www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 3 Issue 4 April, 2014 Page No. 5353-5359

Evaluation of the Reduction in Switching Time and Stress in Constant Electric Power Dependent Public Utilities by Automatic Mains and Phase Changer

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ABSTRACT

Power failure is the major factor that causes constant electric power-dependent public utilities to stop operation, making it paramount to have backup or alternative electric power sources to ensure the continuity of operation of these utilities. The power outage time lag experienced when these public utilities are switched from a failed electric power source to an available backup power source as well as the stress of manual switching, makes the operation of these utilities inefficient.

The Automatic Mains and Phase Changer (AMPC) is a device that aids in greatly reducing the power outage time lag during the switching between power sources. It also eliminates the stress of manually switching between power sources.

This paper reports a research that evaluates the relationship between the time lag experienced with the use of the AMPC and the time lag experienced when the switching is done manually. It also evaluates the relationship between the stress levels during manual load switching and the stress levels using the AMPC for automatic load switching.

The research involved the use of an Automatic Mains and Phase Changer to provide automatic switching from a failed phase of the mains supply to an available phase of the same mains supply. The time lag in the automatic switching was compared with the time lag experienced when the same switching process was done manually. With the load being a single phase load, it can be switched between the phases of a 3-phase mains supply depending on which phase is available.

The research also involved the use of the AMPC to provide automatic switching from a mains power supply to a generator supply. The time-lag in the automatic switching using AMPC was compared with the time-lag when the switching was done manually and the relationship between the time-lags was fully analyzed and evaluated in this paper. 20 different time-lag readings were taken with the AMPC used and with the switching done manually and the analysis of the relationship between the time-lags as well as the relationship between the stress levels of both, is well documented in this paper. The result of this research showed that change-over time is greatly reduced with the AMPC, compared to manual change-over time which depends on the position of the operator relative to the position of the change-over switch.

Keywords: Automatic mains and phase changer, power outage time-lag, automatic switching, power failure, manual switching, power source

INTRODUCTION

Power failure has proven to be one of the major factors limiting the amount of goods and services produced by industries and firms, which in turn limits economic growth (Oladokun, 2013).Being in or around cities has special consequences for power outages as public utilities will be largely affected. Urban and suburban areas are highly dependent on electricity. There are several of the areas that electricity directly impacts. As can be experienced at any time the traffic lights in an area are not functioning, traffic flow will be slowed down and can be become dangerous when people become flustered and rushed. Most individuals will behave responsibly and politely when trying to cross nonfunctioning traffic lights. However it only takes a few people acting irresponsibly to cause collision .Small areas affected by power outages for a limited time pose a very small risk. Larger areas affected by outages can have a much greater effect on traffic congestion. Consider how a single accident at an intersection can affect traffic in several directions for considerable distances. Then consider how as the auto accidents start to multiply how it will affect traffic congestion to a larger degree. (Phloydius, 2008)

For some equipment, a reliable uninterruptible and free of disturbance power supply is an absolute need. From this point of view, a fault in the power supply of communications systems, hospital apparatus, security systems, water and gas distribution devices, banking computers and many other crucial appliance may bring about serious problems, with consequences that can easily be imagined. All these applications can be identified as critical power applications: they are specifically designed to leverage a constant and secure power supply

Power instability or outage in general does not promote development in the public and private sector (Robert, 2010). Pumping machines at petrol stations are electrical machines and they will be affected by power failure which in turn affects transportation in cities as most vehicles use petrol as a source of energy. Also, public water systems are controlled by huge electrical pumps meaning the longer the power outage time the longer the period where the pump is non-operational. When the pumping station stops pumping, the water stops flowing. Any water remaining in the pipes may flow down hill (with gravity only) to homes at lower elevations. Additionally water systems that are closed in a vacuum may not flow as easily or at all with no pressure from the pump (Phloydius, 2008). This shows that power outage time affects public water distribution.

