DESIGN AND CONSTRUCTION OF A THREE PHASE AUTOMATIC CHANGEOVER SWITCH WITH VOLTAGE RELAY

BY

OWOEYE ADEDAYO. E.

98/7195EE

A THESIS SUBMITTED

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NOVEMBER 2004

CERTIFICATION

This is to certify that I have supervised, read and approved this project report undertaken by OWOEYE ADEDAYO EMMANUEL with MAT NO 98/7195EE for the partial fulfillment of the requirement for the award of Bachelor in Engineering (B. Eng) in Electrical/Computer Engineering and has been presented in accordance with the regulations governing the preparation and presentation of project in Federal University of Technology, Minna.

....	9th Dec, 2004
ENGR P.O ATTAH PROJECT SUPERVISOR	DATE
....	31/01/2005
ENGR ABDULLAHI HEAD OF DEPARTMENT	DATE
....	....
EXTERNAL SUPERVISOR	DATE

DECLARATION

I, OWOEYE ADEDAYO EMMANUEL hereby declare that this project to my knowledge is solely the result of my work and has never been submitted anywhere for the award of Bachelor Degree in Engineering.

DEDICATION

This piece of work is dedicated to the Triune God. God the father. God the Son and God the Holy Spirit the source of my inspiration.

ACKNOWLEDGEMENT

I give thanks to the almighty God who spared my life and see me through this work. To Him I ascribe all glory, honour and majesty.

My profound gratitude goes to my able supervisor, Engr. P.O. Attah who took pain to go over this work, corrected and guided me despite his busy schedules. I am glad to be his student.

I am very much indebted to my uncle Mr. Lucas Komolafe who has always been there for me, supporting me morally, financially and spiritually. I cannot thank you enough.

My unreserved gratitude also goes to Mr. J. O. Onifade who laboured day and night to ensure that this work is a reality

I also appreciate the effort of my mother Mrs. Mary Owoeye, for her care and support both financially and spiritually.

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ABSTRACT

This project entails the design and construction of a Three phase automatic changeover switch with voltage relays. The auto-changeover unit was designed to automatically switch from a main to a standby power supply (generator). To feed a common load in the event of loss of the mains supply source. The internally mounted components comprise of electrically interlocked 8-pole heavy duty contactors, together with a single solid neutral link, voltage relays, phase sensing unit and two control 3-phase ganged circuit breakers. The unit operates by continually monitoring the mains supply whereby the mains contact de-energizes, the changeover circuit automatically closes the standby contactor on the assumption that the alternative supply is available. Upon restoration of the mains supply, the standby contactor automatically drops out and the mains supply contactor recluses restoring the mains supply to the load.

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CHAPTER ONE

1.1 INTRODUCTION

The importance of electricity to mankind cannot be over-emphasized. Electricity has become so indispensable to man to the extent that its outage creates great inconvenience to his existence. The power sector of a nation has immense impact on its economic growth, thus no industrial development can take place without a steady and reliable power supply, not to mention economic losses and inconveniences. The use of electricity covers every sphere of human endeavour ranging from domestic use to commercial and industrial use.

However, in spite of the great uses of electricity to man, power supply is not without the problem of incessant outages. These power outages are usually accompanied by the danger to the life of humans, enormous damage to the economy, stoppage of complex engineering processes, massive non-production of products, disturbance of normal living condition of the people etc. In view of these, the need for a generator set as an alternative power source now arises to augment the utility supply. The generator may be switched ON either manually or automatically in the event of power failure from the utility supply. Switching the generator set manually however requires human effort, energy and time wasting especially if the generator set is located some distance away from the load.

From the McGraw Hill dictionary of science and technical terms, a changeover switch is defined as "A means of moving a circuit from one set of connection to another". From the above definition, an automatic changeover switch can be said to be a switch that ensures the automatic re -closure of the circuit having its source from the generator in the event of power failure from the utility supply and closes back to the mains when the utility supply is restored.

This project work showcase the design and construction of an automatic changeover switch that incorporate both manual and automatic means of switching ON and OFF of the generator set and with the view that it will be readily compatible with highly rated generator by merely replacing the contactors and circuit breakers that makeup the plant with highly rated values and will find its use in both domestic and industrial application. The project also explains the details of operation of the changeover circuit and other associated circuitry.

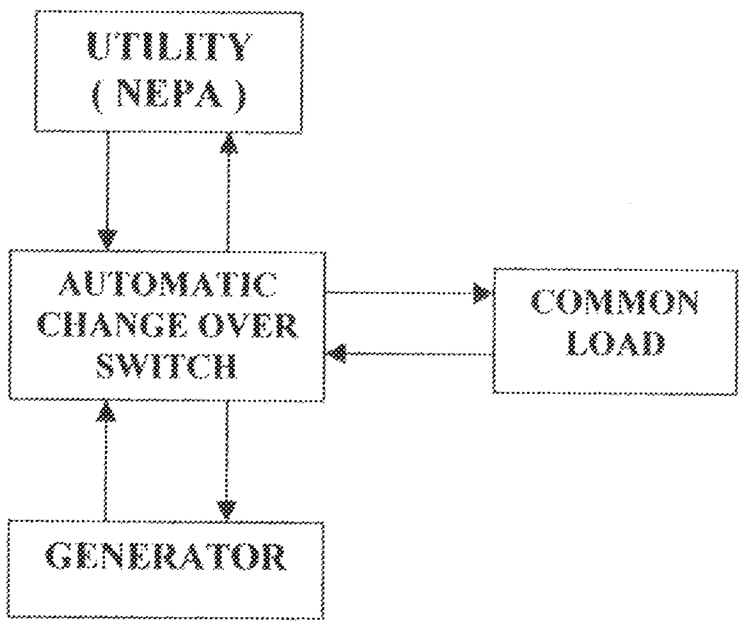

Fig. 1.1 Block Diagram Showing The Connections Of The Changeover Switch.

