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Design and Development of an Intelligent Uninterruptible Power Supply Stabilizer for Small Scale Industrial Application with Specifications 6000va, 220v, 50HZ

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ABSTRACT

An uninterruptible power supply (UPS) is a voltage storage device that allows an electrical or electronic appliance to maintain functionality while connected to the source of electricity for a reasonable period of time when the primary source ceases to provide power. There are different types of UPS. There are different types of UPS namely, Voltage and Frequency Independent (VFI-UPS), Voltage Independent (VI-UPS) and Voltage and Frequency Dependent (VFD-UPS). These types are dependent on the use, application and level of sensitivity of the appliance for which the UPS is designed. In the work implemented, new VFD concepts have the inverter producing power within 2 milliseconds after being activated which is an improvement of 12 to 20 milliseconds in earlier developments. This yields a 99% efficiency which is an obviously good result. It is recommended from the result that VFD-UPS be used in industrial applications where sensitivity has a high premium in boosting production.

Keywords: *Uninterruptible Power Supply (UPS); Voltage and Frequency Independent (VFI-UPS); Voltage and Frequency Dependent (VFD-UPS); Voltage Independent (VI-UPS)*

1. Introduction

An uninterruptible power supply (UPS) is a voltage storage device that allows an electrical or electronic appliance to maintain functionality while connected to the source of electricity for a reasonable period of time when the primary source ceases to provide power. Additionally, UPS devices also provide protection from power surges. The need for the device arises due to obvious breakdown occurrences which inevitably characterize the power distribution phenomenon in the system. This situation has been with the power sector for many years in the past even in the relatively advanced nations. The difference in power instability between the developing countries is only a matter of duration and not in actual occurrence. According to (1), even Germany experiences power failures averaging about 100 mains failures annually lasting less than 20 milliseconds in addition to about 30 failures lasting between 20 milliseconds and 1 second. The situation is worse in developing countries like Nigeria where the frequency of complete grid failures is more rampant. This has caused terrible damages to very costly equipment and appliances which break down with spurious and erratic power failures as they occur more frequently. Thus, when such equipment and appliances are put to use after experiencing erratic power off and on, it is usually discovered that they have either been totally damaged or have dropped considerably in efficiency functionality. Sometimes, death may occur when such equipment is used in hospitals to support life, such as in the case of oxygen support machines. All these developments have combined to make the need for the UPS device a necessity rather than a mere innovation or technology discovery.

A battery is a component part of a UPS. Its use is to kick in when the device senses an impending power failure from the primary source of power. To be able to react in this way, a measure of intelligence is required to be incorporated in the design of the device. This way, the UPS responds appropriately in the performance of its primary function. The primary function of every UPS is to convert incoming Alternating Current (AC) to its corresponding and equivalent Direct Current (DC). A rectifier is used to convert the AC to DC while making use of an inverter. The battery or flywheel acts as energy storage device for use in a utility future. Power is routed using a bypass circuit around the rectifier and inverter.

An incorporated intelligent system is meant to complete the real-time monitoring of the running UPS in addition to the normal operation of the corresponding part of the UPS, through the analysis and synthesis of various types of information, thereby analyzing and processing the important data information in the circuit. If some UPS fails, it can analyze according to the test result, diagnose the fault location, and give the treatment method; take necessary emergency protection control measures according to the site needs in time to prevent malfunction. This added facility ensures the expansion of the influence surface; the completion of the necessary self-maintenance, the exchange of information functions, as well as the ability to input data to or from the networked machine at any time. This project is aimed at developing an intelligent uninterruptible power supply stabilizer for use in small scale industrial operations.

2. Review of Related Works

Earlier works done in this area of research were reviewed and presented here.