To limit the effects of power failure on the economy of a nation, back-up power supplies are paramount. A device to provide an almost instantaneous switching from the mains power supply to the auxiliary/back-up supply when there is power failure in the mains supply is also important to reduce the effects of power failure. This device is called an Automatic Mains Failure (AMF). The AMF is composed of series of relays and timers and automatically transfers an electrical load from the primary power supply (e.g. Power Holding Company of Nigeria (PHCN)) to a back-up power supply e.g. generator (Oladokun, 2013). The AMF continually monitors the level of voltage at the main supply till it fails (Saiful, 2008).

Most countries, including Nigeria, utilize 3-phase 4-wire lines for power transmission to homes and industries. Most industries will utilize the entire 415V line voltage from the 3-phase 4-wire power transmission for the operation of 3-phase machines such as 3-phase motors and rotary fillers. But for domestic use in homes and establishments such as banks, hospitals, hotels, and computer centers where single phase machines and electronic devices are used, only 220V phase voltage is needed. Despite the need for just 220V phase voltage, most homes, banks, hospitals and offices in Nigeria are connected to 3-phase 4-wire power supply. This is done because, sometimes power failure occurs in one or more of the phases making it necessary to have a cut-out fuse to transfer electrical load to any available phase. To eliminate the stress of manually switching between the phases and also reduce the power outage time between the switching, an electrical device known as an automatic phase changer is needed (Oladokun, 2013).

An automatic phase changer automatically transfers an electrical load from a phase when there is power failure in the phase to another phase with available power supply in a 3-phase 4-wire power system. The automatic phase changer can only be used in firms and establishments that utilize single phase devices or electronic devices such as banks, hospitals, hotels, cinemas, cyber cafes, and government secretariats. It is composed majorly of series of relays and timers, configured in such a way that it provides almost instantaneous switching between phases (Oladokun, 2013). An Automatic Mains and Phase Changer (AMPC) combines the function of an AMF and an Automatic Phase Changer.

It consists of a configurable automatic control associated with an emergency manual operation with on-load switch disconnector providing safety isolation combined with high making and breaking characteristics (Socomer, 2014). One of the basic operations of the device is to switch ON an auxiliary power supply (like a generator). This operation connects the power supply from the generator to the load after a predetermined time interval. This is intended to normalize the current from the generator. Switching is possible through the use of the relays. The system was designed to automatically change power supply back to the main supply moments after the A.C. mains are restored and to switch OFF the generator (Jonathan, 2007). The AMPC monitors all three phases to ensure appropriate supply of mains power. If all three phases are powered, it connects them to a 3-phase four pole contactor, whose output is connected to the load (Ezema et. al, 2012).

METHODOLOGY

The methodology of this research involves the design, construction, development and incorporation of an Automatic Mains and Phase Changer. The incorporation of the Automatic Mains and Phase Changer involves the use of the AMPC to provide automatic switching between the phases of the mains supply and automatic switching between the mains supply and the generator/backup power supply. The main objective of this research is to compare the time-lag experienced during automatic switching with the aid of the AMPC and the time-lag experienced when the switching is done manually, analyzing the relationship between them and drawing conclusions based on the analysis. Also the stress levels of the switching with the use of the AMPC and with the switching done manually are also compared and analyzed and conclusions are drawn from the analysis.

