable and efficient power supply system that will provide uninterrupted power during an ECG power outage. As required by the project brief, this document will offer a clear and simple overview of the design procedure, simulations, and prototypes used in the project. The design and simulation were performed using the CADe Simu automation software and proteus.

LITERATURE REVIEW

In [1] Kolo designed an automatic change-over switch that can automatically switch between a primary power source and an alternate power source in the event of a power outage or failure. The switch consisted of a relay, two power contactors, and a control circuit based on a 555 timer IC. One technical limitation of the automatic power changeover switch described in the paper is that it relies on a single relay for switching between the primary and alternate power sources. While this may be sufficient for some applications, it may not be adequate for high-power loads, and the relay may wear out more quickly over time. Another limitation is that the automatic power changeover switch requires a manual reset after restoring the primary power source. This means that the switch may not be suitable for critical applications requiring an uninterrupted power supply, as it may cause downtime or data loss in power outages.

Osaretin et al. [2] outlined there are three types of changeover switch: manual changeover, electrical changeover, and electronic changeover. Although manual changeover is the most popular changeover switch in use, they are disadvantageous as it requires major human action to operate. On the other hand, electrical changeover overuses the A.C. relay in its operation. Often referred to as an Automatic Transfer Switch (ATS), it provides automatic switching of power supply between a primary source, and a secondary power source. Finally, the electronic changeover works in a similar manner to the electric changeover, however, it solves issues of shortcomings in the a.c. relay-based changeovers that are present in the electric.

Singh et al. [3] also designed and implemented an automatic changeover system for a three-phase power supply .The system uses microcontroller-based control circuits to switch between the main power supply and the backup generator in the event of a power outage, three power relays to switch between the main power supply and the backup generator, three current sensors to monitor the current flowing through each phase of the power supply, an LCD display that displays the status of the power supply and the system's operation, push buttons, resistors, capacitors, diodes, and transistors for various purposes, such as voltage regulation and signal conditioning. This changeover does not provide a redundant backup in case of failure of the main generator or the changeover system itself. Also, the system cannot be monitored or controlled remotely, which could be useful for institutions with multiple buildings or locations.

DESIGN AND IMPLEMENTATION

A. Software used

- Proteus
- CAD Electrical Simulation (CADe Simu)

B. Considerations made.

To design the automatic changeover switch, we made some considerations.

- The load is always connected to a 3-phase supply.

C. Generator selection

Following the Electricity Company of Ghana's standard ratings of about 220V-240V/415V, with transformers operating at 50Hz frequency, we selected a generator with the same rating to ensure a smooth load running when the generator is turned on. A generator operating at a rated 220V/415V, 15KVA and at a frequency of 50Hz with a power factor of 0.8was selected.

D. Block Diagram and Flow chart of the Automatic changeover switch.

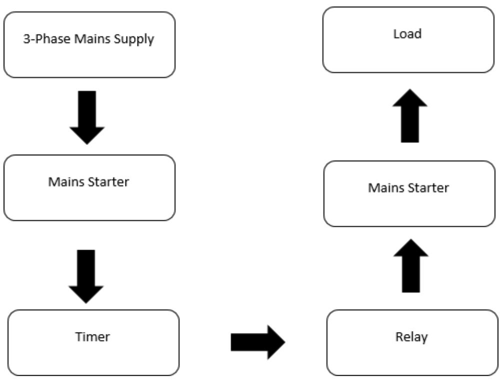

Fig 1: The block diagram above shows the operation of how the 3-phase supply from ECG gets to the intended load (Ashesi University)

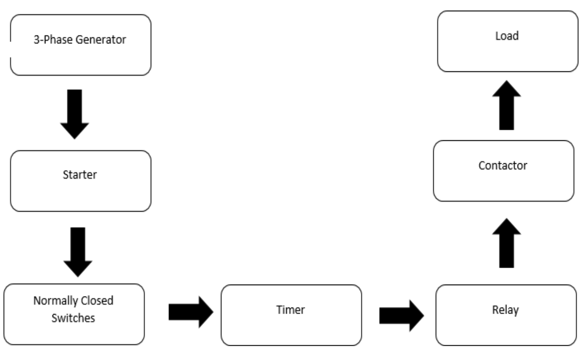

Fig 2. The block diagram shows the order in which the 3-phase generator is operated when there is no power supplied by ECG.

