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Design of an Automatic Power Phase Selector

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Abstract*— Phase selector is a mechanism used in alternating or switching between power phases with respect to the availability of power on any of the phases. Over the decades, there has been frequent phase failure in the power phases resulting to manual switching of the fuse from one phase to the other. However, this paper focuses on the design of a phase selector using automatic switching mechanism. This during its operation, transfers the consumer's loads to the available power source in the case of power failure in the power supply from the national grid and automatically detects when power is restored to the failed phase and returns the loads to this source. In the course of this design, several tests were carried out such as the continuity test of contactor and relay coils to ascertain low resistance, continuity test on the contacts of the materials used to ensure free flow of current, conductivity of the wires and the whole system was also simulated using the Proteus electronics software.

Keywords: **Conductivity, Power, Phase, Voltage, Proteus.**

I. INTRODUCTION

Power failure or outage has been a major challenge to national development as economic activities are at most times brought to standstill.

In addition, there are processes that need not be interrupted because of their importance, such as surgery operation in hospitals, transfer of money between banks and lots more [1]. Most industrial and commercial processes are dependent on electrical power [3][7]. As industrial processes and IT applications diversify, power consumers have adopted another means of power supply so as to compensate for the inconsistence of the power supply from the power providers, thus the use of Generators since there is need to alternatively supply power from another source as a result the need to combine the use of power supplied by the national Power Supply/Distribution Sector and Generator, leads to the introduction of change-over switch between nation's power supply and Generator[13]. The introduction of change over switch proffer the means to change from national power supply to Generator or vice versa but it was manually done .hence this system often results in waste of time and energy. It was faced with a lot of limitations which includes:

i. The stress of turning the metal gear to effect the changeover manually.

ii. Inability to detect the level of the voltage and the sequence of the three phases.

iii. Inability to select between the phases as in the single phase consumers.

As such, a changeover switch or automatic changeover is required to change from one source (PHCN) to another (Generator), which is needed to be automatic [10]. The human relief stand-by switch is designed simply to monitor, operate and maintain power, as its principle of operation is based on combine operations of the relays, contactors and overload coil. In the whole, the duration of starting and closing of the loads to the contactor should not be more than 5 sec. Their complexity has increased as lots of features are added to its intelligence aimed at making it automated process, be it in industries, commercial complexes, hospitals, hotels or even modern residences. The need, as such, for independent standby power system has therefore increased manifold.

In the quest to get such a changeover switch, some challenges are encountered.it was observed that single phase electricity customers having three (3) phases found it difficult to automatically change from one phase to another when the need arises. It still renders or limits the changeover to a semi-automatic and a semi-manual device. Considering a case scenario where the changeover is very far from the user and the phase on which the consumer was, went off (as experienced in most African countries like Nigeria) at an ungodly hour, hence the reason for this paper is to proffer remedy to such a case so as to make the changeover pure automated switch with less human stress. The incorporation of a phase selector design to the changeover switch brings the dream of such a design to a reality. It then makes the changeover sensitive enough to distinguish and select between poor phases and phase failure.

II. METHODOLOGY

A. Design Development and Considerations

During the design of the phase selector, a lot of considerations, conditions and cases where considered which at the end give rise to the design of phase selector control [6]. These considerations are guided by a truth table of a three variable input of a digital system as shown below.

TRUTH TABLE

S/N	R	Y	B	X
1	1	1	1	1
2	1	1	0	1
3	1	0	1	1
4	1	0	0	1
5	0	1	1	1
6	0	1	0	1
7	0	0	1	1
8	0	0	0	0

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Having these conditions in mind and also knowing the fact that the coming up and going off of power supply from power providers (Nigeria), does not notify anyone before making their decision in this part of the world. As such the conditions and questions considered are as follows;

i. The power supply of 240 volts single phase for the three phases at a frequency of 50 HZ was assumed.
ii. The load of 10kilowatts (kW) was assumed.
iii. If the whole three phases comes at once, how do I select a phase out of them?
iv. If two out of the three comes up, what happens?
v. If one phase comes up, what happens?
vi. How does one communicate to a particular contactor to close while others are open?
vii. How does one avoid the bridging of two or more phases?

The above conditions and questions were considered during the design of the phase selector control. Having cited the truth table, the "X" is the output of all the conditions in a particular row in the table, with "1"meaning on, up or high while "0" means off, down, low or no output from the phase selector.

B. *Design Method*

Having considered these conditions in the truth table, several scenarios were then considered so as to achieve the switching mechanism needed for the device and to control and transfer the load easily, as such the device chosen is a single phase contactor with three poles operating at a frequency of 50 Hz, since we are controlling single phase[4][11].

With the targeted load at 10kw

Since power is P:

$P = IVCOS\emptyset$;

Where $cos\emptyset$ is the power factor (i.e. 0.8)

v = 240v

P = 10kw

$\therefore I = power/vcos\emptyset = \frac{10000}{240*0.8} = 52.08 \cong 53$ amps.