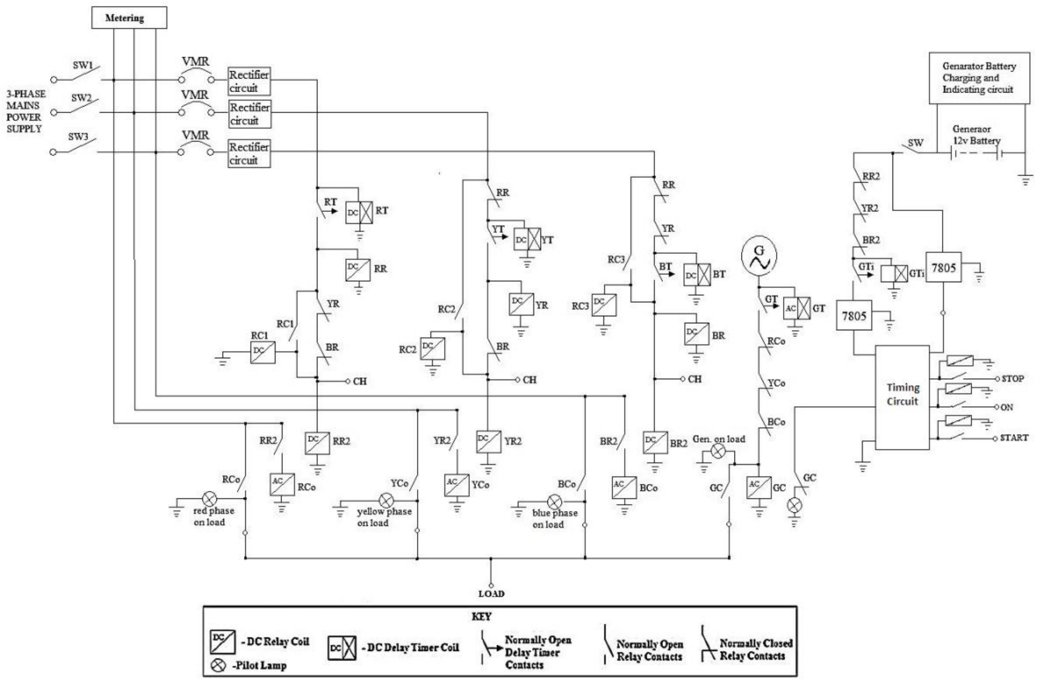

Fig. 1: The full circuit diagram of the Automatic Mains and Phase Changer

Fig. 1 shows the full circuit diagram of the constructed Automatic Mains and Phase Changer with the three phases of the mains supply connected to the SW1, SW2 and SW3 switches to enable emergency shutdown of a faulty phase. The metering circuit shows the voltage levels of the phases of the mains supply and the generator when it is turned ON. The voltage of each phase is converted from 220v ac to 12v dc with the aid of rectifier circuits as the relays and timers used in the control circuit have ratings of 12v dc. As shown in fig. 1 the generator battery is charged by a 12v charging circuit to keep the battery's energy level constantly high. Fig. 2 shows the pictorial view of the AMPC.

Fig. 2: Pictorial view of the constructed Automatic Mains and Phase Changer

EXPERIMENT

The AMPC was used to provide automatic switching of a model 200 watt single phase load between the three phases of the mains supply. Afterwards, the same process was done by manually switching the single phase load between the phases of the mains supply with the aid of cut-out fuses. The time delay experienced during the phase-to-phase switching was recorded (with the aid of a stopwatch) with the AMPC used and with the switching done manually. The switching process with the AMPC and manual switching were repeated in 20 tries with the switching time delay readings taken each time. Meaning that 20 readings were taken with the AMPC used and 20 readings taken for manual switching. Table 1 shows the readings. As seen in Table 1, the time delay values with AMPC used are close as they range from 1.2 to 1.4 seconds. These specific time delay values confirmed the pre-defined and set time in the timing circuit design to ensure all the phases do not get switched at the same time when they become available at the same time. The time delay values with manual switching are erratic and relative to the position of the operator from the switching center with the values ranging from 8.6 to 10.8 seconds. The readings for the manual switching were taken with the manual switches and cut-out fuse about 4.8 meters away from the operator for each reading.

