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Design And Development Of A Synchronizing Panel For Two Single-Phase Generators Of 7.5KVA Each

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***Abstract*— Synchronization of the generator is obtained in parallel operation when an incoming generator set is matched with and in step to the same frequency, voltage and phase sequence as the operating power source to increase power. The synchronization of generators could be carried out using three different methods: dark and bright lamps and a synchronoscope. However, every electricity supply authority aims to create a continuous and reliable power supply to meet consumers' increasing demand. Considering the Nigerian power situation, the design and development of this synchronizing panel, specifically for two single-phase generators, is aimed at synchronizing two single-phase generators of 7.5KVA each to achieve greater and desired power demand for our local industry and domestic use. The LAMPS BRIGHT method of synchronization was used. The lamp's bright method successfully achieved this aim with little or no voltage difference.**

Keywords*— *synchronization; single-phase generators; lamps bright method

I. INTRODUCTION

Synchronization is obtained in a paralleling application when an incoming generator set is matched with and in step to the same frequency, voltage and phase sequence as the operating power source. During this operation (installation of a generator), careful checks are carried out to ensure the generator terminals and all other control wiring systems are correct so that the order of phase sequence matches the system. Connecting a generator with the wrong phase sequence will result in a short circuit, which can seriously damage the system, as the system voltages are opposite those of the generator terminal voltages. This synchronizing operation is carried out when the field of the generator is energized, and the voltage at the terminals of the generator is observed using electrical devices that serve as eye and ear to the operator monitoring the phase relationship or sequence between two voltage sources and frequencies and comparing the voltages with the system. The voltage magnitude must be the same as the system voltage. This provides a connection signal to synchronize the system to a known bus called synchronizers and synchronizing lights. Synchronizing lights are lamps connected across the line contactor of the incoming generator set. However, the lights indicate when the incoming and operating power source voltage waveforms coincide, and paralleling operations can be completed. Suppose one generator is slightly out of phase. In that case, it will pull into step with the others, but if the phase difference is large, there will be heavy cross-currents, which can cause voltage fluctuations and damage to the generators in extreme cases. Connecting an alternator in parallel with another alternator or common bus bars is known as synchronizing. Alternators are used in power system where they are in parallel with many other alternators. This means that the alternator is connected to a live system of constant voltage and frequency.

A. Need for Synchronization

The ease of expandability and flexibility attributed to this design has made it possible to use several generators to supply a varying load without spending too much money on a gigantic generator whose full capacity can rarely be utilized; instead, generator units are gradually connected as load demand increases. The efficiency of any machine is maximum at its full load, and generators can be run when required, increasing its efficiency. The system's reliability is improved such that if one generator fails, the other is used for the operation, and the whole system will not be shut down. Thus, there is always constant power to critical loads. However, connecting generators in parallel increases the power capacity by supplying a bigger load, controlling load management, and ensuring ease of maintenance and redundancy.

This research aims to design and develop a synchronizing panel for two single-phase generators of 7.5KVA each. However, the objectives are to have two smaller single-phase generators of 7.5KVA, each running in parallel rather than large single units capable of supplying the maximum peak load. The smaller units can be run single or in various parallel combinations to suit the load demand.

II. DESIGN METHODOLOGY

Three methods are used for the synchronization of generators: the bright lamp method, the dark lamp method, and the Synchronoscope method. The method used in this project is the lamp bright method of synchronizing restricted to single-phase generators.

A. Design Theory

The lamp bright method of synchronization was used to satisfy the design requirements for this project. The purpose is to check that all three conditions listed below are met before synchronization;

i) The incoming alternator's terminal voltage (effective) must be the same as the bus bar voltage.

ii) The speed of the incoming machine must be such that its frequency equals the bus bar frequency (f).

$$f = \frac{PN}{120} \quad (1)$$

iii) The phase of the incoming machine voltage must be the same as that of the bus bar voltage relative to the load.

However, In the case of 3-phase alternators, an additional requirement to be met is that the phase sequence of the incoming machine is the same as that of the bus-bars. The three conditions stated above must be checked each time the alternator is to be put in parallel with the bus bars or other alternators already in operation. A voltmeter condition indicates condition (i) above, and conditions (ii) and (iii) are indicated by synchronizing lamps.

B. Design Information/List of Components

- Overload relay with base
- Ammeter (0 – 100V)
- Voltmeter (0 – 500V)
- Copper bar
- Pilot light
- Start and Stop push button
- Four poles Auxiliary contact
- Two poles auxiliary contact
- Insulators
- Two pole breaker
- Fork shaped connector
- $4mm^2$ cable flex

C. Design Concepts for the Synchronizing Panel

The design of this research project consists of three main components: the power supply unit, the control circuit unit, and the synchronizing circuit unit. The lamp bright synchronization method depends on the operator's decision and experience. The system reads the incoming generator in terms of the voltage and frequency using the voltmeter and frequency meter, respectively. The lamp bright is the preferred synchronization method, and it is made by the operator when the light glows consistently without flickering.

i) The Power Supply Unit.