Aghanwa et al (2017) in a research titled Design Analysis and Implementation of A 0.5 KVA Uninterruptible Power Stabilizer, stated that poor and instability of power supply delivery in Nigeria necessitated the need for a device that can stabilize voltage, protect equipment from damages and also provide power to the loads in the absences of electricity from the utility mains. The design of a power stabilizer (UPS) was motivated by this need. Pulse with modulation (PWM) method was adopted. With this method, modulating a varying input to a stabilized output was possible. Two input sources namely, a fluctuating 220 V volt mains supply and a constant 12 V battery were considered. In the absence of the utility mains, the 12 V battery was rectified to provide an AC power supply to the load. A stabilized output voltage from input range of 140 V to 260 V AC power capable of supplying about ±40V to the usual supply voltage from the utility mains of 180V-220V in Nigeria was ensured. Against surges, appropriate protection circuits were incorporated which ensured the safety of home/office appliances. To obtain various AC voltage levels during the testing, a variac was used. At different loadings (in watts) of the UPS, the voltage and current results were obtained. These results were compared with those of commercially readily available offline UPS of the same rating. Unlike the commercially available types, the UPS delivered a stabilized voltage of 220 V to different loads of 60 W to 400 W ranges at a fluctuating input voltage range of 140 V to 260 V. Thus, the designed UPS was an improvement and better device than the offline equivalent. Portability (light weight) and cost effectiveness (relatively cheap) were other qualities.

Krzysztof and Joanna (2018) in Analysis of the Quality of Uninterruptible Power Supply Using a UPS discussed the problem of the quality of electric current, indicating its disadvantages. On that basis and using the FTA method, a power failure tree diagram was developed. The simplest methods of hardware prevention of low power quality occurrence were shown. In this case, a power failure tree was also developed using the same method. The obtained results were compared and discussed, showing an improvement over conventional design.

Morkat et al, (2017) in Design and Construction of an Intelligent Uninterruptible Power Supply (IUPS), 500VA, 220V, 50Hz stated that an Uninterruptible Power Supply was a system connected between the electric grid and the consumer, comprising of electric hardware and rechargeable batteries. The project was meant to Design and Construct an Intelligent Uninterruptible Power Supply (IUPS) to provide an uninterruptible (continuous, steady, non-stop) and clean (qualitative) source of power supply of 500VA, 220V, 50Hz for domestic equipment it supplies and protects. This was achieved by fundamentally designing and constructing a battery charging circuit and an inverter circuit. An inverter is a power electronics device which converts DC (in this case, from a 12V DC battery) power to AC power (500VA) at the required output voltage (220V) and frequency level (50Hz). Upon power outage, a square wave would be generated using an AT89C51 microcontroller. This program controlled microchip device was the basis of realization of the project. Bipolar Junction Transistors were applied as switching system connected to the oscillating output pins of the chip. An inverter drive MOSFETs pairs were incorporated with a 12V~220V, center tapped transformer to transform the oscillating signal to pure AC signal. This project was powered by two power sources which switched between each other: the utility mains and a DC lead acid battery. The results conformed to the desired design analysis with acceptable and negligible errors. This research showed that the AT89C51 microcontroller can be used as a square wave generator (oscillator) as well as to control the working conditions of the system in which it is used.

3. Design Considerations and Implementations.

The design methodology applied in the development of intelligent UPS devices for use in different applications is presented here for evaluation and appraisal. This is with a view to making the desired choice as expected in this research. This leads to the presentation of types of UPS devices and their core features for clearer understanding of their operational capabilities, design and development.

3.1 Types of UPS, Features, Operational Capabilities and Development.

The following types of Intelligent UPS devices are hereby analyzed in line with their specific applications, technical use design and development considerations.

3.1.1 Voltage and Frequency Independent UPS (VFI-UPS).

A Voltage and Frequency Independent (VFI) UPS device is independent of voltage and frequency variations and also capable of protecting the load against adverse effects from such variations without reducing the stored energy source. Voltage and frequency independent (VFI) UPS systems are called dual or double conversion because incoming AC is rectified to DC to keep batteries charged and drive the inverter. The circuit arrangement of VFI UPS is shown in Figure 3.1. in the figure, an input alternating current, AC, splits into apparel circuit maintained by a rectifier and bypass, controlled by a surge protection device, SPD. A battery connected to the rectified AC and converts the power to a direct current value which is subsequently passed through an inverter. A surge protection device is also connected at the end of the inverter which recreates the required AC power to run any appliance in use. The battery drives the appliances when power fails to ensure continuous operation of the system at all times. The rectifier simultaneously delivers DC to the inverter as well as recharges the battery when power is eventually restored thus making the inverter run full time. Due to the fact that power delivery is continuous, vacuum fault interrupter is usually regarded the most robust UPS. However, it is still frequency dependent because most systems synchronize the output frequency with the input.