1.2 PROJECT OBJECTIVES / MOTIVATION

The aim of this project is to ensure constant and adequate power supply to load in which outage of power may result in great loss to the consumers.This is done by connecting the unit between the utility supply and a standby generator. The changeover system determines which of the power source is feed to the load.

1.3 LITERATURE REVIEW

Man in his quest for a steady power supply invented on alternative means of generating power (i.e. generator set). This breakthrough was immediately followed by the problem of interfacing the generator set with the existing utility supply for optimum efficiency, then came the initiative of a switch called "changeover switch" which will permit switching to the generator set when the utility supply fails and switch back to the utility supply whenever it is restored.

Many different models of changeover switch have existed since the advent of modern technology ranging from the manual type to the automatic types; others are built within the generator set. The manual types consist of changeover switch box, switchgear and cutout. The changeover switch box is used to isolate the mains while making contact with the generator circuit and vice versa. This type of changeover switch requires a lot of energy and it is time wasting since an operator will have to be operating the switch gear lever as dictated by the utility supply.

The generator inbuilt types have been made to be compatible with the generator specifications so that at any instance of failure of the utility supply the generator automatically comes ON. A recent visit to Shiroro Hydroelectric Power Station gave the opportunity to see the automatic changeover system used to switch ON a 200MVA **BLACK START** generator in the event of failure of the turbine driven generator or low voltage output of any of the three phases (3-ϕ) of the power transformer. This changeover switch uses giant contactors and relays for switching and sensing. The contactors have very high contact current rating and thus contain built-in arc chutes that suppress the arc generated during contact breaking.

The high cost of contactors that is directly proportional to its contact rating had limited the desire to design and construct a high power rated changeover switch. This project work has a power rating of 2.2 KVA and can carry a maximum load of 10A.

CHAPTER TWO

2.1 SYSTEM ANALYSES AND CIRCUIT OPERATION

This project work was design and constructed with readily available components with the aim that it will be compactable with any generator using 12V battery. It is made up of four different units namely the Plant (NEPA &Generator Unit), the controller (Voltage relay & Phase sensing Unit), the ignition unit and a common load. The block diagram shown below shows the relationship between the respective units

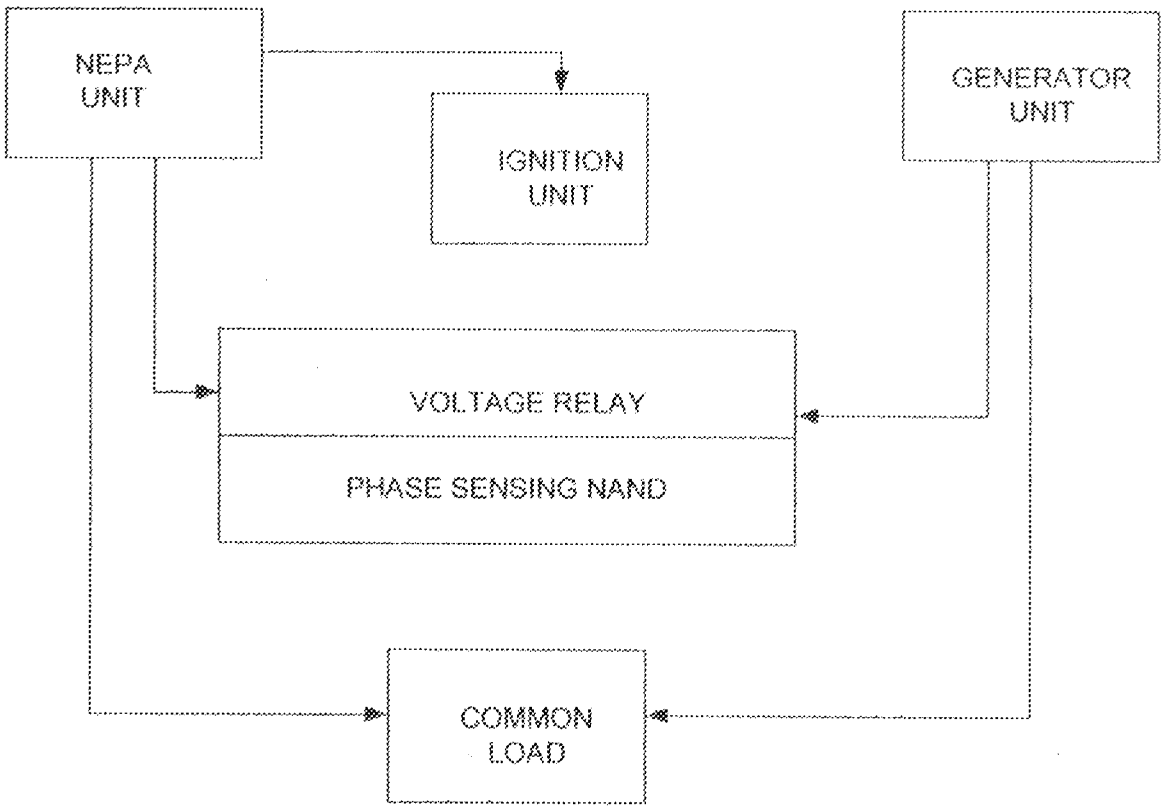

Fig 2.1 Block Diagram Of The Changeover Switch

2.2 POWER SUPPLY UNIT

The power supply unit comprises of an A.C rectifier circuit. It serves as the main source of power to the voltage relay circuit, the bridge rectifier is a full wave rectifier. Diode D_1

and D_2 conduct on the positive half circles while D_3 and D_4 conduct on the negative half circles, as a result rectified load current flows during both circles.

The 240V A.C mains tapped from the red phase and neutral was stepped down using a 220V/12V-0-12V step down transformer and then rectified using four diode mounted in full wave bridge rectification format. The transformer used was a center tap transformer but the output voltage was tapped in order to obtain a peak-to-peak voltage of 24V to power the voltage relay circuit, a 1000uf of 100V capacitor was used to smoothen the output voltage, which was pulsating. The combination of the resistor and the capacitor forms a smoothen network.

