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Design & Implementation of Cost Effective Automatic Transfer Switch

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Abstract— In many developing countries, electric power generated by utility supply authority is inadequate to meet the demands of their customers. This Power variability has necessitated the need for alternative source of power supply i.e. Generator to back up the utility power supply. Changing between the main supply line and the alternative supply poses yet another problem. Various attempts have been made to advance automatic power changeover switch but there are some limitations with them. Our proposed scheme presents the design and construction of microcontroller based automatic transfer switch and a better and cost effective approach that makes use of digital integrated circuits and microcontroller which reduces the number of components as well as increase the speed of the system. The ATS also contains an alarm system for indicating generator failure or fuel outage.

Keywords— ATS; Backup Generator; Power Supply; Cost Effective; Microcontroller; Home Automation;

1. INTRODUCTION

Today, electric power plays very important role in lifeline of any country and its continuous availability at minimum cost certifies the country's growth. That marks it very important factor in developing the economy and the standard of living of a country. [5] [11][12] The role of electric power in everyday requirement of individuals and nations cannot be exaggerated, specifically in this era of the proliferation of consumer electronics and electrical appliances for both home and industrial use. The need is quite evidently on an ever increasing demand. The global economy hang on largely on constant supply of electric power for growth, so countries with deprived supply of electricity may not advance in this 21st century. While the period of inconsistency of supply electricity is long forgotten in many technologically advanced nations of the world, many developing countries still writhe holdups arising from persistent power disasters. The provision of alternative power source i.e. generator has no doubt brought assistance but not without an assistant challenge linked with manual operation of the changeover. [1][6]
Therefore, poor state of power supply in developing countries, demands for alternatives sources of power generation and automation of electrical power generation to back up the electric utility supply. Over time, automation of electrical power supply has become vital as the rate of power outage is predominantly high. As a result of this power outage, developing countries experience slow development processes in both the public and private sectors of their economy. Investors from foreign places don't feel secure to come and set up business in the face of the large market made accessible in such populated countries, because of common power failures practiced. [2][7][8][9][10]

Therefore, it is for these reasons that transfer switches were developed. Initially, these switches were designed for manual operations, but with an increase in the technological advancement of electrical power control, Automatic transfer switches (ATS) were created. It eliminates the element of user contact in starting a generator and changing power supply from one source to another. Some of the approaches which have been engaged to implement change over system include manual change over switch box, automatic change over system with electromechanical relays and change over system with automatic transfer switch. Each of these methods have some drawbacks that make it undesirable. These contribute to the high cost of these methods. [4]

The proposed approach makes use of digital integrated circuits and microcontroller which reduce the component count as well as improve the speed of the system. 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.

2. DESIGN METHODOLOGY

2.1 SENSING THE MAIN SUPPLY VOLTAGE

The main supply voltage can be sensed by down converting the 220V AC to 5V DC using 15k ohm resistor, bridge rectifier and filter. When the main supply is active, the voltage sensing circuit provides 5V DC and when the main supply fails, the voltage sensing circuit gives 0V at its output.

2.2 CONTROLLING THE GENERATOR ON/OFF SWITCH AUTOMATICALLY

The generator ON/OFF switch open or short the two wires connected to it when the generator needs to be started or when the generator needs to be turned off. Relays can be used to open or short these two wires to start or stop the generator. The relay coil is energized by 5V DC main supply voltage coming from the microcontroller due to sensing circuit. When the voltage is available, the relay coil will be energized. Since when the voltage is available, generator remains off so microcontroller will send signal to relays to keep the wires connected to the generator ON/OFF switch open circuited. When the power failure occurs, the voltage sensing circuit sends 0v at its output and the microcontroller will send 5v signal to relay. Relay makes the ON/ OFF switch short circuited allowing the generator to be started by the generator start circuit.

2.3 STARTING THE GENERATOR AUTOMATICALLY

The generator is started automatically when the main power fails and the voltage sensing circuit provides the 0V at its output. Starting the generator requires short the wires connected to Generator ON/OFF switch which is done by sending signal from microcontroller to relay, short circuiting the wires connected to self-start switch momentarily. This circuit needs to be placed in parallel with the self-start switch which is normally open circuited. The circuit also provides a path which is normally open in the presence of grid voltage. The path has to be short circuited for a short period of time to engage the self momentarily. This is implemented by using relays. The whole circuit is controlled by the microcontroller. When the voltage from main supply is present, the path in series with the self-start switch is open circuit. When the main power fails the path is short circuited for a couple of seconds. When the main power fails, the coil of Relay is de-energized and the path is short circuited engaging the self-start mechanism of generator. The self-start mechanism is engaged only for the time duration set in the program dumped in the microcontroller and is disengaged when the timer expires. The generator will take 7 self (number of self are set by user), in case if generator does not start in first self or even after 7 self, then ATS will turn on the buzzer to indicate that generator fails to start.

