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Design and Construction of Automatic Changeover Switch Using Contactors with Generator Shutdown

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A B S T R A C T

The adverse effects of unstable and unpredictability of public power supply on consumers of the electricity and equipment that are operated from the public power supply of electricity supply in underdeveloped countries is on the increase. Automatic change over switch system is used to ensure continuous supply to load in case the mains supply is disconnected. This Research, design and construction of an automatic change over switch using contactors with generator cut off is an automatic switching mechanism that transfers the consumer loads to a power source from a generator in the case of power failure in the mains supply. It thus holds an important key in the provision of a continuous power supply through an ear seamless switching between the mains supply and an alternative stand by sources like the generator set.

Keywords: Contactor, Relay, Mains supply, Generator, Latch, Electromechanical timer

1. Introduction

Public power supply is a major contributor to economic development in every nation. In developing nations like Nigeria, Ghana, Cote d'Ivoire and underdeveloped parts of the world, the public power supply for industrial, commercial and domestic use is highly unstable (Peter,2012). This has negative effect on the economy in such that most of them had to depend on frequent use of alternative power sources such as generator, inverter, solar to meet up with the energy demands. One of the common alternate sources depended on is the use of generator set which is usually connected to a changeover switch and the public power supply also connected to the switch. The application of alternative sources of power supply is being faced with the challenge of switching smoothly and timely between the mains supply and the generator supply whenever there is power failure on the mains source and vice versa. (Ransorne,2009).

Automatic Changeover switch with generator cut off and starter is one of the electrical devices that can aid smooth switching from public supply to generator and vice versa. It automatically switches from one power source to another. When there is power failure in the public supply it starts the generator and switches to the supply (generator) and it equally switches over to the mains supply when power is restored and turns off the generator automatically. The automatic power changeover switch with generator cut off and starter is a device that links the load and mains supply or the alternative supply together. This enables the use of either the mains supply or an alternative source when there is outage on the mains source without the user intervention. The changeover switch can either come in with three phase or single phase. This device maintains constant power supply to the load by automatically activating the generator when there is need. Since the user might not always be in need of the generator, provision has been made to prevent the generator from starting should an outage occur. Therefore, in view of these considerations, the project is aimed at designing and constructing a workable automatic change-over switch with generator cut off.

2. Literature review

Robert Dowuona (2008) found out that emergency power systems were used as early as World War II on naval ships. In combat, a ship may lose the function of its steam engines which powers the steam-driven turbines for the generator. In such a case, one more diesel engine is used to drive backup generators. Early changeover switches relied on manual operation: two switches would be placed horizontally in line and the "ON" position facing each other, a rod placed in between, in order to operate the changeover switch, one source must be turned off, the rod moved to the other side and the other turned on.

With technological advancement globally, maintaining the power quality and a steady energy supply are the major requirements the electricity consumers need. This is because many electrically powered and voltage-sensitive devices like advanced system control, automation precise manufacturing techniques, continuous data processing require uninterrupted power supply. For some of these devices, a temporary disruption or sudden surge of power

can cause scrambled data, a frozen mouse, interrupted communication system crashes and equipment failures. Consequent upon this, there is urgent need to have alternative power supply to come into operation immediately there is power seizure from the mains power supply. An efficient steady supply of power is therefore of tremendous advantage both in terms of cost and efficiency.

With inadequate power supply base of the nation at the moment, it is almost impossible to supply electricity to consumers at all times. The unreliable public power supply has led many to the alternative power supply sources. In Nigeria today, the use of generators to power businesses and machines have become the norm. According to the Director-General of Centre for Management Development, Dr. Kabir Usman that Nigeria has the highest number of standby generators in Africa, averaging to every 2.5 people has at least one standby generator. He also pointed out that about 60million Nigerians spend 1.6 trillion naira on generators annually. Many generators are in use; while some are manually started others are automatically activated.

To ensure the continuity of power supply, many commercial industrial facilities depend on both utility service and onsite generation (generator set). Due to the growing complexity of electrical systems, it becomes imperative to give attention to power supply reliability and stability. Over the years many approaches have been adopted in configuring changeover systems.