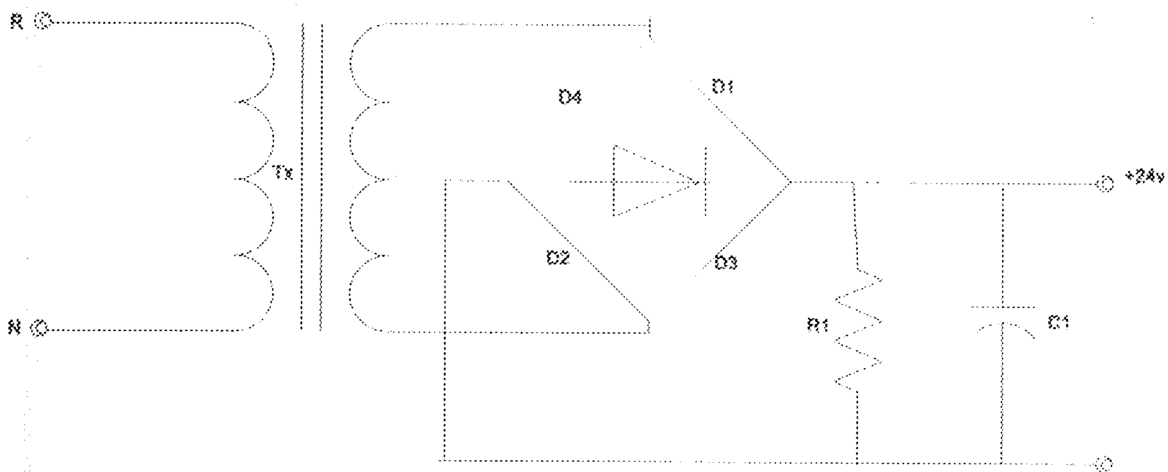

Fig 2.2 Power Supply Unit

2.3 THE VOLTAGE RELAY UNIT

The voltage relay circuits comprises of discrete electronic components and general purpose relays, these relay were used in the circuit to indicate both over voltage and under voltage situations. They are basically mechanical switch operated by magnetic coil incorporating plug-in features that make for quick replacement and simple troubleshooting The voltage relay circuit serves as a protecting circuit to the load incase of over voltage and under voltage from the mains. The circuit was connected across the red phase for both the mains and the generator output.

The voltage relay circuit was powered through the 24V regulated power supply. At normal voltage, the variable resistor was adjusted in order to allow enough voltage to bias the transistor on. The transistor switches ON and pull a large collector current Ic thereby energizing relay RLY_1.At a voltage less than the normal voltage, the transistor is OFF thus relay RLY_1 is de-energized and at a voltage above the normal range, relay RLY_2 become energized to indicate over voltage situation. Resistor R_2 is for simulation purpose to demonstrate over voltage and under voltage situations.