2.4 AUTOMATICALLY TRANSFERRING THE LOAD

The time delay is required to allow the generator output to stabilize and is set to about 30 seconds. The circuit connects the generator output voltage to the load after this time delay. Before the generator turned off, the main power is connected to the load.

Automatic transfer switches for generators consist of three parts namely (as shown in Figure (2.0))

- A transfer mechanism to move the contacts from one source to another
- Contactor to connect and disconnect the load to source of power
- A logic control unit to constantly monitor the condition of the power sources.

The ATS monitors the supply of voltage from a single phase line and a generator supply that base its control operation on the availability or unavailability of electric power supply from either source. It consists of a series of relays contactors and protective devices that help form the control circuit of the ATS. [2]

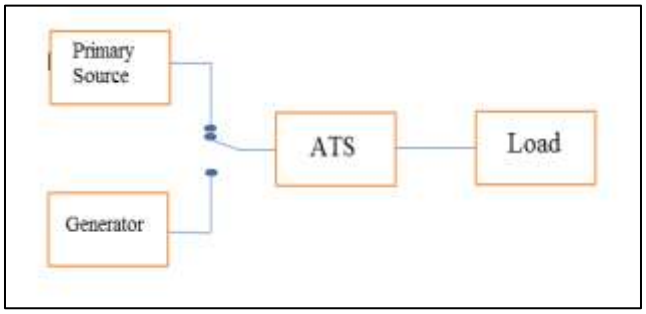

Fig. 2.0: Physical understanding of ATS operation

There are five cases that defines how ATS works; (PS is Primary supply)

1. PS on, Generator off
2. PS off, generator starts & load shifting
3. PS resumes, while generator on self
4. Generator fails to start & buzzer on
5. PS resumes, load shifting & Generator off

The algorithm for ATS is shown in Figure (2.1)