- Manually Controlled Changeover
- Sequential Logic Controlled Changeover
- Microprocessor-based Controlled Changeover

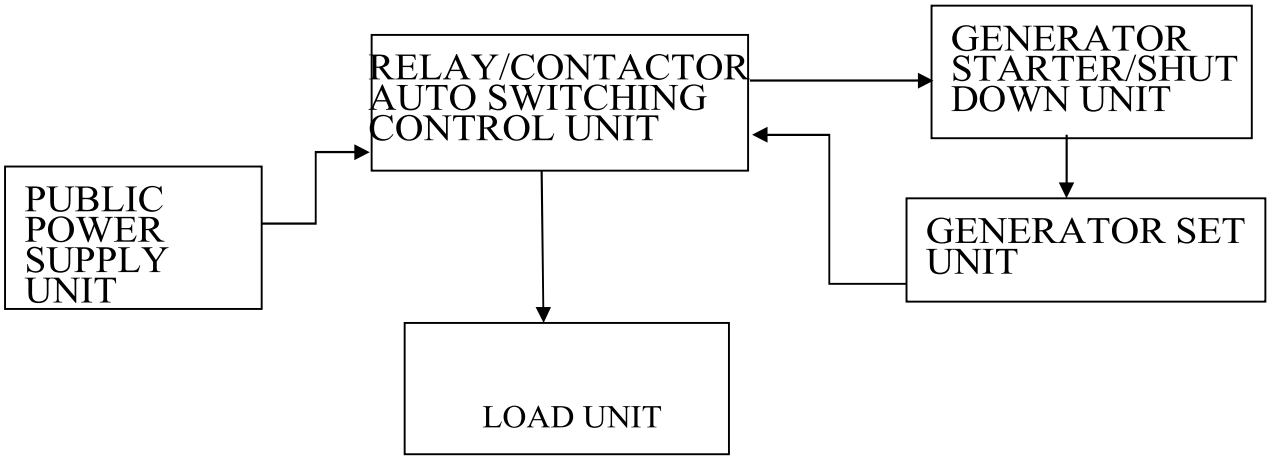
3. Methodology

This study employed a multiple approach system that purely involved the review of existing studies from both online and offline projects on automatic changeover. The data used for this article were systematically reviewed and obtained from the existing academic and industrial based literature to deliver a clear overview of current published research about automatic changeover using contactors. For its core outcomes, discussions, statistics display and knowledge communications, this article explicitly adopts the most recent publications from globally acknowledged organisations and corporations.

4. System Design

Block Diagram of automatic changeover with generator cut-off/starter

The project design is made up of several sub-units which make a whole system. There are five sub-units. The sub-units are represented in form of a block diagram (Figure. 4.1).



The block diagram is made up of several components which are mains power supply unit, generator set unit, generator starter/shut down, relay/contactor auto-switching control unit and load output.

1. Public Power Supply Unit: This is the power supply that comes from public supply (EEDC). It flows into switching control unit through the contactor before passing into the output unit.

2. Generator set Unit: This is the power supply from the generator set which also flows into the switching control unit through another contactor before passing into the output unit.

3. Generator starter/shut down Unit: This is the section of the circuit that controls the starting and shut down of the circuit through the help of relays which switches on the generator when there is power outage from the main with the help of timer and switches off the generator when power is restored.

4. Relay/Contactor auto switching control Unit: This is the unit of the circuit where the main job is done, the contactor receives power from both source at the due time while the relay controls the on and off of the two units by the opening of relays circuit when public power supply is on and closing of it's main is off.

5. Load Unit: This is the unit where the output can be distributed to the load.

4.1 contactor

A contactor is an electromechanical control device that used to make or break the connection between the load and power supply. The use of a contactor is similar to the relay. But the device used for higher current carrying application is known as a contactor and the device used for lower current applications is known as Relay. A contactor has several contacts as per the application and load. Generally, these contacts are normally open (NO) contact. And hence the load is shut off when the coil of the contactor is de-energized. But the contactor can design for both normally open and normally close applications. The most common application of contactor is in the starter that used to turn ON and OFF the equipment like motor, transformer, etc.

A contactor is an electrically controlled switch used for switching a power circuit, similar to a relay except with higher current ratings. A contactor is controlled by a circuit which has a much lower power level than the switched circuit. Contactors are often used for 150 Hp motor. Magnetic contactor is a device or switch which operates magnetically and close or open the electric circuit when needed. A contactor has three main parts;

- Coil or Electromagnet
- Encloser or Frame
- Contacts

Coil or Electromagnet

The coil is wound on electromagnetic core and behaves as an electromagnet. Generally, it has two parts, one is a fixed part and the second is a movable part. A spring is connected between both parts. Hence, there is a spring return arrangement. A rod is connected with the moving part. This rode is also known as an armature. When a force of coil is more than the force of spring, both contacts are connected and when the force of spring is more than the force of the coil, both contacts are extracted with each other. A very small amount of current will flow through the spring from the supply or external control circuit to excite the core of the electromagnet. For AC applications, the electromagnetic core is made up of laminated soft iron to reduce the eddy current. For DC applications, there is no issue of eddy current, the core is made up of solid steel.

Encloser or Frame

The encloser is used to protect the internal parts of the contactor. It is made up of plastic, nylon 6, ceramic, or Bakelite. It provides housing to the electromagnet and contacts. The encloser is used to insulate the contacts and provide protection from the dust, oil, weather, and other explosion hazards. It avoids direct touching of contact when it is powered.