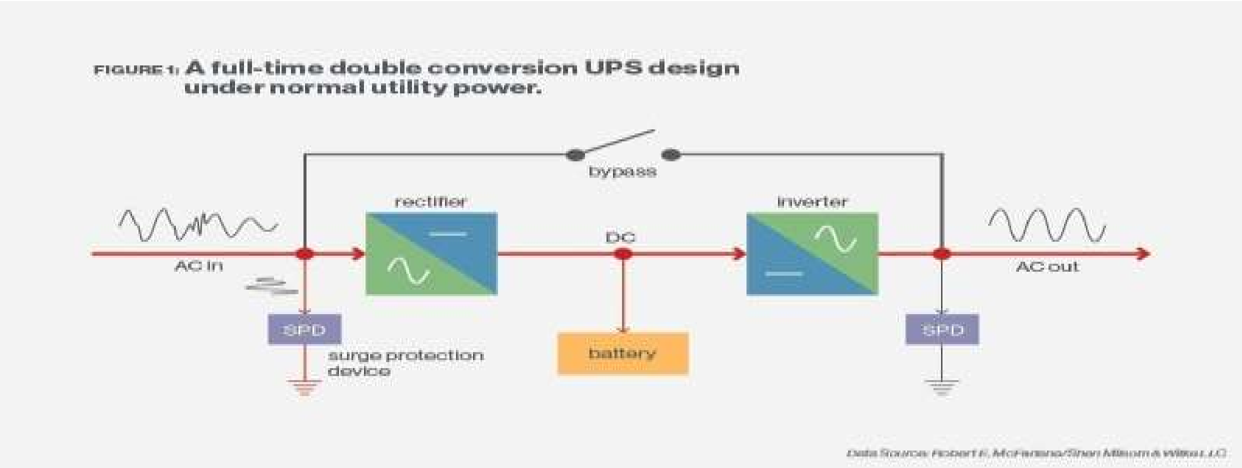

Figure 3.1(i): Voltage and Frequency Independent UPS (VFI-UPS).

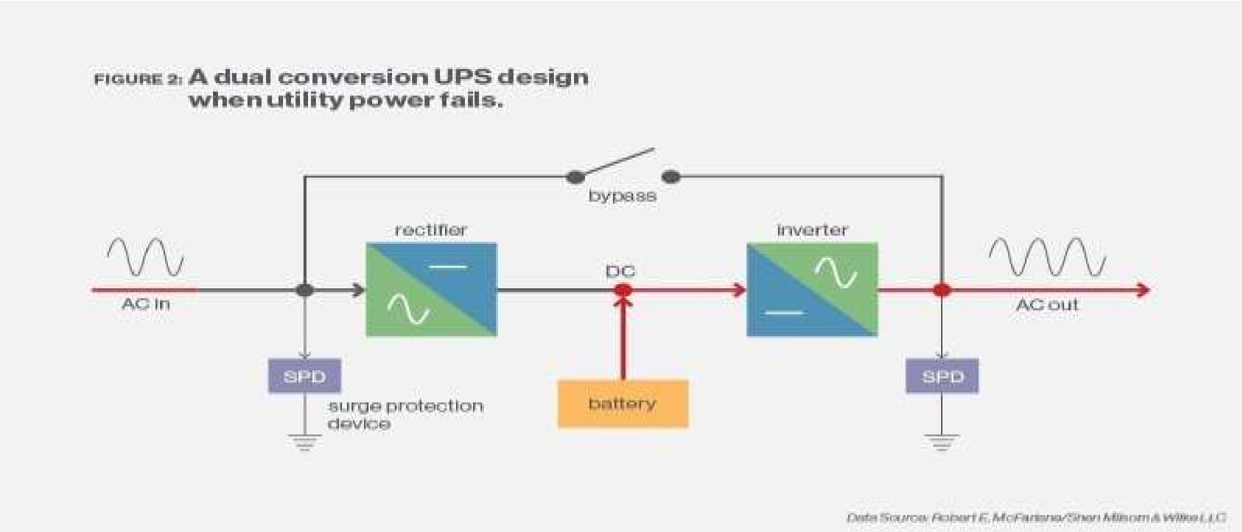

Figure 3.1(ii): Voltage and Frequency Independent UPS (VFI-UPS).

3.1.2 Voltage Independent UPS

Voltage independent (VI) UPS device, also known as true line interactive design UPS has a controlled output voltage while it maintains the same output frequency as the input. In developed countries, frequency independence is seldom a concern with power. Utility power feeds directly to the output and the appliance, and the rectifier keeps the batteries charged. The inverter is paralleled with the output, compensating for voltage dips and acting as an active filter for voltage spikes and harmonics. Rectifier and inverter losses only occur when incoming power fluctuates. Flywheels and motor/generator set also qualify as VI. Figures 3.2(i) and 3.2(ii) depict this phenomenon. These are under normal power utility 3.2(i) and when power fails 3.2(ii).