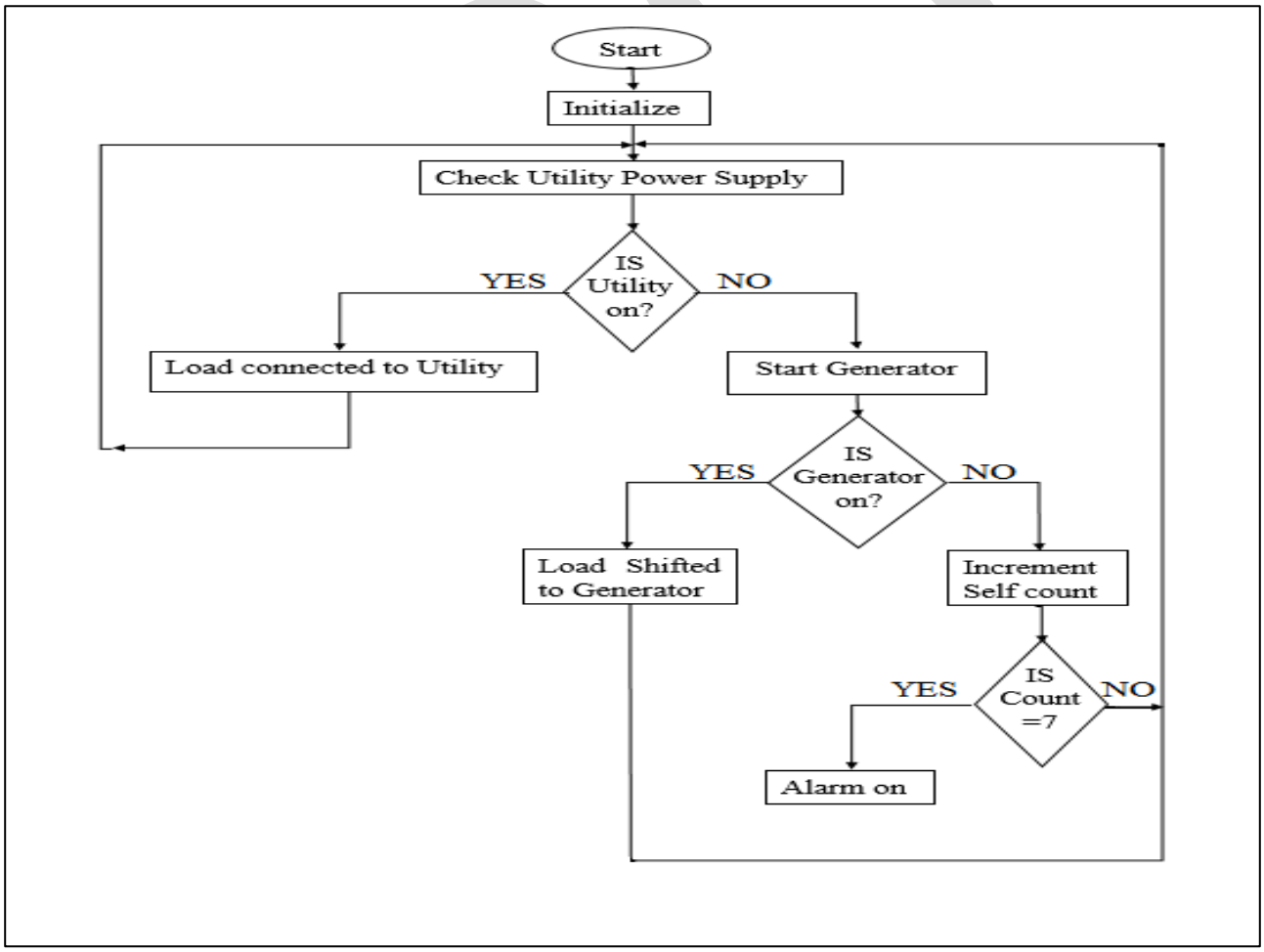

Fig. 2.1: Algorithm for purposed control scheme

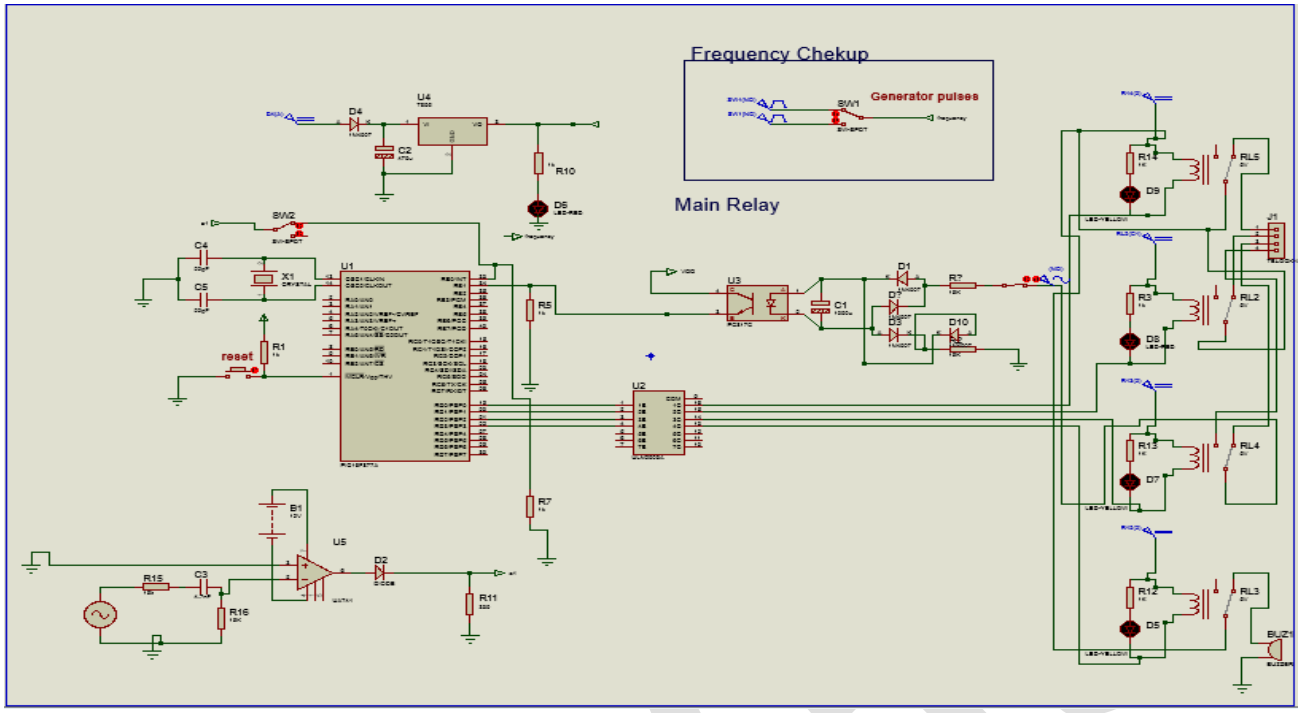

Fig. 3.0: Simulation results proteus

3 SIMULATION RESULTS

Simulation diagram of ATS is shown in Figure (3.0)

3.1 PS ON, GENERATOR OFF

Initially system is in normal condition i.e. PS is available and generator is at standby mode. Throughout this condition load is being served from primary source of power. At that moment GS is off, while ATS continuously checking the state of system. As PS shut down ATS proceeds to further steps and eventually shift the load from PS to generator. Figure (3.1)

