DESIGN AND IMPLEMENTATION OF MULTI-INPUT UNINTERRUPTIBLE POWER SUPPLY

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Abstract— The paper is on the design and implementation of Multi-Input Uninterruptible Power System (MIUPS). The system [1] [2] consists of the inverter section, the charger, the control circuit and the change over circuit. The inverter changes the DC voltage from the battery to AC voltage; the charger charges the battery when there is supply from the AC mains; the control unit monitors the battery against over charge and over drain; while the change over circuit select the AC input by changing from failed one to available one. The response time to overcome or detect any irregularity in power supply, the ease at which it harnesses various inputs and the ability to quickly change to its internal battery are of keen interest. This write up does not only discuss the design and construction of 1KVA MIUPS but also discusses the operation and limitation of the equipment.

Key Words— Inverter, Level detector, Multi-input, Oscillator, Power system, Rectifier, Uninterruptible.

1 INTRODUCTION

Human beings always need energy - right from the usage of solar heat to dry food for preservation to the other usage like drying of clothing. Due to the indispensability of energy, it is very important to find a way of generating electricity. Some of such sources are thermal, hydro, nuclear and solar. Unfortunately, all the sources in our country could not give stable power supply. In fact, the power supply is so epileptic to the extent that both home and industries are now depending on generators which their disadvantages cannot be overemphasized.

Power supply in general is very important in human endeavor since almost all our electronic gadgets and many others use power in one way or the other. The early discovery of dry cells which led to battery or accumulator paved way for further research on how to get better and more reliable sources of electrical energy. Since this time, researchers and engineers have gone so far to discover both conventional and unconventional sources of electrical energy.

Though there is power supply here and there, it is important this power supply become stable and reliable. All our sources of supply especially, in this part of the world are not reliable. It is unpredictable that public supply will be available for complete twenty-four hours without outage.

Some machines have to be supplied continuously with electricity for proper functioning and retention of information in the volatile memory particularly in the case of computer. Not only that, some may not be able to afford alternative source of power supply like buying petrol or diesel for the continuation of their work. Some may want to operate using different sources of power supply. At times, to manually disengage a source and put another source into operation. All the aforementioned and other reasons have led to the design of Multi-Input power system.

Multi-Input power supply derives its supply to the load from two aspects. It either supplies the load from the normal input supplies or from back up supply such as battery.

2. Literature Review

2.1 Purpose and Limitation

Uninterruptible power supply is not new; nowadays it is being used in many areas where continuity in power supply is of ultimate importance.

Therefore, the purpose of this project is to make use of different sources of power supply available to improve better the performance of such equipment; hence the caption Multi-Input Uninterruptible Power System (MIUPS). The project provides supply by choosing one of the available sources at its input. When there is failure in one source of power supply, other sources are checked.

The limitation of MIUPS is on the capacity of the battery used. It is not easy to have high capacity battery since it will be very costly to do so.

The improvement on the size of the battery is not easy and any attempt to increase the number of battery used will increase the overall weight and size, which may not justify its efficiency.

Another important thing is the size of transformer used. Since the heart of UPS is the transformer and the capacity of the transformer depends on its size. This brings a limitation on the design of high capacity **MIUPS.**

2.2 Application of the System

Multi-Input power supply is useful in almost all areas of life. To start with, MIUPS find application in any computer environment. Computer have volatile

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memory in that any information that is not saved before supply failure may not be retrieved back which means that vital information can be lost due to power failure. MIUPS has come into the rescue and it serves as backup for normal power supply.

In the medical field, MIUPS is relevant. During surgical operation or other life sensitive work, MIUPS can be used to serve as backup so that failure in supply will not affect operation and saves the cost of changing over from mains to generator.

Furthermore, MIUPS is very useful at individual homes and offices where it is being used to lighten fluorescent tube, bulb and even air conditioner; lightening of lecture theatres is also worth mentioning.

The flexibility of MIUPS in the home should be made clear. One input of the MIUPS can be connected to the mains, another input connected to the generator, while one input is connected to solar panel. The MIUPS will select the input in other of priority. In addition, those that cannot afford buying fuel into their generator set can make use of other sources without stress.

2.3 Review of Related works

Numerous works and researches have been done in the area of inverter and UPS design and implementation. Various electronic components are being used to achieve the process of inversion and un-interruption of power supply in electrical power system. Factors such as power handling capacity and switching speed are being researched into on daily basis and these normally dictate the type of switching components to use in a particular circuit.