Hence the current ratings of the contacts made by the contactors will be 60 amps as a result of the load. Since the three phases are involved we would be using three of the contactors with three poles,50 Hz,240 volts ratings each. It was noted from contactor chart that the coil current of such contactor is rated 2 amps. Thus a relay with a contact of a current carrying capacity of 5 amps and 240 volts at 50 Hz, with double pole is suitable for such design. The relay is selected and arranged in such a manner that it can cut off some phases, if at least one phase came up, which means that provided there is normal voltage at any phase, hence it will have the enablement of isolating the other phases pending when the situation changes to another way. It should also be noted that the Red, Yellow and Blue phase sequence was adopted for checking the availability of any phase that can be allowed to supply the consumer. i.e. when there is live in the Red phase, it will be supplied thereby isolating other phases even if they have live, but immediately the Red phase is out, then the Yellow phase will be on check, if it has live, it will be selected for supply even if there is live in the blue phase. Immediately the Yellow and Red phase went off, the Blue phase will be allowed to supply, which means, if the Red phase comes up, then the Blue phase will be cut off and the Red phase will be allowed to supply automatically. Thus the phases check and selection are in the order of preference with the Red phase, Yellow phase and Blue phase respectively.

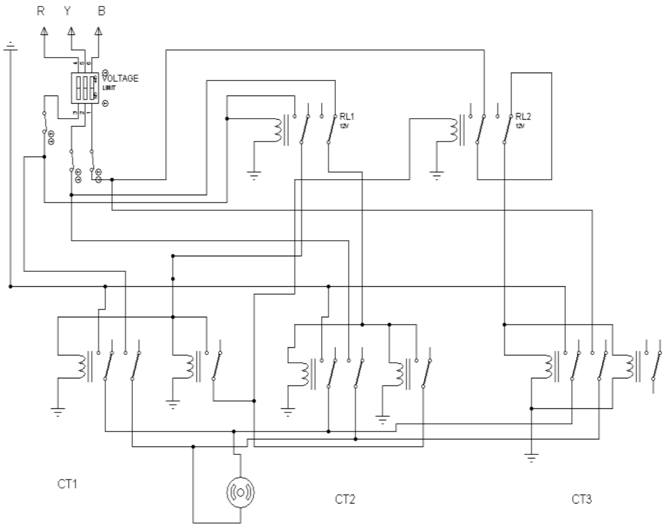

Fig1. (a) Designed Circuit Diagram

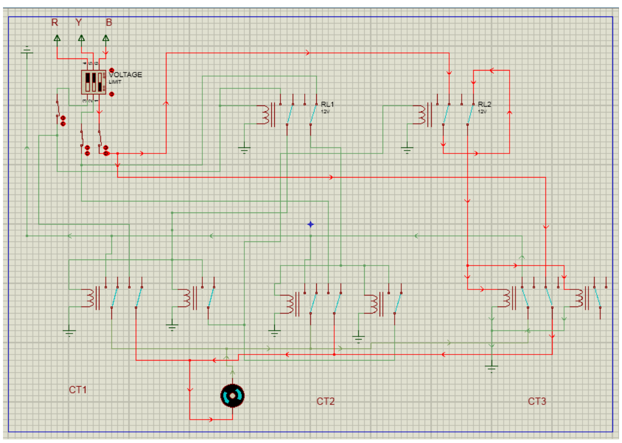

Fig1. (b) Simulation of the Designed Circuit using Proteus

C. *Material Selection*

The components used for this design are the relays and the contactors and are chosen based on the following;

i. They are readily available
ii. Not expensive hence cost effective
iii. Easily replaceable when faulty
iv. And having the same voltage rating as the supply

Contactors of three poles with rating 50Hz, 240volts each and relay with a contact of a current carrying capacity of 5amps and 240volts at 50Hz, with double pole was suitable

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and was selected for such design. However, with these components carefully selected and arranged in such a manner that it can cut off some phases, when at least one phase comes up makes it unique and innovative. Hence the system is a combination of relays and contactors assembling.

D. Relay and Contactors Considerations

The relays and the contactors were selected based on the calculated power and current input in section B above.