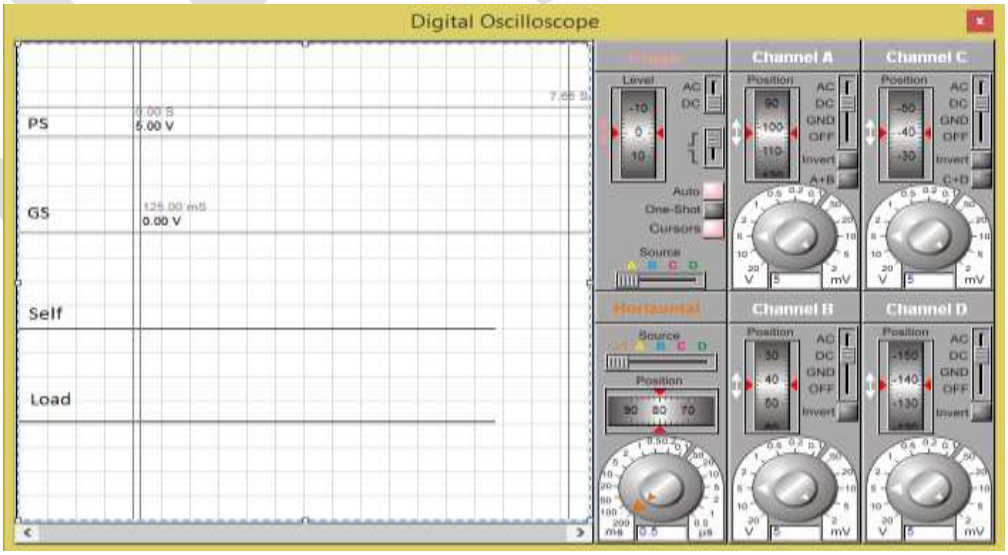

Fig. 3.1: System conditions when load is fed by power source

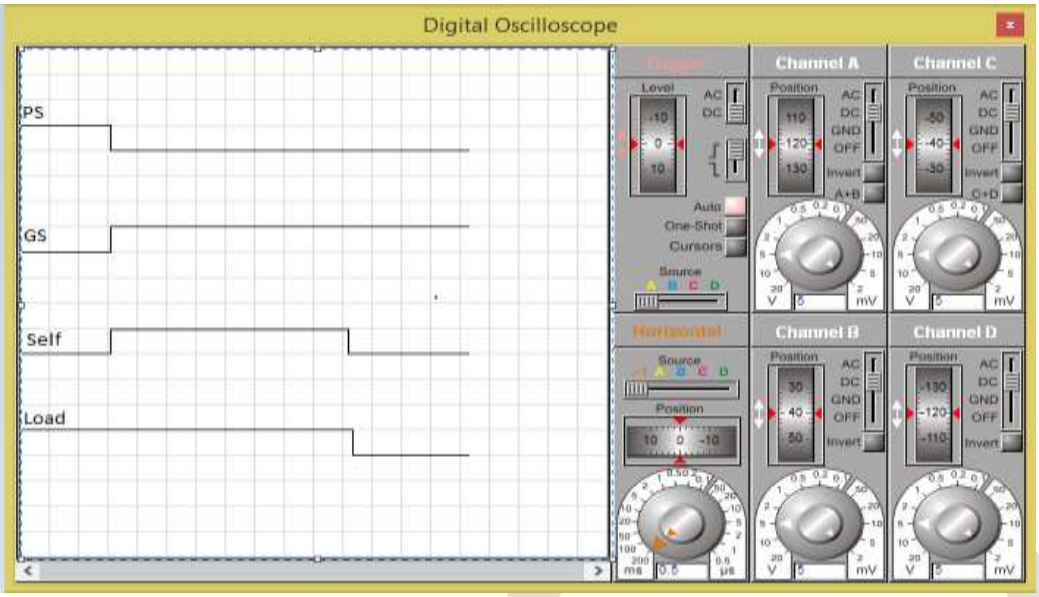

Fig. 3.2: System conditions when power failure from main source occurs

3.2 PS OFF, GENERATOR STARTS & LOAD SHIFTING

ATS working starts, when PS no longer available. Simulation result is attached which showing that when PS shut down, GS instantaneously turns ON and also at the same time generator starts to take self. Self-duration is set to some extent 400ms. A frequency checking circuit is installed. If generator starts within prescribed self-time, next progression is load shifting within 30ms. Figure (3.2)

3.3 PS RESUMES, WHILE GENERATOR ON SELF

When PS is not available ATS starts working which is to start generator and load shifting from PS to Alternative source i.e. generator. In case PS returns when ATS in self mode then normal operation is interrupted and immediately load shifted to PS while GS switched off after 30ms. Figure (3.3)