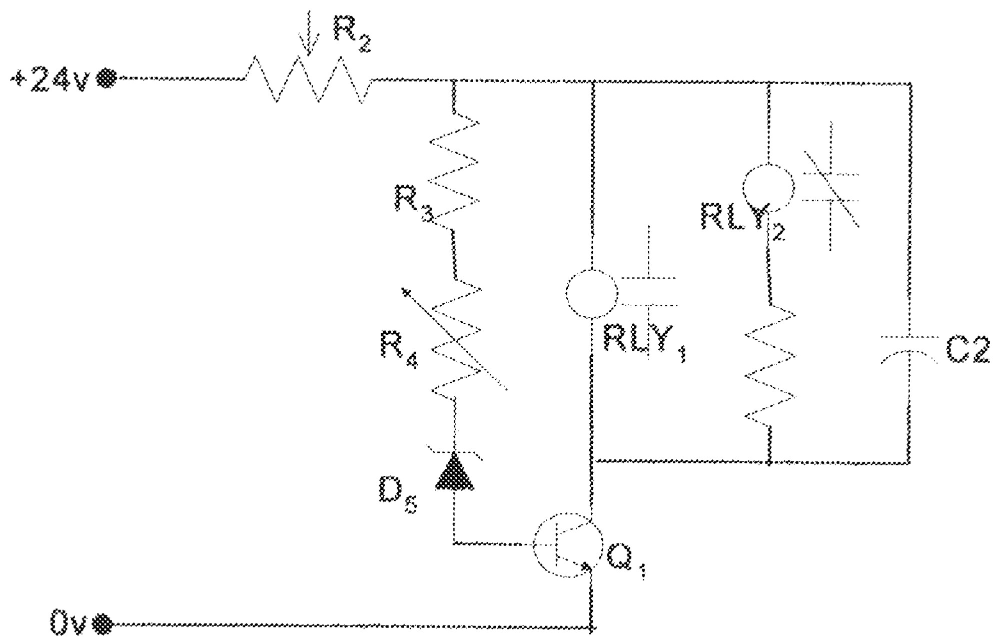

Fig 2.3 Voltage Relay Unit

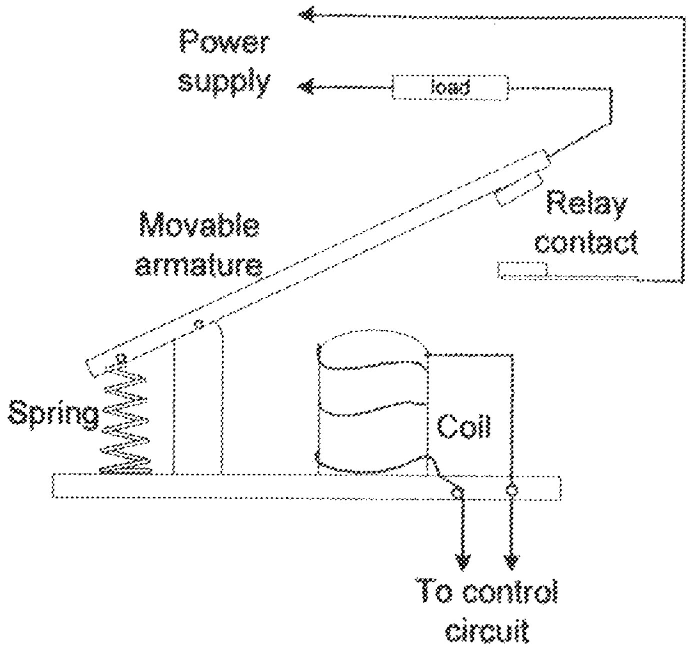

Fig 2.4 General Purpose Relay

2.4 NAND PHASE SENSING UNIT

The phase sensing circuit comprises of three (3) 220V, 10A a.c relays ($A_1A_2A_3$) connected as shown in the figure below. At normal voltage, relay RLY1 becomes energized and its normally open contact (NO) close, relay A1 become energized this lead to the closing of its normally open (NO) contacts 1 and 4 thereby energizing relay A_2.at the same instance the normally open (NO) contacts 1and 4 of relay A_2 closes to energize relay A_3.with the three relay on, the phase sensing unit is able to detect the availability of power supply along the three (3) phases. The three situations that can de-energize the relay $A_1A_2A_3$ are power failure from the mains, over voltage and under voltage, which are all interpreted as power failure from the mains. The phase sensing circuit along the mains forms a NAND gate with respect to the generator. The truth table is given in Table 2.1

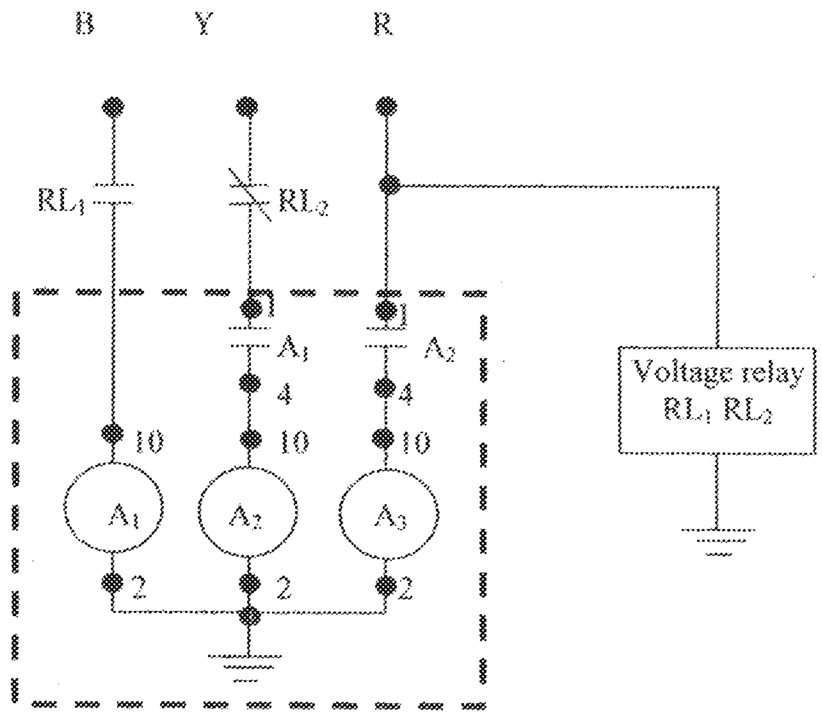

Fig 2.5 NAND Phase Sensing Unit

Table 2.1 Truth Table Of The Mains Input Wrt Generator

Input (mains) $A_1A_2A_3$	Output (generator)
0 0 0	1
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	0

2.5 THE IGNITION, START-STOP UNIT

The ignition, start- stop unit is used to start up the generator, keep it in ignition and shut it down when there is power failure from the mains. The circuit has three (3) selections position i.e. the manual, off and Auto position as shown in the figure below.