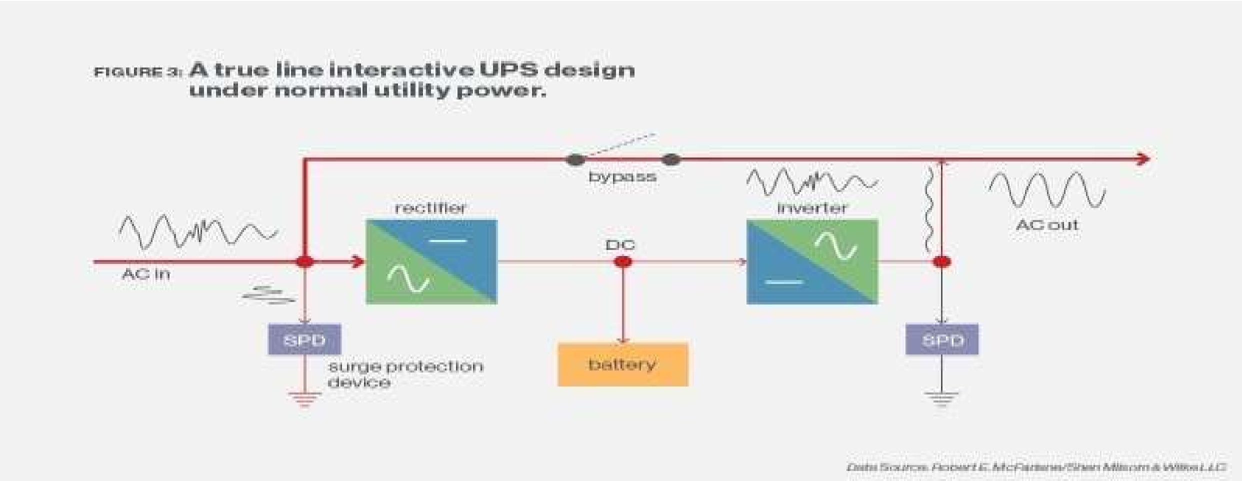

Figure 3.2(i): A Voltage Independent UPS

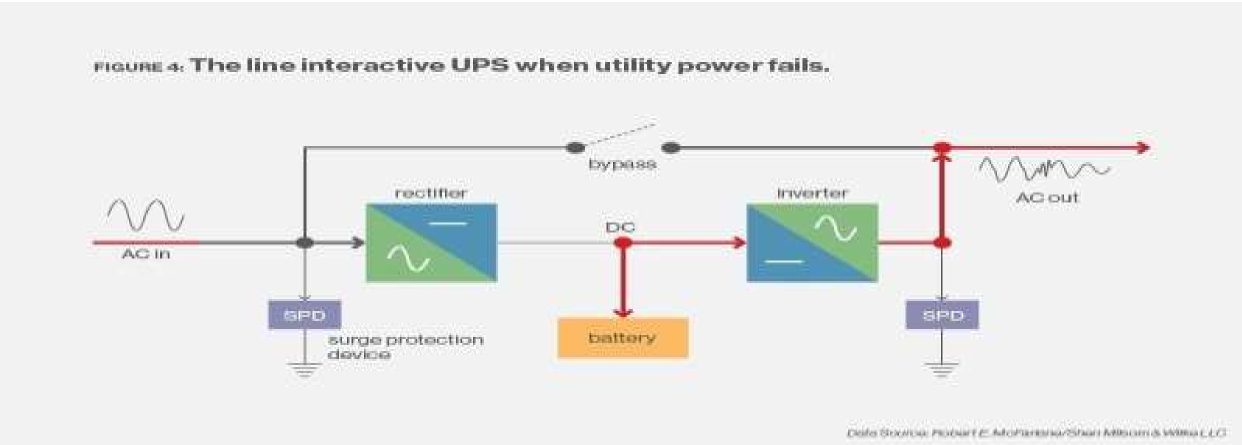

Figure 3.2(ii): A Voltage Independent UPS

When incoming power fails, or when the voltage goes out of range, the bypass quickly disconnects from the input and the battery drives the inverter. Conversely, when input power is restored, the bypass re-engages the input, re-charges the batteries and keeps output voltage constant. UPS vendors who use paralleled power sources claim no loss of reliability, thereby achieving a result of around 98% energy efficiency.