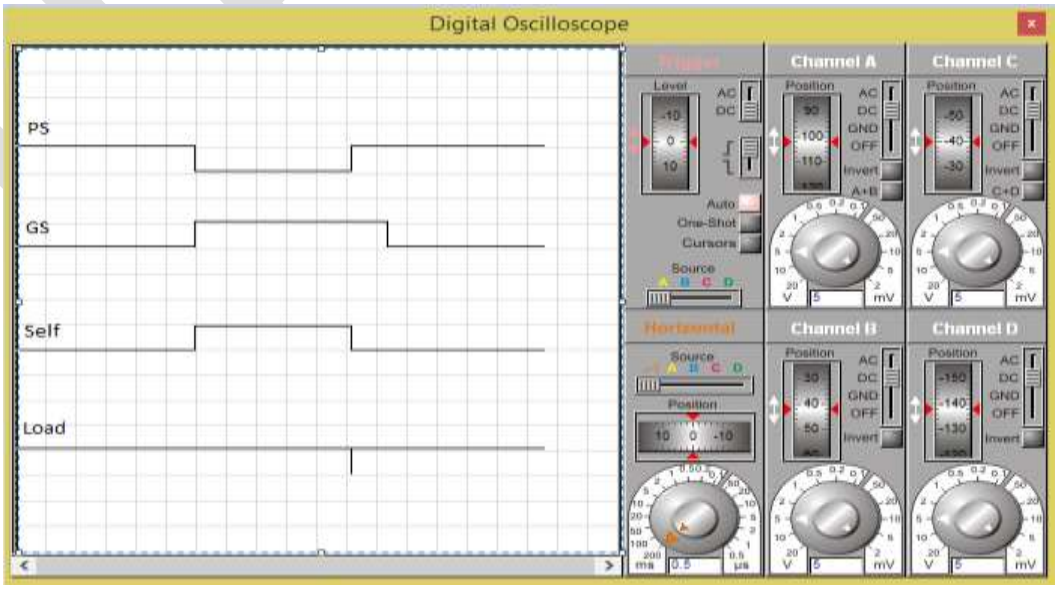

Fig. 3.3: Case when power take up again while generator on self

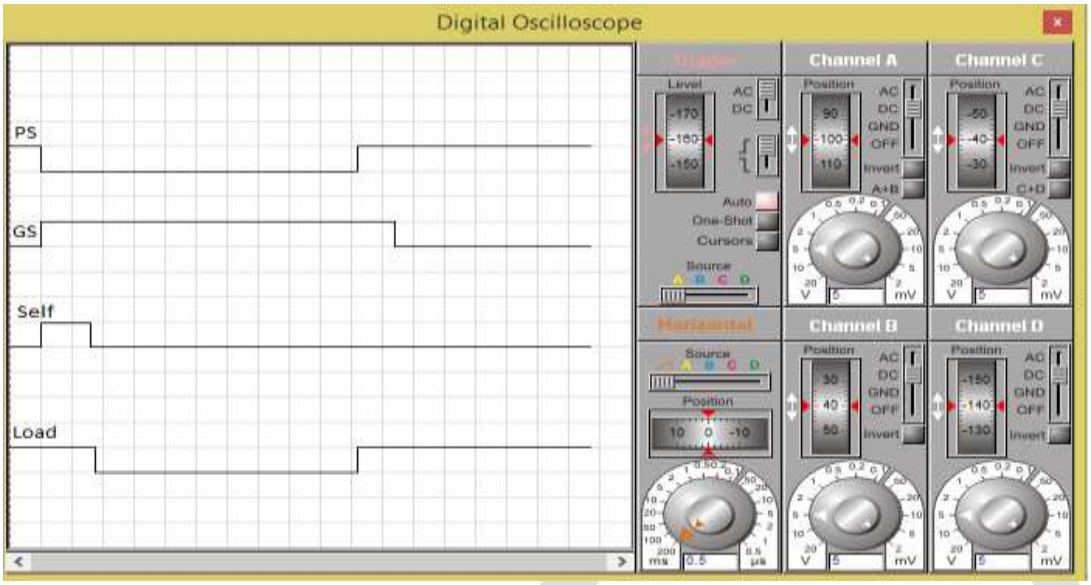

Fig. 3.4: Load shifting from generator when power from main source take up again

3.4 PS RESUMES, LOAD SHIFTING & GENERATOR OFF

When generator is in operational condition and load is being attended from generator, ATS constantly sense the PS. When PS resumes, ATS shifts the load immediately to PS and turns off the generator after delay of 30sec. Figure (3.4)

3.5 GENERATOR FAILS TO START & BUZZER ON

In case of power failure GS turns on and generator drives on self-mode. If generator fails to starts after seven self's due to fuel shortage or any fault in generator which are some hurdles that