DESIGN AND CONSTRUCTION OF AN AUTOMATIC TRANSFER SWITCH FOR A SINGLE PHASE POWER GENERATOR.

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ABSTRACT

An Automatic Transfer Switch (ATS) for a single phase power generator has been designed to enable the automatic operation and transfer of power supply between a public utility supply and a power generator. The ATS, which is a switchgear control system, provides a functional system that provides an automatic switching of power supply between a primary source (public utility) and a secondary power source (generator). The methods employed in designing the ATS involve the use of electromechanical type relays, contactors, voltage monitoring relays and delay timer relays as main components of the system. Incorporated in the ATS is a digital multimeter (DMM) made up of a 12V d.c and a 5V d.c power supply unit, precision rectifier unit, current transformer and Microcontroller (PIC 16F877) to convert the measured analogue alternating current(a.c). voltage and current quantities to digital values for display on the liquid crystal display (LCD). The result of the automatic transfer switch demonstrates its ability to perform automatic power change over activities easily and with little or no human interaction.

Keywords: *automatic switching, automatic transfer switch, delay timer relays, public utility supply, switch gear.*

1. INTRODUCTION

The poor state of power supply in developing countries, calls for alternatives sources of power generation and automation of electrical power generation to back up the utility supply. Over time, automation of electrical power supply has become so vital as the rate of power outage is predominantly high [1]. As a result of this power outage, developing countries like Nigeria, experience slow development processes in both the public and private sectors of their economy. Investors from foreign lands do not feel secure to come and set up business or industries - in spite of the large market made available in such populated nations, because of frequent power failures experienced. In addition, delicate processes and operations such as surgery cases in hospitals, transfer of money between banks, data and information transfer at data centers, require constant power supply in order to prevent the loss of life or data resources which could be very expensive to business operations.

Therefore, it is for these reasons that change over or transfer switches were developed. Initially, these switches were designed for manual operations, but with an increase in the technological advancement of electrical power control and automation that, Automatic transfer switches (ATS) were created. It eliminates the element of manpower interaction in starting a generator and changing power supply from one source to another.

An Automatic transfer switch (ATS) is an electrical/electronic switch that senses when the mains or public utility supply is interrupted and automatically starts up a secondary supply (i.e. a generator) if the utility remains unavailable. ATS also known as “Generator Transfer Switches, has an additional circuit component which is normally in the form of a computer that monitors the incoming power supply. This circuit according to Silva and Kolo [2-3], also monitors the voltage sags, power surges, power spikes, or brownouts. It also initiates the changeover action when there is a complete power loss. Whenever a fault is been detected, the automatic transfer switch starts up the emergency power supply. The ATS is connected to both power supply sources and supplies the load with power from only one of the sources at any particular instant in time.

In contrast to the manual change-over switch system that requires manual stress in starting the generator and switching over from public supply to generator and vice-versa, that, the need to develop a system that will effectively manage power supply between two sources (utility and a standby power generator) therefore influenced the motivation for this project work.

According to [4] and [5], all automatic transfer switches for generators consist of three parts namely:

- Contacts to connect and disconnect the load to source of power
- A transfer mechanism to move the contacts from one source to another
- An intelligent or logic control unit to constantly monitor the condition of the power sources and so provide the brain necessary for switching and related circuit to operate correctly.

The ATS monitors the supply of voltage from a single phase line and a generator supply, it then base its control operation on the availability or unavailability of power supply from either sources. It consists of a series of relays contactors and protective devices that help form the control circuit of the ATS.

The ATS switchgear system can be divided into four main functional blocks namely; the relay switching block, timer relay block, the contactor switching block and the Digital MultiMeter (DMM) Unit. The relay switching block comprises the voltage monitoring relay that monitors the supply voltage level and the 11-pin relays that act as sensor relays. The delay timer multifunctional relays of the utility and that of the generator sections provide some delays before energizing the contactors which in turn provide power supply to the connected load, while the DMM measures the output voltage current and frequency of the supply to the load. The block diagram of the working principle of the ATS is as shown in figure 1.