Table 1: Comparison of Phase-to-Phase Switching Time Delay

S/N	Time Delay with AMPC used (seconds)	Time Delay with Manual Switching (seconds)
1	1.2	8.7
2	1.3	9.8
3	1.3	10.8
4	1.2	9.3
5	1.4	8.7
6	1.3	9.0
7	1.3	8.9
8	1.4	9.5
9	1.3	10.0
10	1.2	8.6
11	1.3	8.9
12	1.3	9.7
13	1.4	10.5
14	1.3	9.9
15	1.4	8.5
16	1.2	8.8
17	1.3	8.9
18	1.3	9.4
19	1.4	9.7
20	1.4	9.2

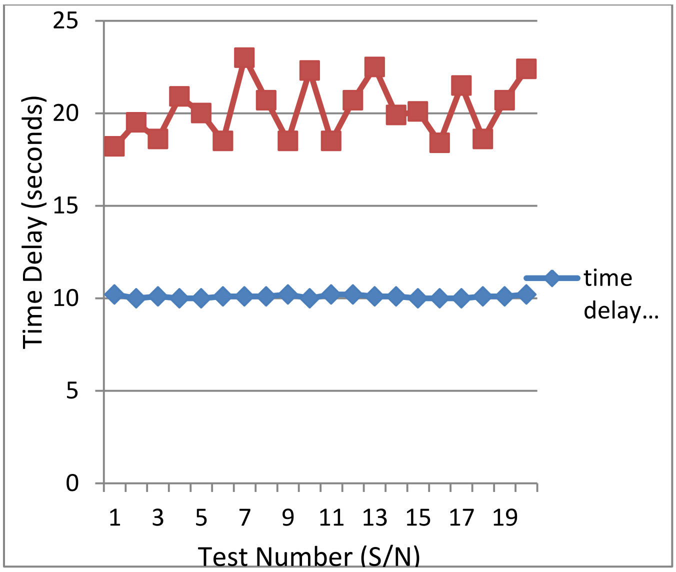

Fig 3: Line chart showing the relationship between the phase-to-phase time delays for manual and AMPC switching

The AMPC was also used to switch from the mains power supply when all the phases fail, to the generator power supply, automatically kick-starting the generator in the process. This process was carried out with a 200 watt model single phase load with 20 tries with the AMPC and 20 tries with the switching done manually and the generator started manually. Time delay readings were taken with the AMPC and with the switching and generator starting done manually. Table 2 shows these readings. The time delay readings with the AMPC used are close and range from 10.0 to 10.2 seconds with most of the delay due to the time it takes the generator to start, come up to speed and maintain a constant voltage level. The time readings with the switching and generator starting done manually are greater than when the AMPC is used and are erratic and random, with the values ranging from 18.0 to 23.0 seconds. The randomness of the values is due to variation in how long it takes the operator to get to the generators location when the mains fails, which for this research is about 4.8 meters from the operators' initial position, and how long it takes the user to start the generator. It also depends on how long it takes the operator to get to the switching box after the generator has started and manually switch the load from the mains to the generator.

Table 2: Comparison of Mains to Generator Switching Time Delay

S/N	Time Delay with AMPC used (seconds)	Time Delay with Manual Switching (seconds)
1	10.2	18.2
2	10.0	19.5
3	10.1	18.6
4	10.0	20.9
5	10.0	20.0
6	10.1	18.5
7	10.1	23.0
8	10.1	20.7
9	10.2	18.5
10	10.0	22.3
11	10.2	18.5
12	10.2	20.7
13	10.1	22.5
14	10.1	19.9
15	10.0	20.1
16	10.0	18.4
17	10.0	21.5
18	10.1	18.6
19	10.1	20.7
20	10.2	22.4