intrude the normal operation of ATS. In this case ATS conduct yourself like user friendly and indicate the interruption by alarming, turns off the GS and stop to take self. After initiating alarm ATS must be reset manually by user later on clearing the fault i.e. fuel check/hardware check. Figure (3.5)

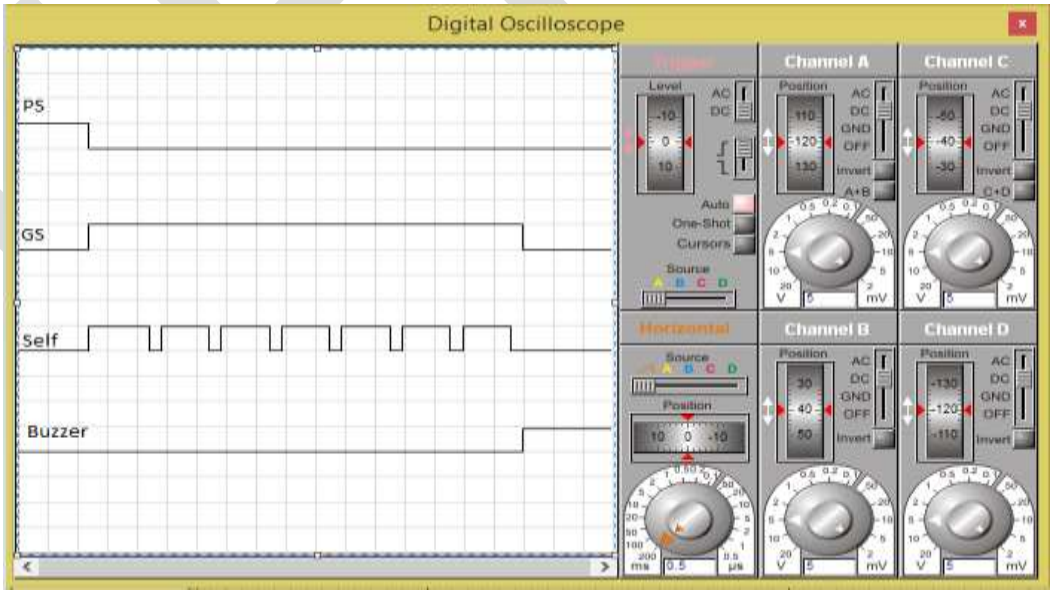

Fig. 3.5: Situation when generator fails to start

4 HARDWARE RESULTS

The automatic Transfer switch was successfully implemented and tested. The photograph of the implemented system is shown in Figure (4.0)

Fig. 4.0: Hardware implementation

4.1 HARDWARE OUTCOMES

The switching mechanism of the generator is done with a 12V dc supply battery and auxiliary contacts of the timer relays and the contactor.