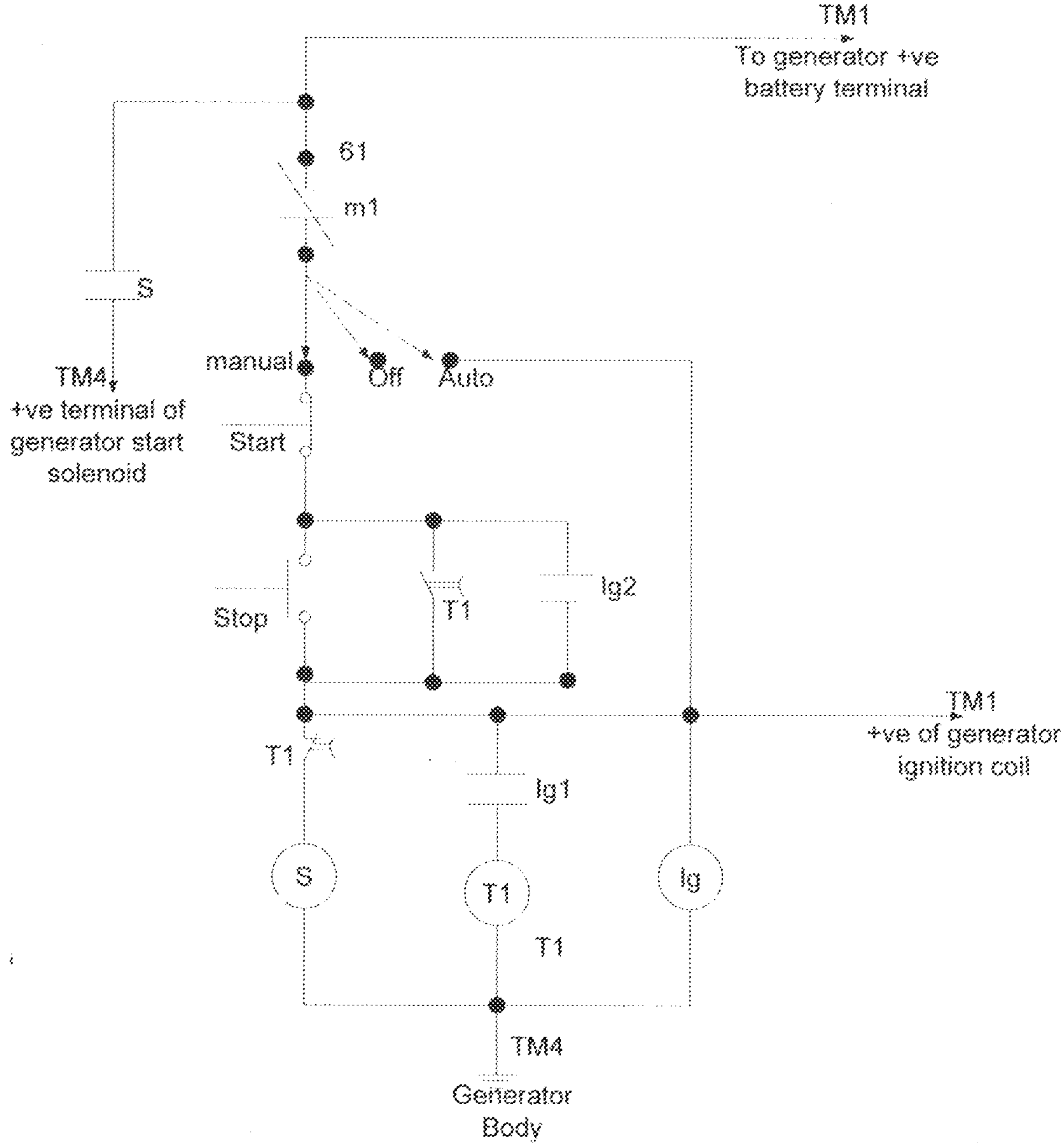

Fig2.6 The Ignition, Start- Stop Unit

When the selector switch is in the manual portion and the mains is not available. The normally closed contact m_1 of contactor M remains closed connecting the positive terminal of the battery to the ignition circuit.

Depressing the start button completes the circuit to initiate the ignition relay. The initiation of the ignition relay energizes the timer relay T_1 and the start solenoid S which in turn engage the generator start solenoid to start up the generator .The generator is started within the period preset by the Timer T_1 to timeout (in this case 2 seconds) after which the start solenoid S de-energize to disengage the generator start solenoid.

In the off position, the generator is temporarily out of use. In the Auto position, provided the main is not available, the generator automatically comes ON. This automatic switching is made possible by the contact m_1, which opens and closes on the availability and unavailability of the mains respectively. As soon as the main is restored, the contact m_1 opens to shut down the generator.

2.5.1 STARTING SYSTEM

The operation of the start solenoid of the ignition start-stop unit causes the contact S to close, the current is then directed to the cranking motor of the starter from the battery. The motor is provided with a pinion, which is made to mesh with a larger gear intergral with the flywheel of the engine. The electric current is completed through earth terminals, thus making the Crankshaft of the engine to rotate until the engine start. Once the engine starts, the automatic device in the starter pinion disconnect the pinion from the flywheel as soon as the starting switch S is switched off as determine by the timer T1 of the ignition unit

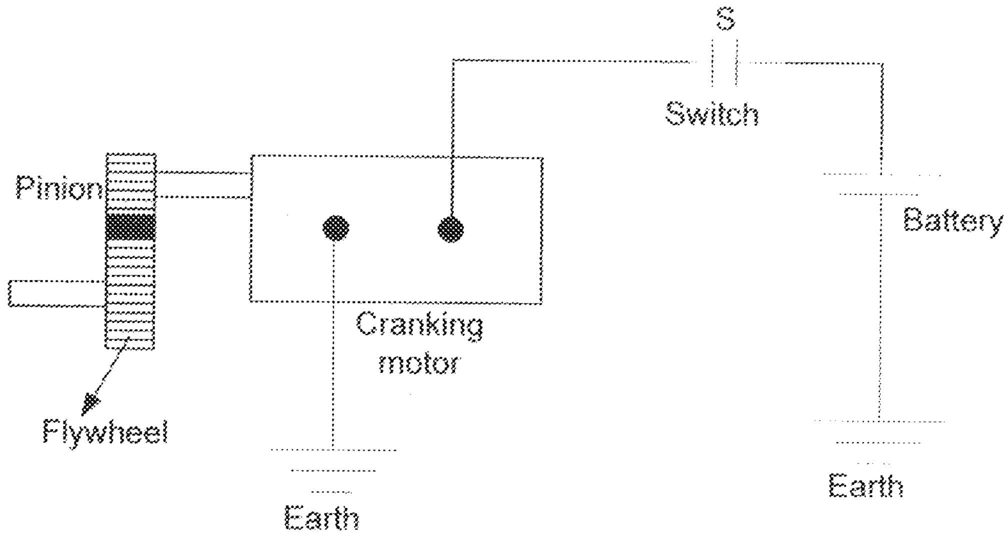

Fig 2.7 Starting System

2.5.2 IGNITION SYSTEM

The ignition system plays an important role in the operation of petrol engines. It provide a high voltage surges from 4000 to 20000V at accurately timed intervals for the purpose of igniting the mixture of petrol and air compressed inside the Cylinders of the Engine.

In this project, a 12V ignition system was adopted. During Cranking, the ignition system impresses full battery voltage on the ignition coil for good engine performance. Once the generator has started, the ignition remains in the ON position to keep the generator running. The electric ignition system is not deployed by diesel engine since the air temperature is sufficient at the end of the compression stroke to cause burning of the fuel when the fuel which is injected at that time.