E. Important Calculations Made

Having selected the generator with its ratings, to design the switch, the phase current has to be calculated to determine the contactors and relays to be used and the specifications of cables to be used.

Based on the generator ratings in accordance with ECG standards,

Apparent power(S)= 15KVA

Line Voltage (VL) = 415V

Phase Voltage (V_p) = 220V

Power factor (Pf) = 0.8

considering the ECG standards,

Real power(P) = pf *apparent power(S)

P = 0.8 *15KVA = 12KW

P= $3*V_pI_p\cos(\theta)$

$$Power\ per-phase = \frac{P}{3} = \frac{12Kw}{3} = 4Kw$$

$$current\ per-phase = \frac{Power\ per\ phase}{(V-phase*cos(\theta))}$$

I_P = 4000W/ (220*0.8) = 22.7272A

To increase the efficiency of the system, the current is given a tolerance of 25%.

This brings the phase current I_p to 22.7272A *125 = 28.409A

This Implies that we are going to need a contactors and relays that operates at ratings within 28A to 30A.

We will use a cable that can carry about 1.5 times the phase current to avoid any unforeseen accidents when the system is implemented. That is, the cable should be able to carry 1.5* 22.7272A + 22.7272= 57A

F. Implementation

After calculating the phase current, we were able to select the contactors and relays that would be able to operate within those ratings of about 28-30A. The electrical automation software, CADe Simu was then used to connect the component. As seen in the figure below.

COMPONENTS USED AND THEIR FUNCTIONS.

Component	Function
Conductors	For carrying current between the power sources (such as the main power supply and the generator) and the load.
Relays	Switches between the power sources and the load by opening and

	closing the contacts to prevent the flow of current
Switches (Normally Open, Normally Closed)	To control the flow of current in the circuit
Starters	Use to start the control circuit by closing two contacts.
Emergency Push Button	Stop the flow of current in the case of an emergency
Pilot Bulbs	Used in the absence of a load to test if the load is receiving its intended power.
Wires	To connect the various parts of the ATS together.
On-Delay Timer	To control the activation of a circuit by delaying the initiation of current flow

HOW THE CHANGEOVER SWITCH OPERATES

Three-phase power from the mains, ECG, is connected to the Normally open contacts of the mains contactor. The starter circuit is connected to the mains to serve as a means of controlling the circuit. A voltage signal is fed into the on-delay timer (KT1) when the starter is closed. The delay of the mains timer is set to 0 since there is no need for a delay when the mains power is restored after a fault. Once the timer receives the signal, the coils of the relay (KM1) are energized, and its Normally Open (NO) switches are closed, which allows current to flow to the mains contactor to energize it and cause its NO switches to close, allowing current to be passed to the load—the Pilot bulbs V and L1 lights to show that current is passing through to the contactor and load.

To ensure that there is an automatic changeover when the mains supply is faulty, the on-delay timer of the mains circuit (KT1) and the relay (KM1) are connected to the Normally closed (NC) switches of thegenerator circuit. When the mains are in operation, the NC switches of the generator circuit are open (**see fig 3)**. In the event of a fault in the mains supply, when the generator starter is closed, the generator control circuit's NC switches close (**see fig 4**), allowing a voltage signal to be fed into the on-delay timer (KT2) of the generator. After a delay of 5 seconds, the relay (KM2) of the generator circuit is energized, which causes its contacts, the NO switches to close to allow current to flow through the generator contactors, which in turn, gets energized and supplies current to the load. The pilot bulbs J and L1 lights to show that current is flowing through the contactors and the load.When the mains supply is restored after a fault, due tomechanical interlocking, the generator contacts are deenergized. The mechanical interlock mechanism prevents both contactors from being energized at the same time. Essentially, the mains control circuit controls the opening and closing of the NC switches ofthe generator circuit.