4.1 PS ON, GENERATOR OFF

According to simulation results in fig3.1 hardware results are also same i.e. when power is available from utility generator in it's off condition.Fig4.1

Fig. 4.1: System conditions when load is fed by power source

4.2 PS OFF, GENERATOR STARTS & LOAD SHIFTING

In case of power failure switching take place between power source and generator as shown in Fig4.2

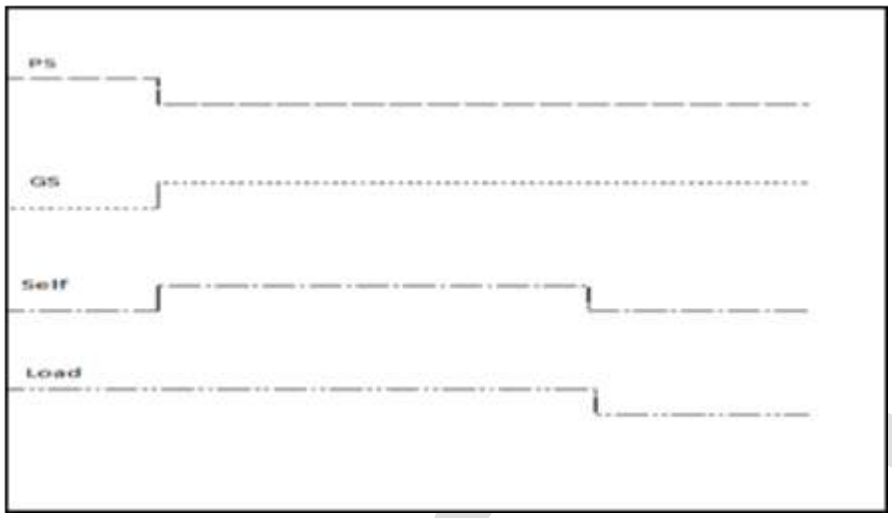

Fig. 4.2: System conditions when power failure from main source occur

4.4 PS RESUMES, LOAD SHIFTING & GENERATOR OFF

Fig4.4 is an explanation of a case when utility power take up again major switching take place i.e. load shifting & after some while (about 30S), generator choke signal activate and turned off the generator.

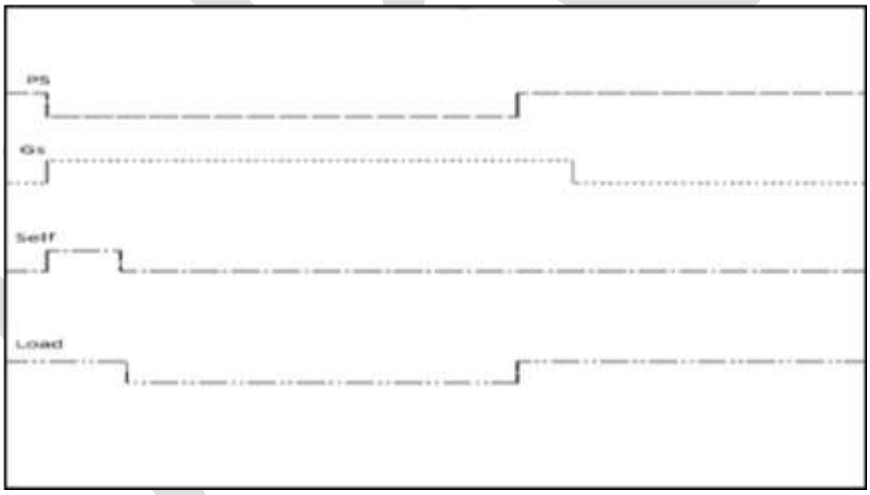

Fig. 4.4: Load shifting from generator when power from main source take up again

4.3 PS RESUMES, WHILE GENERATOR ON SELF

In case power supply take up again when generator on self immediately load shift to main power source and generator stop to start. Fig4.3 is an evident.