The power supply unit consists of two single phase generators of 7.5KVA each, which is used to supply electrical power to the bus bar through the contactors for synchronization, as illustrated in Figure 1.

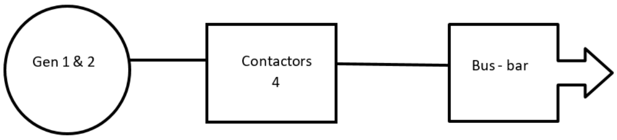


Figure 1: Block diagram of the Power Circuit Unit

These contractors are electrical devices that make and break the power circuits to such loads as lights. The four contactors used in this design, as shown in Figure 2, form part of the power circuit, with two contactors for each side of the generator. Figure 2 shows the circuit diagram of how power is supplied to the bus bar through the contactors from the different generator units, G1 and G2.

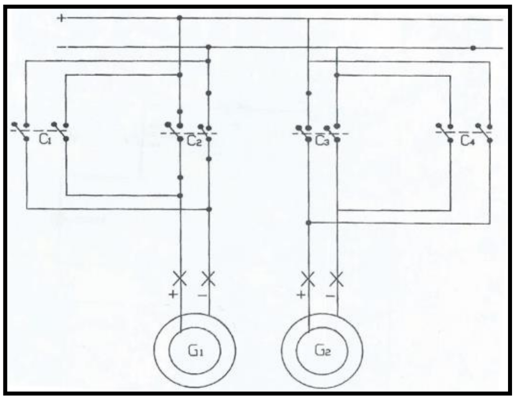


Figure 2: Circuit Diagram of the Power Supply Unit

The contactors connect the generator voltage to the bus-bar and also isolate it from the bus. Thus, contactors C1 and C2 connect generator G1 to the bus during synchronization, which is when generator G2 is already on. Similarly contactor C3 connect generator G2 to the bus provided G2 was started first and contactor C4 connect generator G2 to the bus during synchronization, which is when generator G1 is already on. This connection indicates that synchronization could be made either side based on the functional operation of the contactors.

ii) The System Control Unit

The system control unit is the unit that houses the push-button station and pilot light, where the sequence of operations is carried out to ensure synchronization. It consists of the auxiliary contacts, relays, push-button station and pilot light. The connection arrangement of the system control unit is shown in Figure 4.

a) Circuit Breaker

This mechanical protective device makes and breaks a circuit under normal and abnormal conditions. The circuit breaker is selected for a particular duty based on the following considerations: the normal current it can carry and the fault current it can sustain. The circuit breaker in a closed position retains its contact while the contacts are open when the release contacts are pressed by hand or fault condition occurs. Thus, the primary function of the circuit breaker is to protect the installation cables and other components from damage resulting from circuit overload or from short circuit faults.

b) Contactors

Contactors are devices for repeatedly establishing and interrupting an electrical power circuit. They are used to make and break the electrical power circuit to such loads as lights. Four contactors are used in this design, and they form part of the power circuit. Two contactors are used for each generator side. The contactors connect the generator voltage to the bus bar and also isolate it from the bus. However, contactors C1 and C2 connect generator G1 to the bus during synchronization, which is when generator G2 is already in position. Similarly, contactor C3 connected generator G2 to the bus provided G2 was started first, and contactor C4 connected generator G2 to the bus during synchronization, which is when generator G1 is already on. This connection indicates that synchronization could be made at either side based on the functional operation of the contactors.

c) Auxiliary Contacts

These are electrical devices which can be added to a contactor to form an electrical holding circuit. They are used to eliminate the necessity of someone holding the push button continuously. Four auxiliary contacts are used in this circuit design: two 4-pole and two 2-pole contacts. They are used for controls and perform the following functions:

i) They act as electrical interlocks between contactors C1 and C4 and contactors C2 and C3. That is when C1 is energized; C4 will never get energized unless a button is depressed.

ii) They monitor the contactor and buttons to ensure they are ready for synchronization.

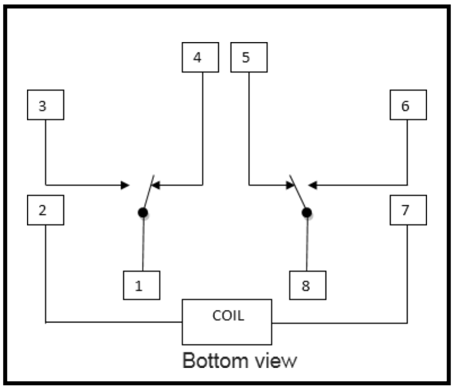
iii) They provide the logical operation of the system

iv) They checkmate the short-circuiting of the two generators.