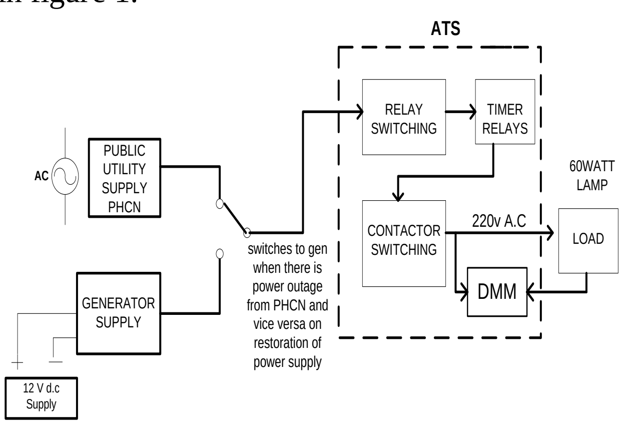

Figure1 Block diagram showing the working principle of the ATS

2. Methodology

The A.C voltage monitoring and control circuit are designed and constructed. This was achieved by using voltage monitoring relay (VMR) as a primary component of the power sensing and control circuit; which is used for measuring and comparing the voltage level of the utility supply with a set voltage tolerance range (185-250V A.C) while a 12A miniature circuit breaker will act as a switch to the power supply from the public utility end of the ATS.

The power switching circuit was designed. ABB-type power contactors rated 12A, 220V a.c, timer relays to provide some delays (5 seconds) during the starting of the generator and transfer of the connected load vice versa from the both power sources depending on the side with steady electrical power at any point in time are used.

The switching mechanism of the generator is done with a 12V d.c supply battery and auxiliary contacts of the timer relays and the contactor. The automatic ignition and stopping of the generator depends on whether the contactors are energized and de-energized. Display unit was also designed. The digital multimeter (DMM) displaying the output voltage and the rated current of the ATS have a 12V and 5V d.c power supply unit (PSU), a current transformer (C.T), an ADC microcontroller (PIC 16F877) to convert the measured analogue a.c voltage and current to digital values for display on the liquid crystal display (LCD) display.

3. DESIGN STAGES/COMPONENTS

The Relay switching stage: This block consists of the combination of the voltage monitoring relay(VMR) and the finder relays (11-pin relays) which serve as sensor used to determine the availability or non availability of voltage supply from either power sources before triggering the control sections of the ATS. The VMR is used for measuring and comparing the voltage level of the utility supply with a set voltage tolerance range (185-250V A.C).

The Timer relay Stage: This block is made up of delay timer relays operating as normally open timed closed (NOTC) timer relays on each section of the ATS. The Timer relay on the utility section helps to delay the supply of electric power from the public utility, thus preventing the occurrence electrical damage due to fluctuations in voltage supply. The Timer relay on the GENERATOR section helps stabilize the power generator and allows it to warm up before it finally supplying power to the connected load. The delay time for the utility timer relay is 5-6 seconds while that of the generator is about 10 seconds.

The contactor switching stage: This block is made up of Contactors on each side of the ATS (i.e. the utility contactor (KN) and the generator contactor (KG)). The function of the contactor is to switch the current to the connected loads easily. This is because they are made to handle large amount of current flow in electrical installations. The maximum load rating of the contactors is 12Amps.

CONTACTOR SELECTION

With the input voltage supply from either power sources (V) = 220-240Va.c supply

Generator power rating (P) = 2.5KVA

Assuming Power factor (Cos ϴ) = Unity

Rated generator set current (I) in Ampere

$$= \frac{Power\ in\ KVA \quad X \quad 1000}{Operating\ voltage} \qquad \textbf{(1.1)}$$

$$= \frac{2.5 \times 1000}{220}$$

$$= 11.36 \approx 12A$$

Therefore the contactor selected for the ATS is a 12A rated contactor.

The Digital Multimeter (DMM): The digital MultiMeter in the ATS is an electronic device used in measuring the output voltage, load current and frequency of the supply voltage to the connected load. It consists of a current sensing circuit, amplifying and signal conditioning circuit and a digital display of the measured electrical quantities. The DMM used in the

ATS can be divided into four functional units namely;

- The D.C Power supply unit (PSU)
- The Current sensing circuit
- The Precision rectifier and
- The Microcontroller based LCD display unit.

The Power Supply Unit (PSU): This stage consist of a limiting resistor (440Ω) resistor connected in series with the half-wave rectifying diode (IN4007), then the 220µF capacitor helps to filter the rectified AC voltage. Connected across this is two 12V Zener diode which gives 24V supply to the MOSFET (IRF460 FET Buffer). The MOSFET provides a high input impedance, high current and voltage for the voltage regulator. The series 78** regulators provide fixed regulated voltages from 5 to 24 V. An unregulated input voltage (Vin) is filtered by the 2200µF capacitor and connected to the IC's IN terminal. The IC's OUT terminal provides a regulated 12 V and 5V, which is filtered by the 470µF capacitor. Figure 2 shows the circuit diagram of the 12 V and 5V dc supply unit.