Contacts

This is the only component from which the entire load current will flow. Hence, it is a very important component of the contactor. The contacts are classified as power contact, auxiliary contact, and contact spring. There are two types of power contact; stationary contact and movable contact. The material used for the contacts has stable arc resistance and high welding resistance. These materials must withstand mechanical stress, erosion, and arc. The resistance of this material is as low as possible because the full load current will pass through the contacts. For the low current application, these contacts are made up of silver cadmium oxide and silver nickel and for high current application and DC current, it is made up of silver tin oxide. The armature of the electromagnet is connected with the moving contact. Hence, the moving contact moves with the action of an electromagnet and connect/disconnect with the fixed contact.

Public power supply contactor

Public power supply is the electrical supply from EEDC. Current from here flows into the interlocking relay, it disconnects/interlocks the Generator contactor coil from the Mains. The Timer is energized thereby closing the circuit; it passes through the auxiliary contact of the Generator contactor to the coil of the Mains contactor, which energizes it. It disconnects the coil of the Generator contactor.

Generator contactor

Generator is started when there is phase failure from the mains. Then no current gets to the interlocking relay thereby leaving the relay closed. Current from the timer passes through the auxiliary contact of the Mains contactor to the Generator contactor coil thereby energizing it. It disconnects/interlocks the Mains contactor/supply

4.2. Electromechanical timer.

A timer is a specialized type of clock. A timer can be used to control the sequence of an event or process. Whereas a stopwatch counts upward from zero for measures elapsed time, a timer counts down from a specified time interval, like an hourglass. Timer can be mechanical, electromechanical, electronic

(quartz), or even software as all modern computers including digital timer of one kind or another. When the set period expires some timers simply indicate with an audible signal, while others operate electrical switches, such as a timer switch, which cuts electrical power.

The electromechanical timer thus gives the required delay the generator needs before load is been transferred to it and also a delay when public power supply comes on before shutting down the generator. Their operating voltage is 220—240Vac

5. Mode of operation

The control provides an Automatic Transfer Switch function, that monitors the incoming AC mains (utility) supply and in the case of a Mains failure, the control instructs the Generator to start and take - up the Load. When the mains supply returns within limits, the control, after a configurable stabilization time period, will transfer the load back to the mains. The Generator is then requested to stop after a predetermined cool-down period. Simple operation is provided via a two-way key switch located on the panel; Auto Mode and manual Mode. When there is power public utility power supply, contactor KN which is the power public utility contactor energized and its auxiliary contacts NC become open while NO of KN closes. The generator contactor KG which is energized by the generator, is interlocked with the NC of the public utility power supply (KN) contactor. This enables the supply from the generator and public power utility not to jam, which will lead to spark or fire break and damaging of electrical gadgets. Also, a timer is included in the circuit which helps to switch off the generator whenever there is public power supply through the contactor pin outs 7 and 2 which is the coil of contacts of the contactor. Pin 8 and 6 are the normally open (NO) of the mechanical timer which closes when there is public utility power supply thereby shutting down the generator and when the public power utility goes out, the contacts open thereby causing the generator to be in ON switching mode.

When the public power utility goes out, then NC of KN closes and when the generator starts running, generator contactor (KG) becomes energized and it closes, causing power to flow through it to the Mains. And when there is public utility power supply, the electromechanical timer becomes energized. The electromechanically timer helps to cause a delay when the public utility power supply comes ON. This is to determine if it was a flash from the public utility power supply before causing the generator to shut down.

25Amps circuit breakers were included in the circuit in other to serve as a protective device and also as a switch when the user wants only the public utility power supply or generator only.