Auxiliary contacts operate when the parent switch does, such that a normally open contact closes and a normally closed contact opens when the coil is energized.

d) Relays

A relay is used to switch smaller currents in a control circuit; hence, it is used as a switching element in the control circuit. They are used to switch starting coils and pilot lights. The circuit design consists of four relays; two relays are used for each generator to isolate the synchronizing

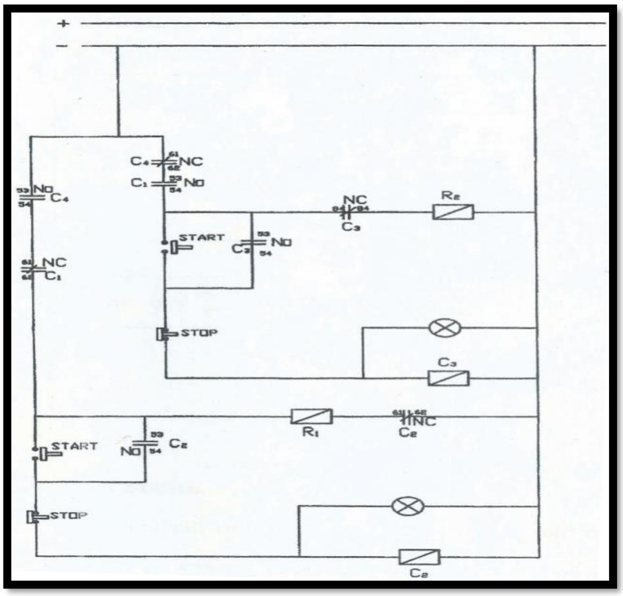


lamps from the generator that is not operating. They also isolate the lamps from the line after synchronization. The contact arrangement of the relay is shown in Figure 3, where contacts 2 and 7 are the coil contacts. The Figure 3 illustrates the schematic design of a relay with the coil contacts at 2 and 7. The coil contact is energized when a button is depressed; the normally open contact opens while the normally closed contact closes.

Figure 3: Relay Design Showing Coil Contacts 2 and 7

e) Push-Button Station and Pilot Light

The push-button station consists of two buttons, namely, the start and stop buttons. When the start button is pressed, normally open contacts are closed; when the stop button is pressed, normally close contacts are opened. The illumination of the pilot light



notifies the operator that any sequence of events may be taking place.

Figure 4: Control Unit Circuit Diagram

III. OPERATIONAL PRINCIPLE OF THE SYNCHRONIZING SYSTEM

Figure 5 shows the detailed operational model of the synchronizing panel, followed by a circuit description of the synchronizing model. Both generators are at rest at a standstill. However, from the operational design, any of the generators can be started or shut down at any time. On no account should the two generators be powered onto the bus bar at the same time.