2.6 THE TIMERS

Both ac and dc timers were employed in this project to achieve the necessary timing operations. They are solid state (electronic based) timers with built-in solid-state electronics such as resistance/capacitance (RC) network along with transistors and silicon-controlled rectifier (SCR) to provide the time delay and switching characteristics

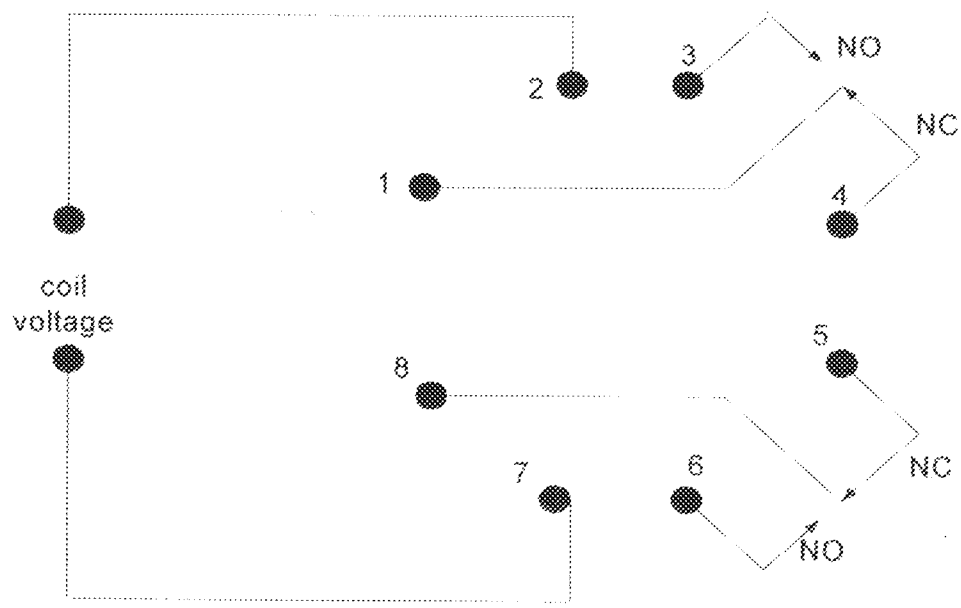

Fig 2.8 Timer Pin Arrangement

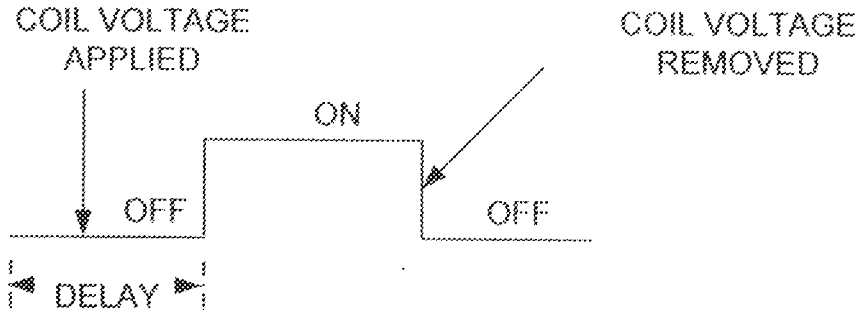

Fig 2.9 Timing Graph

2.7 THE CHANGE OVER UNIT

Figure 2.9 shows the change over circuit of the system. When all the three phases are adequate and available, the contactor M is energized to supply power the load. In the event of power failure from the mains, the auxiliary contact m_2 of contactor M performs the change over action thus the load is now connected the output of contactor Z of the generator circuit assuming the generator is now fully running.

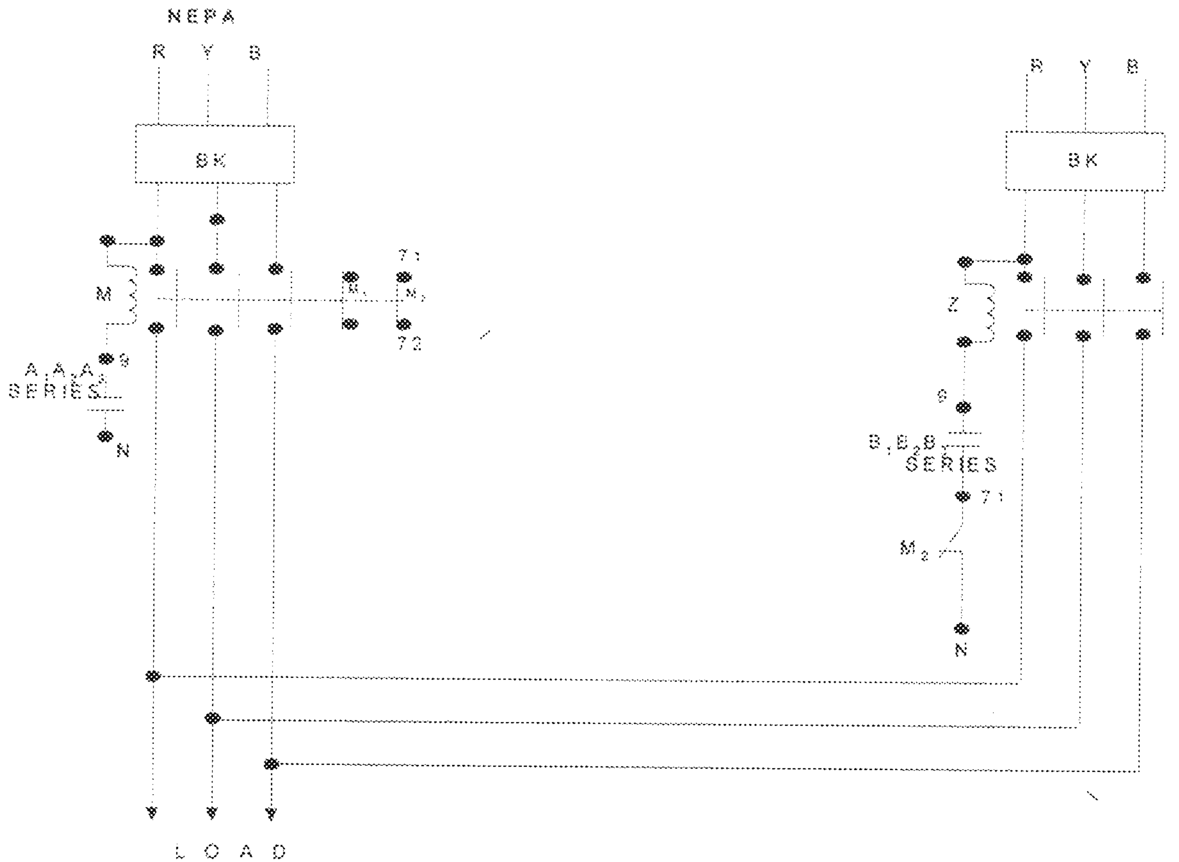

Fig 2.9 The Changeover Circuit

2.8 DESIGN CALCULATIONS

Voltage relay design calculations

The AC relay used for the phase sensing circuit has the following specifications.