3.1.3 Voltage and Frequency Dependent (VFD)

Voltage and frequency dependent (VFD), or standby UPS, is operationally similar to VI and is sometimes erroneously called line interactive. In conventional VFD systems, the inverter is turned off, so it can take as long as 10 to 12 milliseconds to start creating power. That break can crash servers and other similar sensitive appliances, making legacy VFD UPS device a bad fit for data centers and other operations where sensitivity is required. This is shown in Figure 3.3(i).

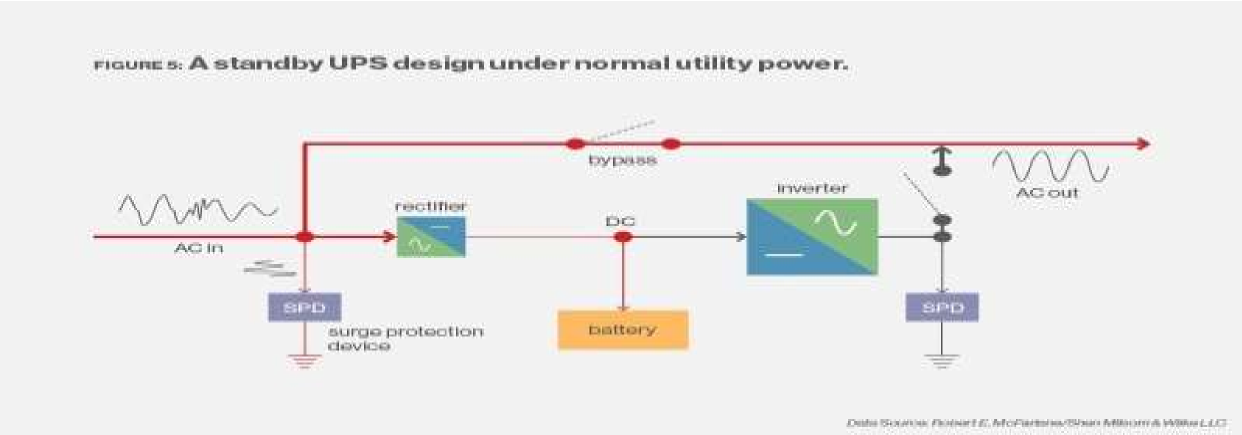

Figure 3.3 (i) Voltage and frequency dependent (VFD)

New VFD concepts have the inverter producing power within 2 milliseconds after being activated. The bypass is normally engaged, just as with VI, so that applied equipment operates directly from the utility or generator. Since the inverter does working until power fails, there is no voltage control or power consumed, enabling efficiencies as high as 99% which is evidently a really high design advantage. Power failure or voltage outside of range opens the bypass switch, disengaging input from the output thereby making the inverter to start operating from the batteries. The rectifier is only large enough to keep the batteries charged. This condition is shown in Figure 3.3(ii).