In the work of Omitola et al, "Design and construction of 1kW power inverter," the system voltage is 12V DC and the output is 220V AC at 50Hz. The basic principle of its operation is a simple conversion of 12V DC from a battery using integrated circuits and semiconductors at a frequency of 50Hz, to a 220V AC across the windings of a transformer.

Also, Kabir Usman submitted a project titled "Design and Construction of 3kVA Power Inverter (24V DC – 230V AC)" which works on the principle of UPS. He made use of appropriate oscillator circuit, transformers, switching, and control circuits. Incorporated into these systems are devices such as transistors, MOSFETs, diodes, resistors and batteries which work hand in hand to obtain the overall desired operation of an inverter. Considering the effort of Babarinde et al in "Design and Construction of 1KVA Inverter" The overall operation of the system comprises inter connections of many sub-circuits to give optimum performances. The sub circuits include the oscillator circuit, PWM circuit, driver circuit, low battery/overload shutdown circuit, charging control/soft charging circuit, surge protection circuit, changeover/power supply circuit, and the output circuit (MOSFET and transformer section). None of these works incorporates into their inverter system the section that is capable of making use of more than one source of AC input e.g. the use of generator and public utility supply as AC inputs in an interchangeable manner.

3. Design Analysis

The design of MIUPS is in phases. Efficient design is achieved by breaking the systems into different subunits.

3.1 The Inverter Circuit

Inverters are designed to produce square waves with the help of oscillator since in this way the conversion is efficiently maximized. The output of oscillator is fed into the primary winding of the step-up transformer.

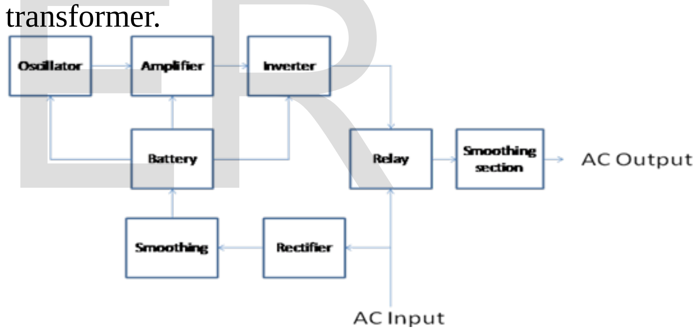

Figure 1: *Inverter block diagram*

The power handling capacity of the MIUPS is dependent on the power rating of the transistor used in the inverter circuit and the battery. The power transistors arranged in cascade are employed to achieve the desired power handling capacity. Specifically, it consists of two set of four FET power transistors connected in cascade. Each set is supplied by the output of the multi-vibrator stage. This arrangement provides a high current gain but almost unit voltage gain. The FET transistor used in the inverter stage is IRFP150N with the following specification.

Working voltage	100V
Maximum current	75A
Average current	36A
Power rating	150W

To know the number of FETs to use, the formula below is used

$Number\ of\ FETs = \frac{}{}$ … … …(1)

In this case, the intended inverter rating is 1KVA and the power rating of the FET is 150W, therefore,

$Number\ of\ FETs = \frac{}{}$

$Number\ of\ FETs = 6.667$

So, the higher even number than this is picked (i.e. 8) to account for tolerance.

These FETs are therefore arranged in two rows.

The total output power is the sum of the power rating of transistor in the two rows.

Therefore,

$PT = P1 + P2 + P3 + P4 + P5 + P6 + P7 + P$

$PT = 150 \times 8 = 1200W$

The output from the inverter is connected to the input of the transformer in the push-pull configuration. Since the transformer is center tapped (12V-0-12V) at the primary each row of FETs is connected to each arm of the transformer. The 24V winding is therefore fed with the complementary signal while the secondary is connected as the output.

When the circuit is in operation, each set of power transistor alternatively switches the transformer thereby producing an AC voltage in the primary winding.

In addition to the MOSFETs used, there are resistors that are connected between the gate and the source of each MOSFET. The gates are fed from the oscillator which generates the 50Hz sinusoidal signal necessary for the FETs. The source of each MOSFET is grounded while the drain is connected to the transformer primary. The diagram below illustrates this.