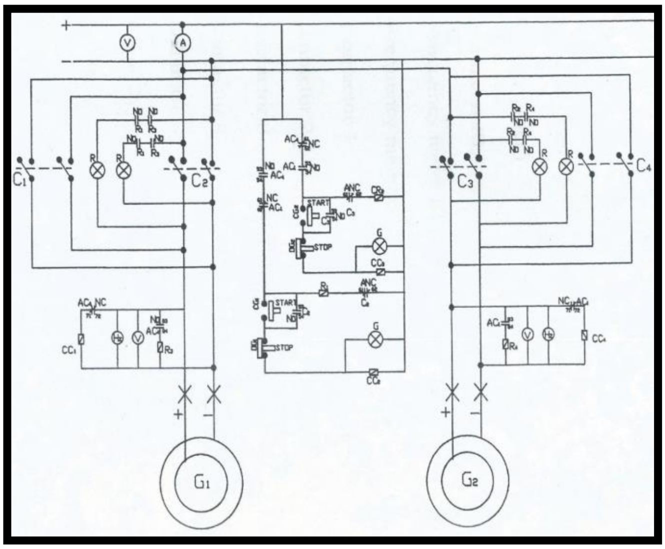


Figure 5: Detailed Synchronizing Circuit Model

Circuit Description of the Synchronizing Model

i) G1 – Generator 1 (7.5KVA)
ii) G2 – Generator 2 (7.5KVA)
iii) V – Bus Voltmeter (0 – 500V)
iv) A – Bus Ammeter (0 – 100A)
v) V1 – Voltmeter (0 - 500V)
vi) V2 – Voltmeter (0 – 500V)
vii) Hz1 – Frequency meter (f_1)
viii) Hz2 – Frequency meter (f_2) xxvii)
ix) C1 – Contactor 1
x) C2 – Contactor 2
xi) C3 – Contactor 3
xii) C4 – Contactor 4
xiii) CC1 – Coil of C1
xiv) CC2 – Coil of C2
xv) CC3 – Coil of C3
xvi) CC4 – Coil of C4
xvii) CR1 – Coil of Relay 1
xviii) CR2 – Coil of Relay 2
xix) CR3 – Coil of Relay 4
xx) CG1 – Close G1
xxi) OG1 – Open G1
xxii) CG2 – Close G2
xxiii) OG2 – Open G2
xxiv) NOAC4 – Normally open auxiliary contact of C4
xxv) NCAC1 – Normally close auxiliary contact of C1
xxvi) NCAC4 – Normally close auxiliary contact of C4
xxvii) NOAC1 – Normally open auxiliary contact of C1
xxviii) NCAC3 – Normally close auxiliary contact of C3
xxix) NOAC3 – Normally open auxiliary contact of C3
xxx) NOAC2 – Normally open auxiliary contact of C2
xxxi) NOR1 – Normally open of relay 1
xxxii) NOR3 – Normally open of relay 3
xxxiii) NOR2 – Normally open of relay 2
xxxiv) NOR4 – Normally open of relay 4
xxxv) G/R – Green/Red pilot light

Generator one is started first, while generator two is at rest. Current flows through a voltmeter and frequency meter, thus measuring voltage and frequency from the generator one. This also energizes the coil of contactor one CC1 because the normally close contact of NCAC4 is closed, thus closing the normally open contact of NOAC1 and opening the normally closed contact of NCAC1. This, in turn, supplies power to the bus bar via C1. The relay R3 is not energized because NOAC4 remains open. Also, relay R1 is not energized because NCAC1 is open, thus breaking the supply from supplying the synchronizing lamps of generator one. Also, it isolates C2 from operating even when the close button is pushed. Normally, the Open (NO) of relay R2 closes because NOAC1 is closed and NCAC4 remain closed, thereby energizing the coil of relay R2. But Normally, the Open (NO) of R4 remains open since its coil is not energized, thereby cutting off the supply of synchronizing lamps G2 and preventing the supply from G2 which is at rest from the bus voltage.

Starting generator two while generator one is running, it supplies the frequency meter and the voltmeter connected across its terminal, thus measuring the generated voltage and frequency of generator G2; the coil of contactor four CC4 is not energized because the NCAC1 was open. The synchronizing lamp of generator two begins to glow because the NO of R4 is close. The generated power of G2 can be added to the bus by closing C3 through the start button of generator G2. This is done when the conditions for synchronization is fulfilled. The reverse is the case where generator G2 is started first.

A) Design Calculation

The circuit components used/ employed in this design are considered based on the known input signal of the two generators rated 7.5KVA each. However, the circuit comprises the interconnection of circuit elements through which their ratings are considered based on the generated output of each generator.

Considering the design power P = VI

Where V is the design voltage of the single-phase generator (220V), I is the design current.

The design current (I) can be obtained as follows;

design current I,

$$I = \frac{7.5 \text{ x } 1000}{220} = 34.09\ Amp \quad (2)$$

B) Cable Size Selection

The cable used for the construction is a $4mm^2$ cable flex conductor, and the choice was made based on the current design. However, the choice of size/rating of the circuit elements used in this work is made based on the design current /voltage. The approach used in selecting the correct size of components for a particular load condition is recommended by the IEEE regulations based on the overcurrent protective device rating.

C). Design Construction and Packaging

The whole unit was constructed and packaged using an already-made metallic panel, which met the requirements of strength, durability, heat conduction and ease of earthing. Holes were drilled on the sides of the panel to accommodate the fixing of the pilot lamps, voltmeter, frequency meter, and ammeter indicators and to enhance air ventilation for the whole unit. Enough space was given and properly insulated in-between components to avoid short circuits. Also, the fork-shaped connectors were used to adequately terminate cable ends and connect the $4mm^2$ cable flex to the system components.

IV. CONCLUSION

The parallel operation of two generators of 7.5KVA, each connected to a common bus bar, known as synchronization, was successfully achieved using the lamp bright method. The design was carried out in such a way that the synchronizing process could be done either way – either by starting G_1 first or G_2 first. The power generated from paralleled alternators covers large areas of consumers. Therefore, parallel generator operations are necessary to improve power supply quality, continuity of service, production efficiency, and scheduled maintenance. Hence, this system can function when power supplies are erratic and protect equipment and appliances connected to it.

V. RECOMMENDATION

At the end of the project, the following recommendations were made: ensuring that the conditions for the paralleling of alternators are met before synchronization. This enhances the achievement of the synchronizing process. Otherwise, faults may develop as a result of a short circuit.

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