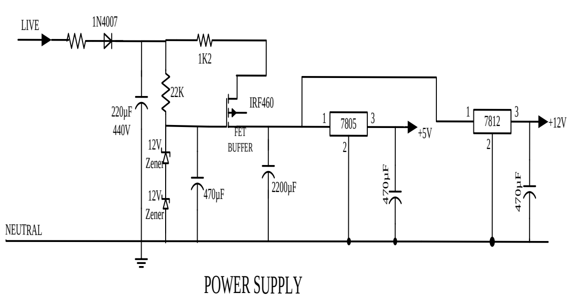

Figure 2 Circuit diagram of the 12V and 5V dc power supply unit

In the circuit diagram above, the input supply to the DMM is 220Vac. The half wave rectification of the a.c voltage is done by the rectifier diodes D1 (1N4007) converts only the positive half cycle of the 220vac to d.c. This diode has a forward bias voltage of 0.7volts must be exceeded for them to conduct. Thus, the output dc voltage level from the half wave rectifier circuit can be calculated to an approximate as shown below in equations (1.2), (1.3) and (1.4) for half wave rectification [6],

$$V_{dc} = 0.318V_m \quad (1.2)$$

Where; Vm = maximum voltage after rectification

$V_{d.c}$= rectified d.c voltage

Where Vm measured from the DMM circuit= 15.97V = 16V

$$V_{d.c} = 16 \times 0.318 = \quad 5.088V$$

The selection of the 22KΩ was achieved using five 110KΩ resistors in parallel:

$$\frac{1}{R_T} = \frac{5}{110\ X\ 10^3}$$

$$R_T = \frac{110K\Omega}{5} = 22K\Omega$$

SELECTION OF FILTER CAPACITOR

For an appropriate selection of the capacitor as a filter, the peak value of the ripple voltage must be known. This can be calculated as shown below:

$$V_{(p)} = V_m - V_{dc} \qquad (1.3)$$

Where $V_{(p)}$ = peak value of the ripple voltage

$$V_{(p)} = (16 - 5)\ V = 11V$$

Therefore, the filter capacitor value C can be determined using the equation below

$$C = \frac{\sqrt{3}}{V_{r\,(peak)}} \times 2.4\, I_{dc} \qquad (1.4)$$

Current Sensing Unit

This section of the circuit is made up of a current transformer (C.T) which actually steps down the current flowing through the load so we can measure it the current transformer is of nominal ratio 400:1.

Precision rectifier (IC4558)

This is an IC which consists of two bipolar operation amplifiers (A and B). It gives a full rectification of the AC supply giving a precise output voltage and current, it is this rectified output that is filtered by the 47µF capacitor to remove noise. The variable resistors help in calibration and the Zener diode connected in parallel before connection to the microcontroller helps to chip the voltage to exactly 5V. Figure 3 shows the circuitry of the current sensor and the precision rectifier used in amplifying the measured analogue current signal before conversion to digital signal by the ADC ports of the microcontroller.

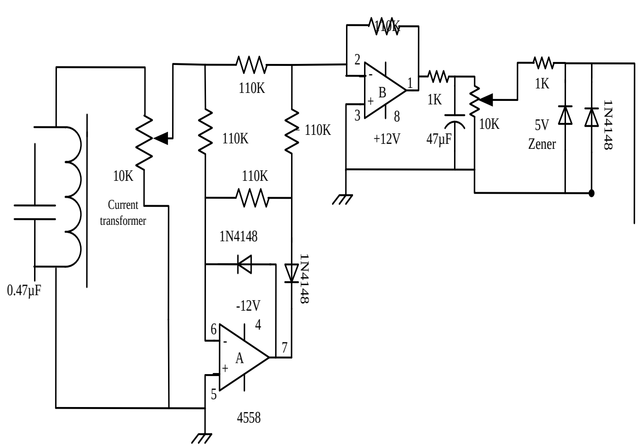

Figure 3 Circuit diagrams of the current transformer and precision rectifier unit

The PIC16F877 microcontroller: The PIC16F877microcontroller [7], is a 40 pin CMOS flash microcontroller. It has 8K of program memory, 368 bytes of data memory and 256 bytes of EEPROM data memory. It has 16-bit wide instruction and 8- bit wide data path. Pins RA_1 and RA_0 acts as the ADC converter for the current and voltage sent from the precision rectifier to the microcontroller and the voltage supply. The 5V Zener diode around the PIC16F877 circuit ensures that the positive voltage supplied to the microcontroller does not exceed 5Vdc. The microcontroller then converts and measure this current and voltage values flowing through the load and send its output via the LCD display.