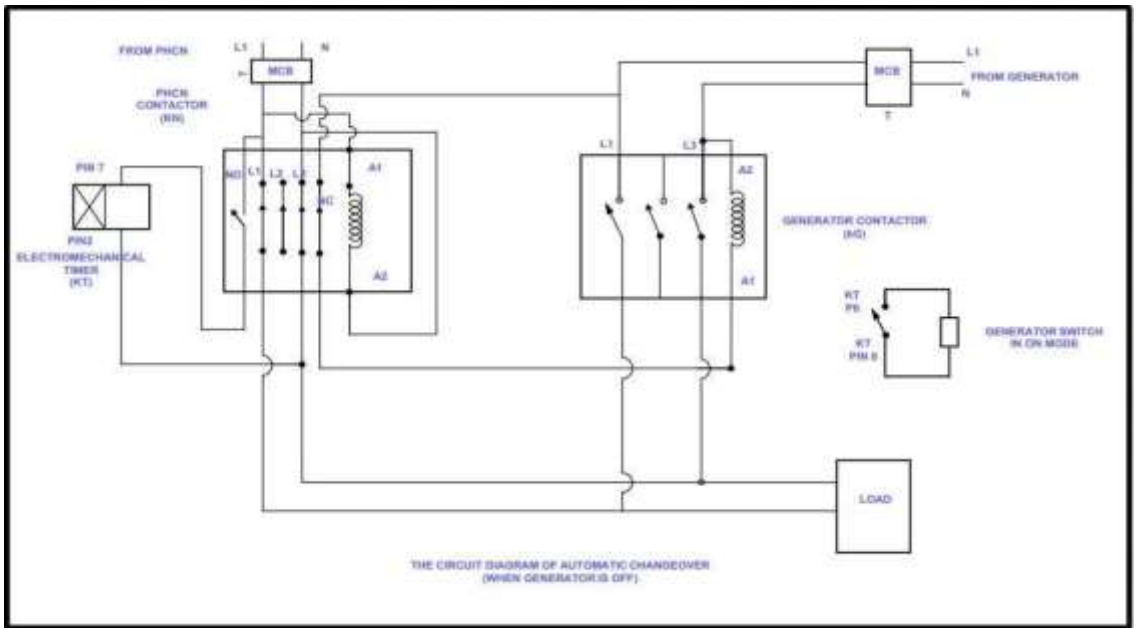


Figure. 2 – Circuit diagram of automatic changeover using contactors

5.1. Choosing a contactor

In choosing the contactors to be used, the running currents would be considered. With the input voltage from either power sources,

V=220---240Va.c supply

Generator power rating (p) =5.5kva

Assuming power factor (cos θ) = unity

Rated generator set current (I) in Ampere = (Power in kva * 1000) / operating voltage = (5.5 * 1000) / 220 = 25A.

The full load current is 25A. At starting, current is passed through the Mains or Generator contactor to the load. The contactor to be used must have a rating higher than 25Amps.A contactor of 30Amps is selected for the Mains and Generator contactors. .

5.2. Choosing Copper Conductor

There are a variety of cables available in the market in various sizes. However, to decide which size will be appropriate for this application, an Electrical Cable Size Calculator is required. It helps you understand the best fit size for your requirement. It is calculated against IEC and British standards. A power factor of 0.8 is used in calculating the kilowatt.

To calculate the cable sizing, one needs to divide the voltage running through the cable by the target current.

Electrical cable size calculation formula is tedious and complicated hence we get you the simplest way to calculate the size appropriate for your application. We use the Bs7671 Cable Sizing method to calculate the size which is the British standard for the current carrying capacity of single core armoured XLPE insulated copper cable. Recommended cables sizes are based upon information given by user and are intended to use as guide only. Above calculation is derived from BS7671 Requirements for IEE Wiring Regulations, Installation method C, for cable types BS5467 and BS6724 and is based on voltage drop selected at 230 and 400 volts

Since we are looking at 30amps, we choose the size of cable within the range of 30amp. The size of cable within that range according to the table is 2.5mm^2 copper cable within C clipped direct. Below is the table;

Table 1- Cable sizes and ampere rating

	Cross-sectional area in mm^2						
Installation reference method	1.0	1.5	2.5	4	6	10	16
C Clipped direct	16	20	27	37	47	64	85
B Enclosed in conduit or trunking on a wall (from table 4D2A of BS7671)	13	16.5	23	30	38	52	69
100 In contact with plasterboard ceiling or joists covered by thermal insulation not exceeding 100mm	13	16	21	27	34	45	57
102 In a stud wall with thermal insulation with cable touching the wall	13	16	21	27	35	47	63
A Enclosed in conduit in an insulated wall	11.5	14.5	20	26	32	44	57
101 In contact with plasterboard ceiling or joists ceiling covered by thermal insulation exceeding 100mm	10.5	13	17	22	27	36	46
103 Surrounded by thermal insulation including in a stud wall with thermal insulation with cable not touching a wall	8	10	13.5	17.5	23.5	32	42.5

Table 1- Cable size and ampere rating table

4.3. Legend of the circuit diagram

COMPONENT	ABREVIATION
Mains Contactors	KN
Generator Contactor	KG
On Delay Timer	KT
Miniature circuit breaker	MCB
Generator indicating light	H2
Phase of electrical power	LI

Table 2- Legend of the diagram

6. RESULTS

The control circuit of the Automatic change-over switch was tested on a single-phase supply by connecting wires from the mains to both the mains and generator contactors. It was observed that when the MCB N switch is in the ON position, the mains contactor was energized immediately. When the MCB N was turned to the OFF position representing mains failure, the generator contactor was energized. When mains were restored by switching the mains selector switch back ON, the mains contactor was immediately energized again. A situation was created for the mains lost, causing a failure to occur, hence de-energized the mains contactor and energizes the generator contactor. During normal operation, automatic change-over switch supplies load from mains. When the mains fail, a generator start signal is given automatically.

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