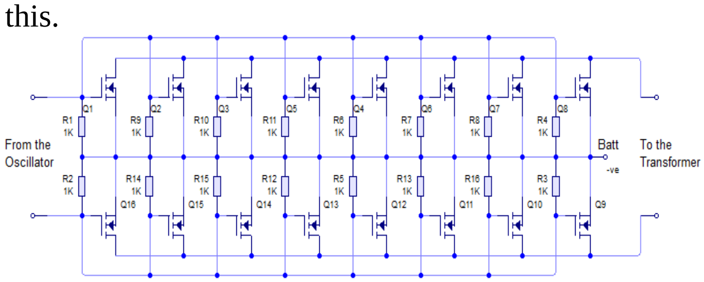

Figure 2: *Switching circuit*

3.2 Astable Multi-Vibrator

In the astable multi-vibrator, two cascade RC coupled stages are given 100% positive, feedback and this gives rise to a conducting process whereby one stage is fully conducting while the other is switched off. Conduction is being transferred from one stage to the other by discharge of a capacitor through a resistor. The output has two quasi-states consisting of a square wave or pulse whose repetition depends upon the time constant involved.

The circuit in the figure below has things in common with the bi-stable multi-vibrator, but uses capacitors instead of resistors (i.e. C_1 and C_2) between transistors.

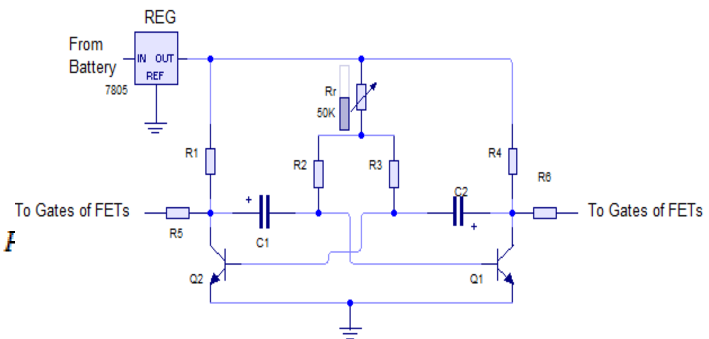

Figure 3: *An astable multi-vibrator (oscillator)*

The effect of this is clearly seen as the circuit was constructed in such a way that the transistors switch alternatively ON and OFF with a frequency determined by the circuit time constant C_1R_1 and C_2R_4. The output can also be monitored by oscilloscope.

$freq = \frac{1}{}$ … … … … … … … … … … … … … … … …3.3

The multi-vibrator used in this project is built with transistor. The regulator used is 7812; this gives a constant supply voltage to the oscillator. Also the variable resistor is used to properly adjust the frequency to 50Hz.

Voltage input $Vcc = 12Volt\ DC$

To determine the frequency at switching, the output from the multi-vibrator is selected from either collector.

$T = 0.693R1C1$ … … … … … … … … … 3.4

$T2 = 0.693R4C2$ … … … … … … … … …3.5

Let the period be denoted by Teq, then

Error! Bookmark not defined. $Teq = T1 + T2$ (fo

$Teq = 1.38Rc$

If $R2 = R3\ and\ C1 = C2$

$f = \frac{}{}$ … … … … … … … … … … … … … … …3.7

$Teq = 1.38RC$ … … … … … … … … … …3.8

$f = \frac{}{}$ … … … … … … … … … … … … … …3.7

If $R4 = R3 = 220K\Omega\ C = 60nF$

$$f = \frac{1}{[illegible]} \ldots\ldots\ldots\ldots\ldots \quad \ldots 3.9$$

$$f = 54.9 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.10$$

With the help of variable resistor, the frequency can be adjusted to 50Hz. So, Rr is adjusted to roughly 22KΩ.

3.3 The Charger Circuit

Since the output of the transformer is alternating, it is necessary to convert it to a direct or steady voltage before being used to charge electrical equipment.

Battery chargers have an input supply from the mains. A transformer is used to transform the voltage to the right voltage while on inverter section, and charging the battery while on mains supply.

A rectifier to convert the alternating input current into full-wave direct current and battery over-charge prevention circuit, ceases charging current from getting through to the battery when fully charge. Battery over-charge causes undesirable side reactions, in particular, decomposition of electrolyte. The latter leads to gas production and in turn leads to increase battery internal impedance. An over charging prevention circuit was incorporated to this design. More so, for efficiency and durability of the battery, low voltage status circuit detector is also incorporated with the project to prevent the battery from being drained excessively.