SIMULATION OF THE CIRCUIT WHEN THE MAINS SUPPLY IS OPERATING.

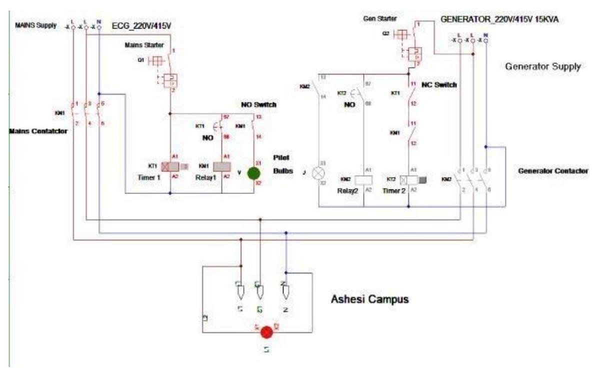

Fig.3 NC switches of the generator circuit open when the mains are operating.

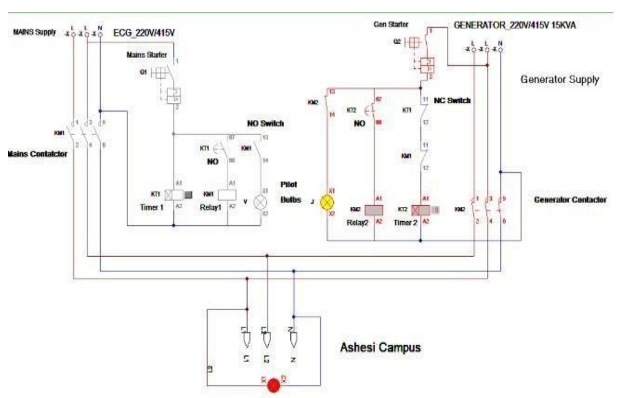

Fig. 4 NC switches of the generator circuit close when the mains circuit is interrupted.