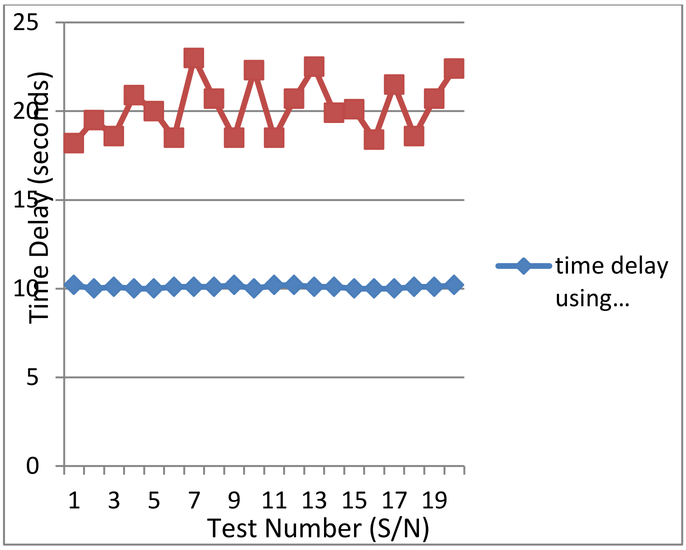

Fig. 4: Line chart showing the relationship between the mains to generator time delays for manual and AMPC switching

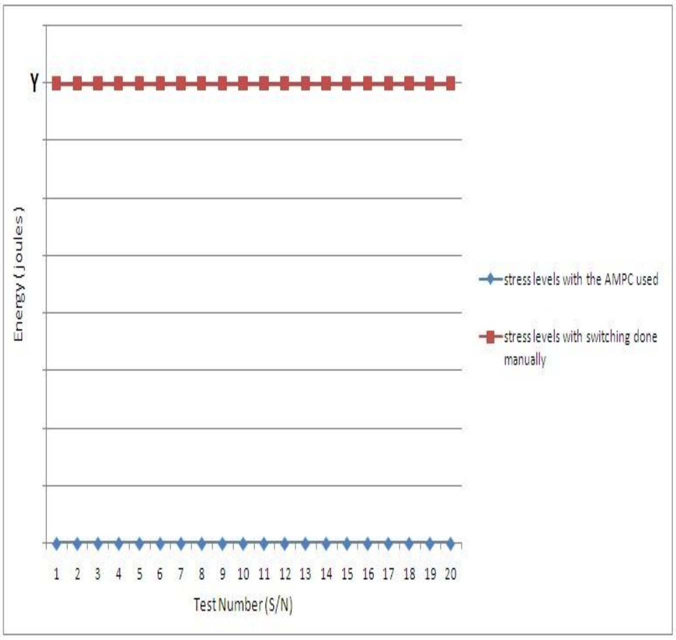

Fig. 5: Line chart showing the relationship between the stress levels of automatic and manual switching

RESULT DISCUSSION

Fig. 3 is a line chart showing the relationship between the time delays with the AMPC used for automatic phase-to-phase switching and time delays with manual phase switching. As shown in fig. 3, the line for the phase-to-phase switching time delay with AMPC used, exists much lower in the chart than the line of the manual phase switching as manual switching time depends on the relative position of the operator to the switch board. The time delay values for manual phase switching have a wide range of values as the speed of switching is dependent on the operator's physical speed and relative position. This is shown by the zigzag line in fig 3.

Fig. 4 is a line chart showing the relationship between the time delays with the AMPC used for mains to gen switching and the time delays with manual mains to gen switching. As shown in fig 4, the line for the mains to gen switching with AMPC is almost straight as the time delay values have a close range. These close range values are possible because the AMPC timing circuits have set time values. This is as opposed to the line for the manual mains to gen switching which has a wide range of values as switching speed depends on the operator.

Fig 5 is a chart that shows the stress levels for manual switching and the stress levels for automatic switching with more energy in joules (Y joules) being expended by the operator for manual switching and no energy expended for automatic switching. Where Y is a positive natural number.

CONCLUSION

In conclusion, the difference between the time delay in automatic load switching and manual load switching is large enough to prove that automatic load switching makes public utilities more efficient and an Automatic Mains and Phase Changer is the most reliable device to achieve this.

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