This over charge protecting circuit cuts off the supply to the battery if a specific voltage level is reached while the low level detector automatically short down the inverting unit of the system when the battery is drain beyond the preset voltage. The first stage is to convert the AC into unidirectional pulses and then these pulses pass through a filter where upon direct current at steady voltage is supplied to the load. The process of converting the AC to unidirectional pulses is known as rectification and filtering after rectification is called smoothing.

In this project, full wave rectification is used. Below is the diagram of a regulated power unit used for charging the battery. It consists of transformer, a bridge rectifier, a filter and a stabilizer.

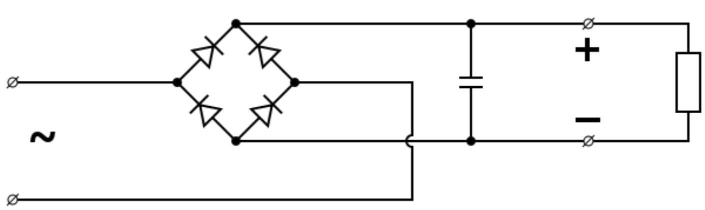

Figure 4: *A typical power supply* (Horowitz, Paul and Winfield))Hill, 1989)

From the above circuit, during the first half (positive) cycle diodes D_1 and D_3 are forward biased while diode D_2 and D_4 are reverse biases. Therefore, D_1 and D_3 will conduct while D_2 and D_4 will not conduct. During the second half (negative) cycle, D_2 and D_4 will conduct while D_1 and D_3 will not conduct. This generates a full wave rectification. The output of the rectifier is not DC in nature. It has to pass through series of network to make it appreciably linear. The stage after rectifier is the filter. This may be half T pass filter or pi network. It could also be T type filter. The purpose of the filter is to fill the trough in such a way that the output will resemble linear signal.

To avoid fluctuation in the output irrespective of the variation in the input signal, a stabilizer can be included and then a regulator. The st abilizer may be transistorized or zener diode built. The regulator assures constant current in the circuit.

The load in the project for this charging unit is the battery which in this case is 12 volts. The battery is charged during the time the mains supply is available. When there is no mains supply, the inverter derives its output from the battery.

3.4 The Changeover Circuit

This is the circuit that selects one of the available AC inputs and rejects the other. The section is basically made up of contactor, fuse and relays.

The choice of contactor is achieved by considering the capacity of the system. The intended capacity of the system is 1KVA and the output voltage is 230V.

Therefore the expected maximum current is given by

$$Imax = \frac{[illegible]}{[illegible]} \ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

$$Imax = \frac{[illegible]}{[illegible]}$$

$$Imax = 4.35A$$

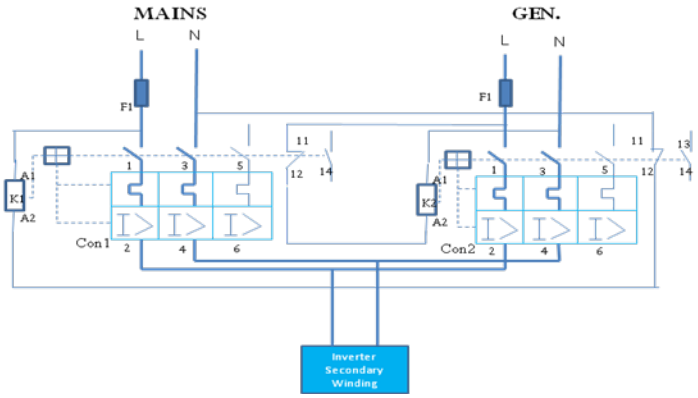

Figure5: *Input Changeover Diagram*

In the above diagram, two contactors (Con1 and Con2) are shown. The aim is for the system to choose its AC input from either Mains or Gen whichever is available. The two contactors are connected in such a way that they cannot be simultaneously energized. This is achieved by connecting the coil of one contactor through the normally close (NC) of the other contactor. If both inputs are present, the system chooses one of them. Note that one input can be deliberately prioritized it all depends on application.

4 Operation and Testing

4.1 The Principle of Operation

Since the operation of Multi-Input power supply is based on automatic switching, the system uses relays having switching time not noticeable by the load. In this section, the basic principle of operation of the system will be explained.

When there is power supply to the UPS, the relays are energized. It should be noted however, that one relay controls the oscillator from the battery. The second relay connects 240V winding of the transformer to the mains supply, thereby the 240V winding side of the transformer serves as primary and the 24v-0-24v winding serves as secondary. With the connection, the secondary winding supplies the diodes at the side of the inverter circuit which steps down the voltage. The diodes then rectify the AC voltage and supply it to the battery. This is the process of battery charging which is provided by the system itself. The battery will continue to charge and the switching circuit will be resting since the power to the oscillator has been cut-off by the relay 1.