4. Results

Various tests were carried out on this project which include relay switching test (this is done to be sure the relays can switch back to generator when the power is out and vice-versa), generator starting test and voltage variation test (this is done to be sure that the output voltage is within permissible limit which is between 195V and 245V) and the testing of the entire ATS.

However, the timer relays provide delay of 5 seconds during the starting of the generator and transfer of the connected load and vice versa.

5. Conclusion

Automatic Transfer Switch has been designed and constructed. The prototype of the system worked according to specification and quite satisfactory. The automatic phase change-over switch is relatively affordable and reliable. It is easy to operate, and it provides a high level of power supply when there are power outages. Finally, it reduces stress associated with manual change-over.

However, for future work on this project we recommend that an actuator for mechanical movement of the choke lever should be included for cases where single phase generators without automatic choke controllers are used for testing operations.

The Digital Multimeter (DMM) Circuit diagram and the entire Circuit schematic diagram are as shown in figures 4 and 5 respectively.

5. REFERENCES

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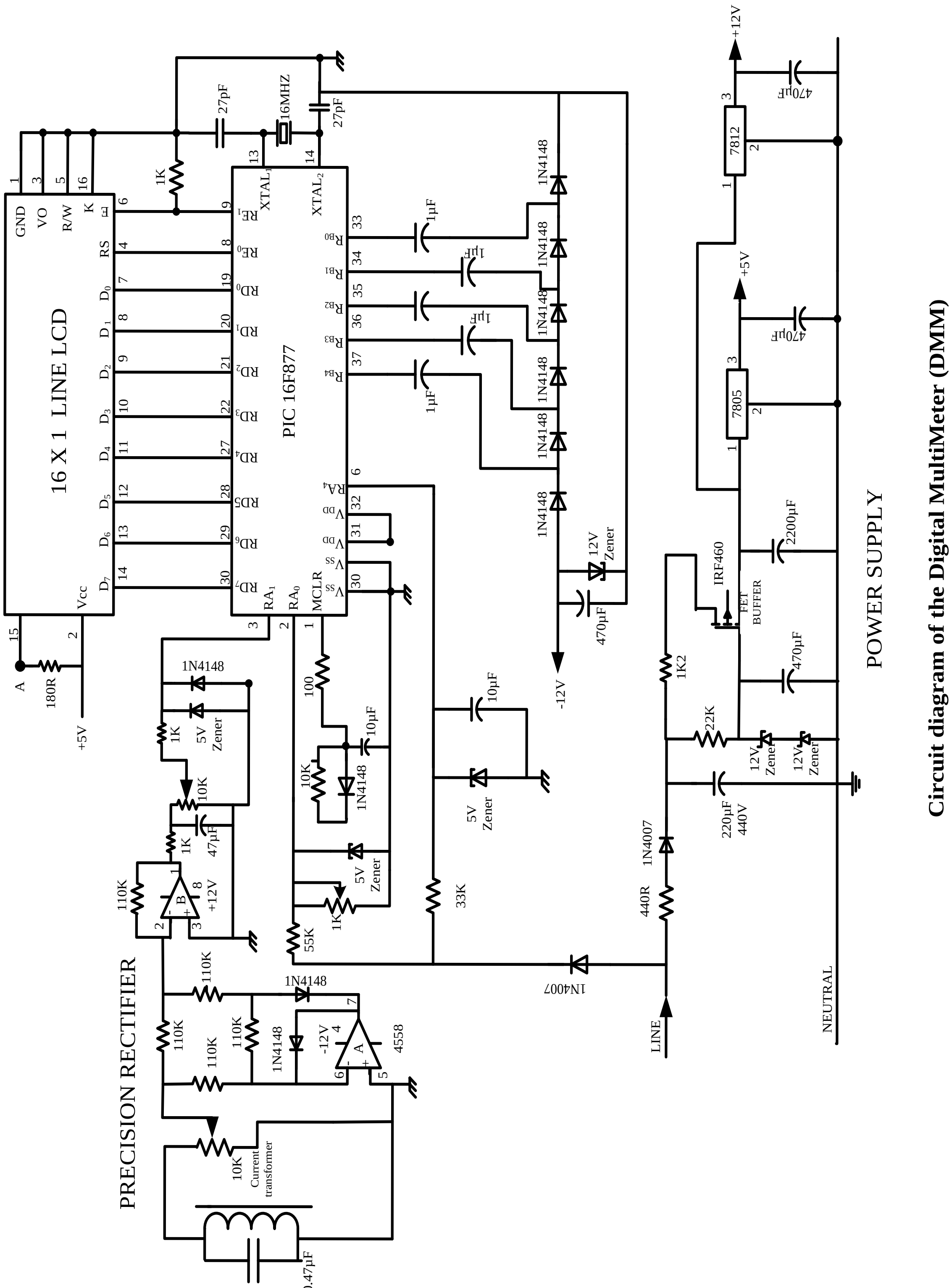