Contact rating 10A,

Normal Voltage 220V,

Pickup Voltage 190V,

Drop off Voltage 150V,

Coil Resistance 6.86KΩ

From $Vn = IcRc$ 2.1

Where

Vn = Normal voltage

Ic = Coil current

Rc = Coil resistance

Therefore the coil current = Normal Voltage / Coil Resistance

= 220V / 6.86KΩ

= 32mA

The miniature relay used has a contact rating of 5A and a voltage of 12Vdc.

Equivalent AC current of the miniature relay is given by this relation.

$P_{mr} = P_{pr}$ 2.2

Where

P_{mr} = power of miniature relay

P_{pr} = power of ac relay

$I_{mr}V_{mr} = I_{pr}V_{pr}$ 2.3

5A X 12V dc = 240V X I_{mr}

I_{mr} = (5A X 12Vdc) / 240

= 272mA.

This current value (272mA) is more than the 32mA coil current needed to energize the AC relays of the phase sensing circuit. Thus, a 5A 12Vdc miniature relay is adequate for use in the voltage relay circuit.

2.9 PRINCIPLE OF OPERATION

The principle of operation of the Automatic change over switch can be divided into three main units as follows;

[a] The switching circuit

[b] The Controller

[c] The Change over unit [Plant].

2.9.1 THE SWITCHING CIRCUIT

The switching circuit [Ignition start-stop circuit] start-up the generator and keep it in ignition in the event of power outage from the mains, it also shut down the generator as soon as the mains is restored. Details are given in page ten of this report.

2.9.2 THE CONTROLLER

The Controlling unit consists of the voltage relays and the phase sensing circuits, they serves as the decision maker for the changeover circuit. The controller ensures the adequacy and availability of the supply voltages across the three phases for both the mains and the generator to determine which input supply to be loaded. The acknowledgement of he desired voltage supply by the controllers sends signal to the plant to operate.

2.9.3 THE PLANT

The plant is basically the changeover unit made up of two power contactors [M and Z] for the mains and generator output respectively and the timer T_1 and two Breakers. The contact m_2 of M permits the automatic switching as dictated by the controllers. If the three phases of the mains are adequate and available, contactor M supply the load isolating the generator circuit through contact m_2, which is normally close. A phase failure de-energizes contactor M, contact m_2 returns back to its normally close condition to energize Timer T_1 which begins timing immediately. The timer timeout after 5 seconds thereby energizing contactor Z. Thus the load is connected to the output of the generator, the restoration of the complete phase of the mains returns the load back to the mains.

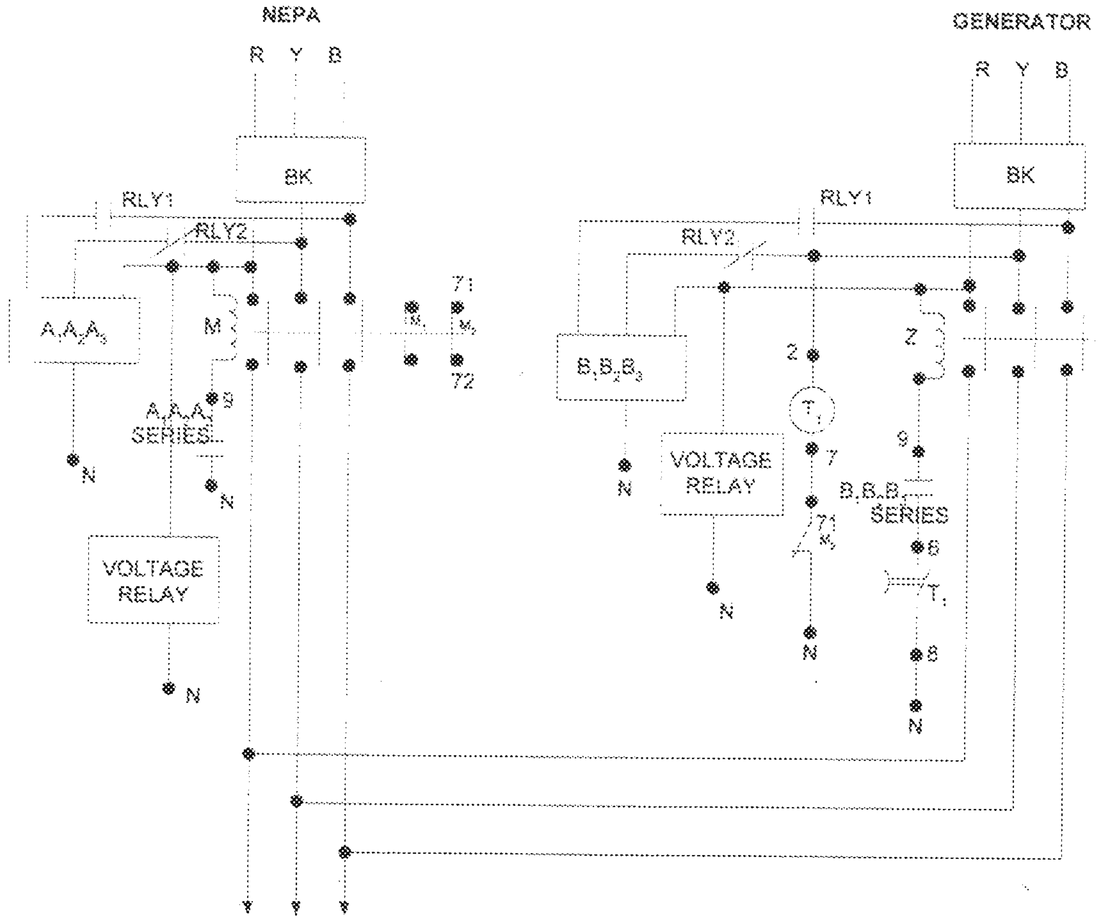

Fig 3.0. Schematic Diagram Of A Three Phase Automatic Change Over Switch With Voltage Relay.