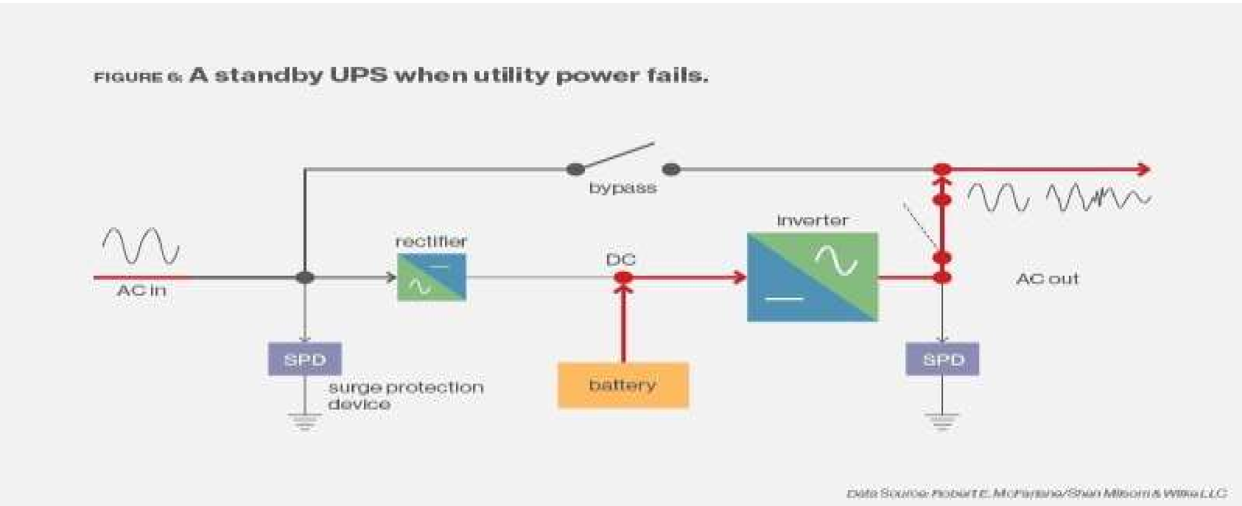

Figure 3.3(ii): Voltage and frequency dependent (VFD) (No Power Scenario).

The different configurations of the UPS device as presented in this research can find use in small scale industrial establishments depending on the capacity and level of operational application required. In each case, a normal rectifier design comprising of diodes meant to rectify the incoming AC power for use in conventional appliances is carried out. This is followed by a battery to provide needed DC power. Thereafter, an inverter arrangement is connected to ensure the inverting of the generated DC power to usable AC by appliances in use.

3.1.4 Design Specifications

The specifications for the design of the intelligent uninterruptible power supply intended in this work are presented as follows.

The DC input voltage, V1 = 12 V (by this it is meant to use a 12V battery).

The AC output voltage, V2 = 220V.

The operating frequency, f = 50Hz.

The output power, Pout = 600VA.

The Operating Time

The operating time is derived using the following principle.

Applying the principle of power balance, Power Input = Power Output.

$P_{in} = P_{out}$ 1

But $P = IV$ 2

Substituting for P in equation 1, the following results:

$V_1I_1 = V_2I_2$ 3

Where

$P_{in} = P_1 = V_1I_1$ 4i

Similarly,

$P_{out} = P_2 = V_2I_2$ 4ii

Considering equation 2, it is evident that

$I_1 = V_2I_2/V_1$ 5.

The data specifications earlier outlined at the beginning of this section is now substituted into equation 5. That is,

$V_1 = 12V$

$V_2 = 220V$

$P_{out} = 600VA$; and

$V_1I_1 = P_{out}$

This yields the following:

$I_1 = 600VA/12V = 50A$.

The design in this work uses a battery with standard battery rating of 12V, 7A-Hr. However, from the relationship:

Ampere-hour = Current x Time.

A-Hr = IxT 6

Thus,

T = A-Hr/I 7

T = 7A-Hr/50A

= 0.14Hr

T = 0.14x60

= 8.4 minutes.

This is the total time for which the UPS will supply energy to a load connected to it before it finally runs down. This means that increasing the number of batteries used in the design will increase the length of time the UPS will supply energy to the load connected to it given that the grid power has continued to be down.

There are merits and demerits of using intelligent based UPS. These are outlined below.

4.0 Merits and Demerits of Intelligent UPS Devices.

Merits of using uninterruptable power supplies in small scale applications include the following:

I. There is no delay between switching from the primary power source to the UPS.

II. It can provide better support for critical instruments compared to generators.

III. Consumers are exposed to choose regarding the type and size of UPS, depending on the amount of power they need to supply to a device.

IV. UPS devices are silent.

V. Maintenance of UPS systems is cheaper when compared to generators.

Demerits of using uninterruptable power supplies include the following:

i. The inability to run heavy appliances- because UPS devices are run off of batteries.

ii. If substandard batteries are used, users may end up replacing the batteries often.

iii. UPSs may need professional installations.

Considering the merits and demerits as outlined above, it is obvious that compared to conventional generators, the use of intelligent UPS in small scale industrial applications presents more reliable power availability.

5.0 Conclusion

The UPS uses the latest digital signal controller (DSC) to digitize the sensor to achieve 100% digital operation of the UPS system. A multi-processor redundant system is also used to control the rectifier, inverter, and internal static bypass with multiple microprocessors with independent power supplies, thus increasing the system's digitization and reliability. Given design considerations given in this paper, reliable UPS devices can be developed for use in small scale industrial applications as desired in this research. This will ensure continuous operational activities given the erratic nature of the power generated from the national grid.

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