Figure 4 Circuit diagram of the Digital Multimeter (DMM)

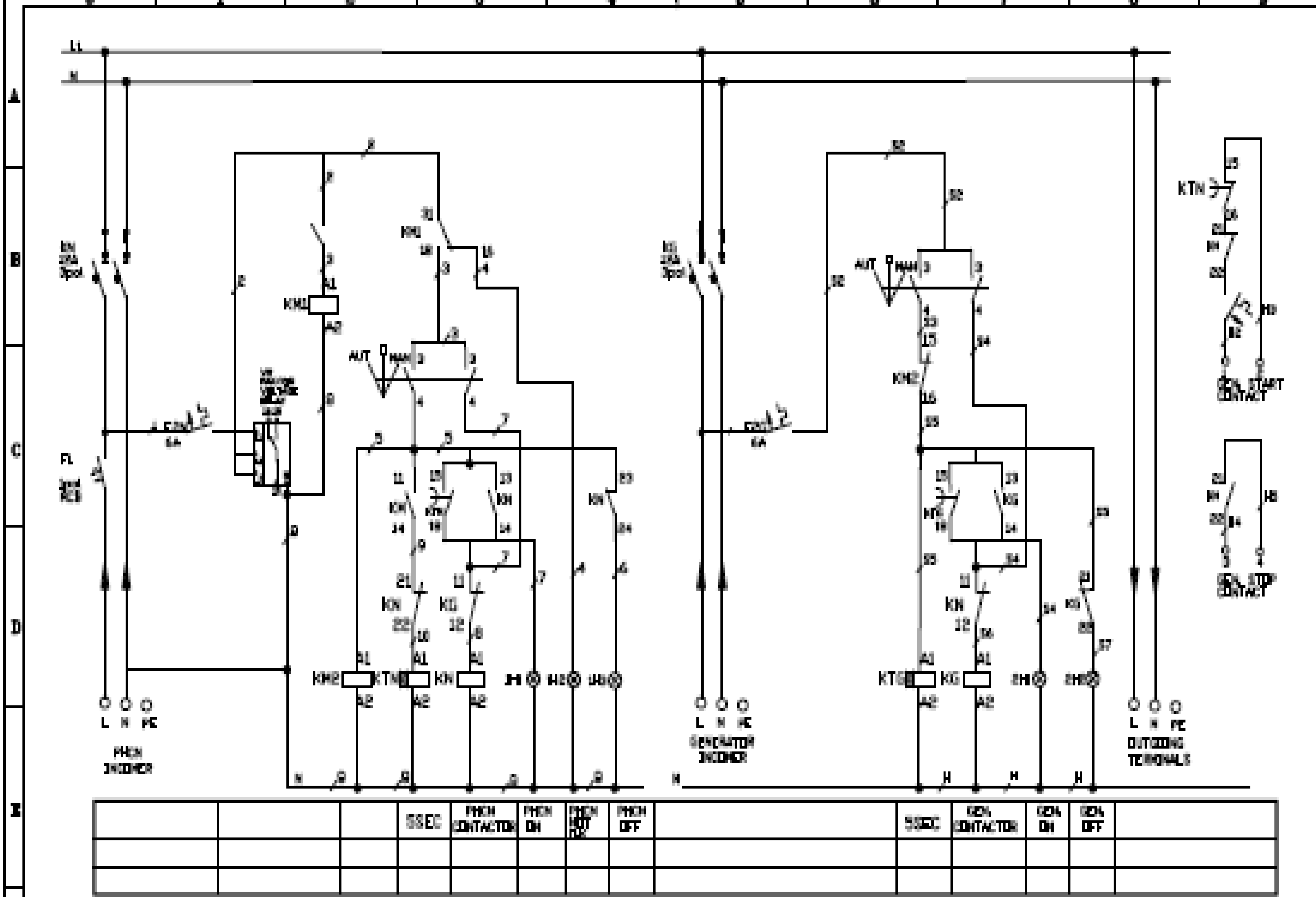

Figure 1.6 Schematic diagram of the Automatic Transfer Switch

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		DATE1	Checked			Project	EIE FINAL YEAR PROJECT GROUP 45	Sheet No. 1
		DATE2	Approved				CIRCUIT DIAGRAM	of 1