CHAPTER THREE

CONSTRUCTION, TESTING AND RESULT

3.1 CONSTRUCTION

The circuitry of fig 3.0 was constructed in modules. The first module constructed was the voltage relay circuit. the components that makeup the circuit were connected together using the Vero board and connecting wires was used to link joints together. Joints were also soldered for proper connection and firmness.

The second stage is the construction of the plant (changeover circuit) and the controller unit (i.e. phase sensing unit). Other necessary interconnections between sub circuits were also carried out during this stage. Appropriate cables were used to achieve the circuit wiring, the plant contactors were then interlocked electrically to achieve the automatic switching, and the third stage is the construction of the ignition start-stop circuit. Finally, the whole modules were integrated to obtain the desired design. All connections made were terminated using cable connectors

3.2 THE CASING UNIT

The casing of the project is made of flat metal sheet. It has a rectangular shape of dimension (47 X 28 X 18) cm. It has a cover that permit opening and closing in hinges. Holes of appropriate dimension were drilled on the surface of the cover and side of the casing to accommodate the indicator lamps, switches, knobs and power cable. Flat metal bars of length equal to the breath of the casing were brazed across the casing. Other joints were also brazed together and then sprayed to beatify.

Racks of appropriate length were fastened to the flat metal bars using tapping screws. All the components used were then slide into position through their slot on the racks. Other electronic cards were fastened to the base of the casing using tapping screws. The final wiring was carried out inside the casing to form a complete unit.

3.3 TESTING

The first unit that was tested is the ignition start-stop circuit. It was first tested using a 12V dc battery as the generator battery. The test gave the desired results. The ignition circuit was thereafter tested using a motor car with terminal TM_1, TM_2, TM_3 and TM_4 connected to the battery positive terminal, ignition coil positive terminal, the battery negative terminal and the start solenoid positive terminal of the car respectively and the selection switch was set to the manual position. Depressing the start push button then starts the car.

Secondly, the changeover switch was tested using a single-phase main supply since there was no generator. This single phase mains supply was looped into the three phases of the two breakers, possible phase failures were then demonstrated and the action of the unit was noted.

3.4 RESULTS AND ANALYSIS OF RESULT

During the testing of the ignition start-stop circuit, it was observed that it took approximately two seconds to engage and disengage the start solenoid as preset by the Timer T_2. The voltage across terminal TM_4 and TM_3 were measured to be 11.92V dc, which is reasonable enough. This voltage is necessary to start the generator and then keep it ignition. These results were obtained for both the manual and automatic operation of the generator. The starting of a car using the ignition circuit is also an indication that the unit can operate any generator using a 12V dc battery.

The over voltage and under voltage levels are

Over Voltage 250V AC

Under Voltage 170V AC

The change over system also operates as desired with a loading delay time of 5 Seconds.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

The construction and testing of this project work was successfully carried out, appropriate corrections and adjustments were made to ensure that the device works as desired and the expected results were afterward obtained.

The testing of the unit with a vehicle prove that this project work will operate a generator set using 12V dc Battery efficiently. The problem encountered during this project work was in getting a dc relays with the required number of contacts.

In conclusion, the aim and objective for which this project was carried out was achieved.

4.2 RECOMMENDATION

I strongly recommend that this project should be improved on to carry higher power ratings. This can be done by replacing the plant (contactors and breakers) with the required ratings.

Also, any student or person intending to carry out this project in future should have sound knowledge on the principles of operation of relays, contactors and Timers. I also recommend that the phase sensing NAND circuit should be miniaturized.

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APPENDIX I

List of components.

Tx = 230/12-0-12v Transformer

D_1-D_4 = PBS2066 Bridge Rectifier

C_1 = 100uf, 35v Capacitor.

C_2 = 68uf 160v Capacitor.

R_1 = 200 Resistor

R_2 = .5Ω Resistor.

R_3 = .5Ωk Resistor.

R_4 = 5Ωk Resistor.

R_5 = 1.2Ωk Resistor

Q_1 = Transistor TIP31C

RLY_1&RLY_2 = 12v, 5A Miniature relay.

A1-A3&B1-B3 = 220v, 10A AC relays

SW1&SW2 = Industrial Pushbuttons

S&Ig = 12v, 10A Miniature relays

T_1 = 12v DC Timer

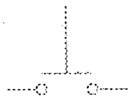
T_2 = 220v AC Timer

Bk = Three phase ganged Breaker

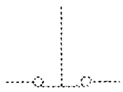
M&Z = 220v, 10A Contactors

APPENDIX II

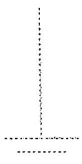
Electrical Symbols



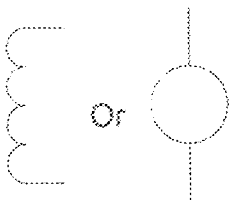
Pushbutton
make



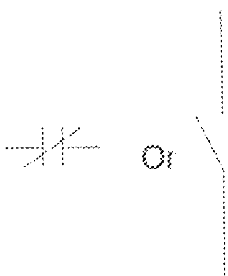
Pushbutton
break



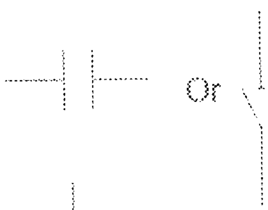
Earth



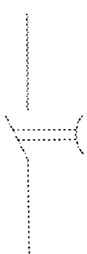
Solenoid/Coil



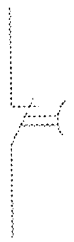
Normally close
contact



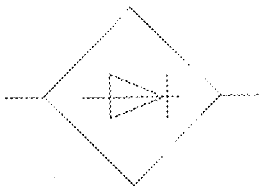
Normally open
contact



Time dependent contact
(Normally open)



Time dependent contact
(Normally close)



Bridge rectifier