When there is failure of power supply from the external supply, the relays are de-energized; they return to their former position. In this position, the first relay for the oscillator supplies power to the oscillating circuit while the second relay cut-off AC supply from the 240v winding side of the transformer. As the oscillator is energized by 12v, which is made accurate by regulator inserted in the oscillator circuit, the oscillator generates pulse train whose rate is dependent on the time constant of the circuit. In this project, the frequency of the oscillator is 50Hz ($\pm$ 5%). The oscillator gives the generated pulses to the gates of two rows of FET transistors in flip flop manner through the drivers which have been incorporated at the output of the oscillator. These powerful FET transistors drive the pulses to the 12v-0-12v winding side of the transformer. This side of the transformer now serves as the primary of the inverter. The transformer then steps up the available AC voltage at its primary to 240v at its secondary.

It should be noted that waveform of the voltage that appears on the secondary side of the transformer of the inverter is square in nature. Therefore, it is necessary to reshape the waveform to resemble sine waveform. This is done by the inductor-capacitor network included at output of the transformer prior to the output to the load.

In other to prevent back EMF from falling back to the inverter circuit thereby damaging the FETs, the diodes are incorporated in the inverter circuit. When the system is on AC external supply the AC indicator will light on. When it is on battery, the DC indicator will light on. The power switch controls the affairs of the whole circuit.

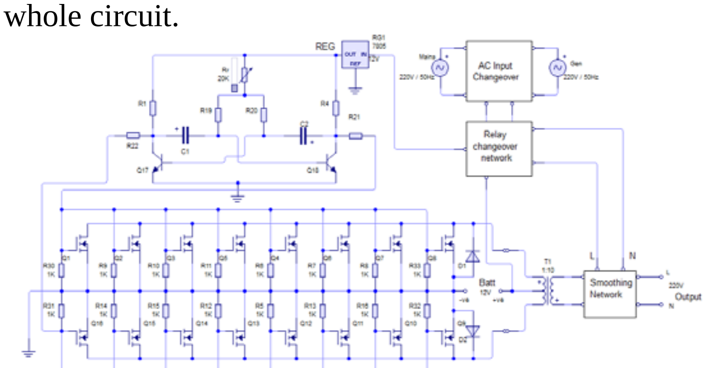

Figure 6: *MIUPS Circuit Diagram*

4.2 Test and result

The results of the tests conducted are tabulated below.

Table 1: Oscillator Test

Terminal	Value	Remark
Bias voltage (DC)	12V	Okay

Output voltage 1	6.2V	Okay
Output voltage 2	6.2V	Okay
Period	0.02s	Okay
Frequency	50Hz	Okay

From the result recorded in the tables above, the following can be deduced.

1. The bias voltage for the oscillator was enough to drive the oscillator in order to generate the required signal. Since the output of the oscillator is fed to the power amplifier. The signal has enough power to drive the transformer.

2. The output voltage 1 and output voltage 2 are equal which means that the two outputs are balance which is good for the transformer.

3. The frequency is 50Hz as designed. This is in conformity with the mains frequency and it will make the load on it not to experience change in frequency.

4. The output voltage from the comparator is adequate to drive the NPN transistor. The transistor is responsible for the energizing of the relay to switch off of inverter when the battery level is too low.

5 Conclusion and Recommendation

The importance of the Multi-Input Uninterruptible Power System (MIUPS) cannot be overemphasized in the industrial world. It finds its application where batteries are used to augments other sources of power and where electrical appliances and instruments are designed to operate on AC mains instead of DC. It can be seen that generator has high cost of purchase and maintenance and it also causes air pollution which are absent in MIUPS. This equipment can also be used with generator which removes the stress of changing from PHCN to generator.

MIUPS is an important equipment for ensuring absolute continuity of power supply to control system. This project dealt with the construction utilizing the present technology. The fact remains that there are lots of improvement and modification that could be made for better performance in the nearest future. The subunits recommended for modification are;

i. **Power rating:** The power rating of the MIUPS should be improved to carry higher wattage loads.

ii. **The switching circuit:** The relay used has relatively high switching time; but for better performance in the switching, transistorized switching circuits may be employed for faster switching.

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