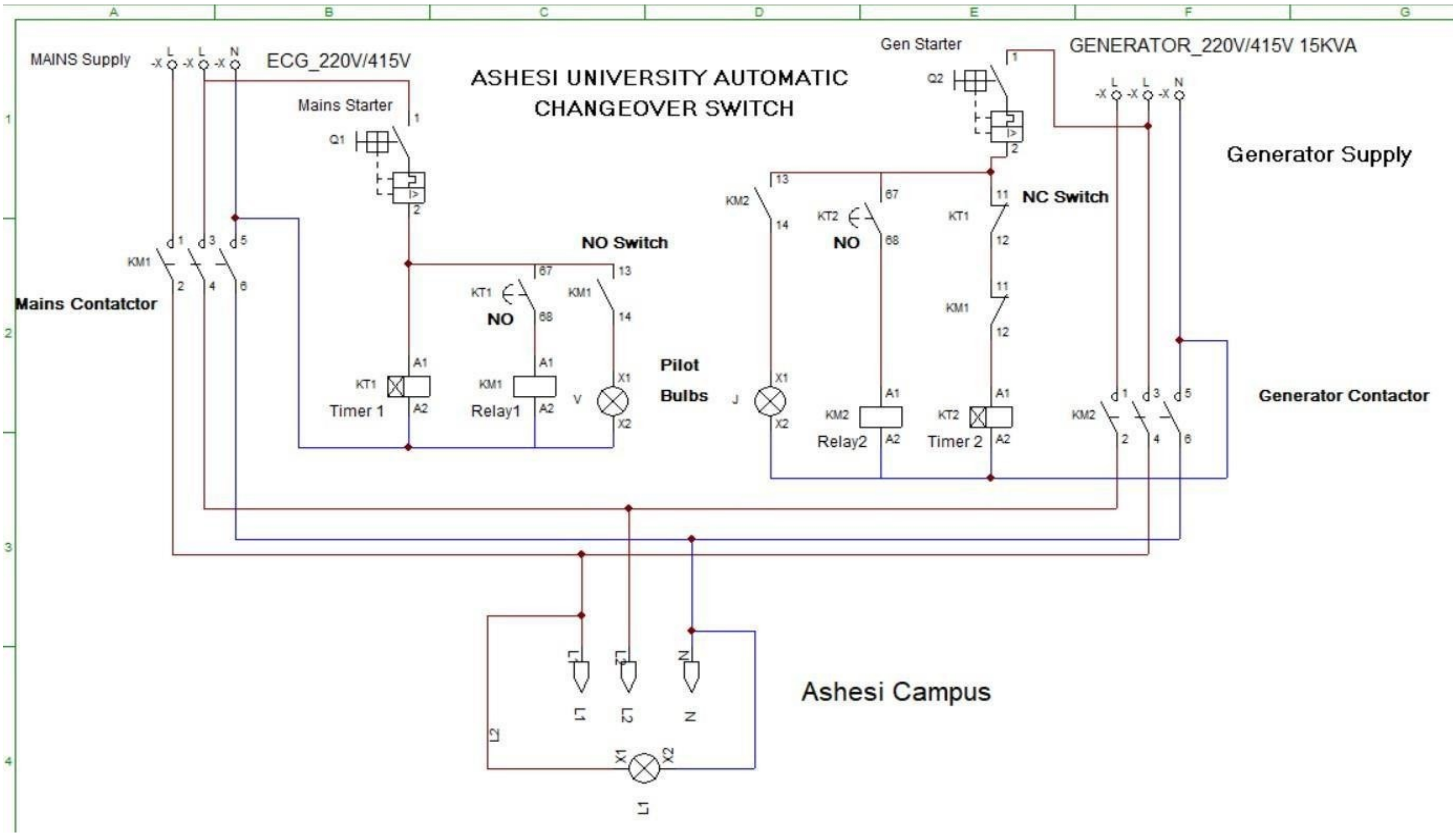

Fig.5 Final schematic of the automatic changeover Switch in CADe Simu

RESULTS/OBSERVATIONS

It could observed from fig. 3 that when the mains supply is in operation, the Normally closed contacts (NC) of the generator control circuit opens and from fig.4 when the grid supply is interrupted the NC contacts of the generator circuit closes to ensure that there is current flown into the on delay timer KT2, which counts down 5 seconds and the relay KM2 is energized, which then closes the NO contacts of the generator circuit and he contactor is energized to enable the flow of current to the load.

Based on these observations, the future implementation of this switch will ensure that we are able to switch between phases. That is, when one phase of the mains supply is faulty one of the generator phases can be switched on to make up for the loss of power in the grid using a microcontroller such as Arduino or ESP32 and other electronic components, such as capacitors and inductors to filter the voltage from the generator before it gets to the load. We may also consider adding a solar energy source which is used as a stanby at Ashesi to the automatic changeover switch so as to be able to switch to solar when both the generator and mains supply are not working.

CONCLUSIONS

This project, to design an automatic changeover switch at Ashesi University can be deemed a success. Simulations of the schematic diagrams show display seamless switching between the mainssupply and the generator set power supply. As a result, if the school experiences power outages, the transition should be similar to that shown through the simulations. The design process involved using relays, contactors, timers, and switches to ensure that the system was well-designed to fit its intended purpose. Should this design be selected for implementation, the final product would be reliable and efficient as it meets the design requirements of

Ashesi University. The automatic changeover switch will play a critical role at Ashesi University, ensuring an uninterrupted power supply. The functionality of the automatic changeover switchcan be enhanced through altering the design to accommodate changes in application demands. All in all, the automatic changeover switch, in terms of power management systems, is an important breakthrough that can improve power supply and reliability in several industries.

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