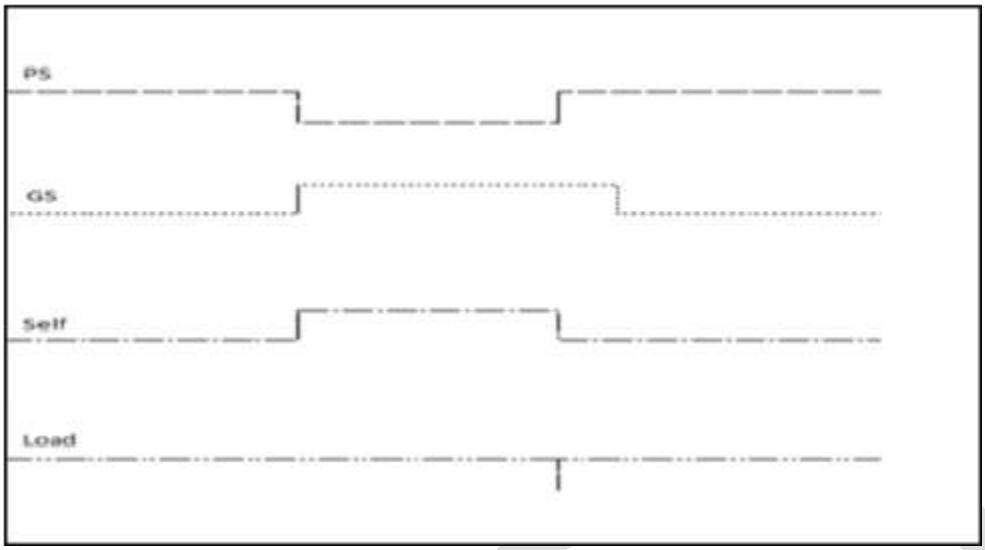

Fig 4.3: When power take up again while generator on self

4.5 GENERATOR FAILS TO START & BUZZER ON

In case generator fails to start predetermined attempt according to fig4.5 (about 7 attempts), buzzer will on showing that there are something wrong like fuel shortage or any kind of hardware failure.

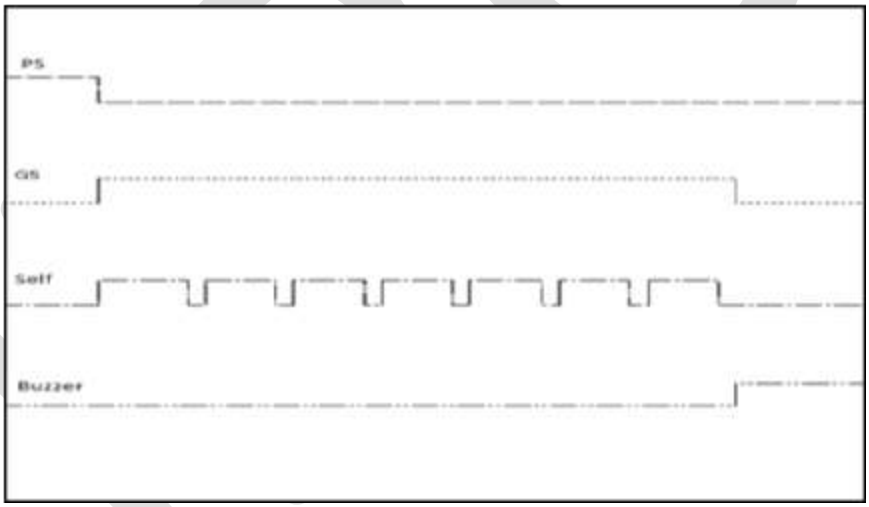

Fig. 4.5: Situation when generator fails to start

CONCLUSION

The manual start/stop and load transfer panel on the generator can still be used after the addition of the automatic controller. There is also a feedback in the circuit to sense whether the generator has started. It engages the self-start motor once at the start of the power failure and retry if the generator does not start in the first try. The total cost of the ATS is very low. Many aspects of automatic transfer systems for the critical power environment have been examined. ATS has the ability to monitor, control and switch between power sources in few seconds. It also provides the comfort of starting a standby generator when there is power failure from the mains without the need of human intervention. The system worked satisfactorily with respect to designed specification. The reliability of the controller is also very high due to the small number of components used in the circuit. The controller also takes very small time to put together and install on a household generator. The circuit is ideal for the countries with high rate of grid power failures.

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