AC Motor Full Load Running Current and Recommended Transformer Ratings ①																
Horsepower	110-120V				220-240V②				440-480V				550-600V			
	Single Phase		Three Phase		Single Phase		Three Phase		Single Phase		Three Phase		Single Phase		Three Phase	
	Amps	KVA	Amps	KVA	Amps	KVA	Amps	KVA	Amps	KVA	Amps	KVA	Amps	KVA	Amps	KVA
½	9.8	1.5	4.0	3	4.9	1.5	2.0	3	2.5	1.5	1.0	3	2.0	1.5	0.8	3
¾	13.8	2.0	5.6	3	6.9	2.0	2.8	3	3.5	2.0	1.4	3	2.8	2.0	1.1	3
1	16.0	3.0	7.2	3	8.0	3.0	3.6	3	4.0	3.0	1.8	3	3.2	3.0	1.4	3
1½	20.0	3.0	10.4	3	10.0	3.0	5.2	3	5.0	3.0	2.6	3	4.0	3.0	2.1	3
2	24.0	5.0	13.6	6	12.0	5.0	6.8	6	6.0	5.0	3.4	6	4.8	5.0	2.7	6
3	34.0	5.0	19.2	6	17.0	5.0	9.6	6	8.5	5.0	4.8	6	6.8	5.0	3.9	6
5	56.0	7.5	30.4	9	28.0	7.5	15.2	9	14.0	7.5	7.6	9	11.2	7.5	6.1	9
7½	80.0	15	44.0	15	40.0	15	22.0	15	21.0	15	11.0	15	16.0	15	9.0	15
10	100.0	15	56.0	15	50.0	15	28.0	15	26.0	15	14.0	15	20.0	15	11.0	15
15	135.0	25	84.0	30	68.0	25	42.0	30	34.0	25	21.0	30	27.0	25	17.0	30
20	–	–	108.0	30	88.0	25	5.0	30	44.0	25	27.0	30	35.0	25	22.0	30
25	–	–	136.0	45	110.0	37.5	68.0	45	55.0	37.5	34.0	45	44.0	37.5	27.0	45
30	–	–	160.0	45	136.0	37.5	80.0	45	68.0	37.5	40.0	45	54.0	37.5	32.0	45
40	–	–	208.0	75	176.0	50	104.0	75	88.0	50	52.0	75	70.0	50	41.0	75
50	–	–	260.0	75	216.0	75	130.0	75	108.0	75	65.0	75	86.0	75	52.0	75
60	–	–	–	–	–	–	154.0	75	–	–	77.0	75	–	–	62.0	75
75	–	–	–	–	–	–	192.0	112.5	–	–	96.0	112.5	–	–	77.0	112.5
100	–	–	–	–	–	–	248.0	112.5	–	–	124.0	112.5	–	–	99.0	112.5

① Recommended KVA rating shown in chart includes aluminum of 10% spare capacity for frequent motor starting.
② To obtain full-clad currents for 200 and 208 volt motors, increase corresponding 220-240 volt ratings by 15 and 10% respectively.

Source: www.wikipedia.com [14]

E. Operational Description of the Circuit

As stated, the operation of the system is literally guided by the Truth Table as in fig.1 with eight possible conditions, based on these possible conditions ,the operations of the system are summarized into four (4) major scenarios[12].

Scenario 1:

From the diagram, when there is voltage and power in the three phases, the power will standby at the line side of the contactors, through the connections of the design system, the Red phase will energized the relay one (R1),thereby powering the contactor CT1 and at the same time the Yellow phase will be disconnected by virtue of energizing the relay one (R1), thereby stopping the yellow phase from energizing contactor CT2.Also at the same time having energizing contactor CT1,Y2 from CT1 will then energized relay two (R2),thereby disconnecting the Blue phase and stopping it from energizing contactor CT3. At the end CT1 will be energized and send as an output phase to the changeover system not minding the fact that other phases are available. The same scenario is applicable to conditions 1 to 4 as in the truth table, provided the RED phase has live.

Scenario 2:

When there is no live in the RED phase, the case changes. Now the yellow phase through the normally closed (NC) contacts of the Relay one (R1) energizes the CT2 and at the same time Y2 through the normally open (NO) contact of contactor CT2 energizes the relay two (R2) and that result to disengaging the Blue phase and as such allowing only the yellow phase to be supplied as an output to the changeover system. The same scenario is applicable to condition 6, provided the Red phase is out and the yellow phase is present.

Scenario 3:

At this situation when other phases are off with only the Blue phase present, the case changes. The Blue phase through the normally close (NC) contacts of Relay two (R2) then supplies the CT3,but it will only went off if the Red phase or the Yellow phase comes up, if such case happened then the previous scenario will be repeated.

Scenario 4:

At this condition no output will be seen at the contactors outputs terminal, hence no supply from the output terminal.in this case the automatic changeover then triggers the Generator set to start.

III. CONCLUSION

Automatic phase Changeover is highly of great importance in Africa, to aid the automatic switching over from Generator to public power source. Changeover of this kind makes it easy for such switching to take place, and with the added advantage of being able to select between phases, Coupled to its flexibility it can be adopted in any automatic changeover circuit with ease, it is also less expensive and easily available. The most important feature of this design is that, electricity consumers in the developing countries, who suffer the challenges of power supply. especially in Nigeria where the power phase are often incomplete have the advantage of selecting between phases for their power consumption without really doing the changing manually, as have been the normal practice.it saves the stress and time ,it also provides better protection as compared to the manual practice because of the use of overload is the changeover system. However, this design can for future work be improved on by incorporating Programmable Logic Circuit (PLC).

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