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Performance Assessment of a Locally Designed and Fabricated Uninterruptible Power Supply

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Abstract - This paper assessed a 2kVA UPS that is locally designed and fabricated by setting up experiments that determined its characteristics and performance. Comparison was made between this UPS and four selected imported types, the local UPS was found to compete favourably with the imported, it measures up to international standard in terms of performance and also met the local demand in terms of geographical location, power fluctuation and it incessant failure. In addition, it is cost effective and easy to maintain.

Keywords: Battery voltage, Cost/effective load, Failure rate, Repair rate, Transfer rate, UPS.

1.0 INTRODUCTION

Due to the frequent occurrence of irrational power supply in a world where there is great need for economic, social and technological development, a need came for development of systems to enhance continuous and efficient operation of electrical equipment during power failure. These systems come in the form of standby power generating plants, backups, UPS, solar systems etc. Though backups and UPS fall under the same category because they depend solely on stored energy (battery) for their operation. The former is used mainly for lighting while UPS systems are designed to be fast enough in switching to avoid power surge that can affect smooth functioning of system like computer and medical instrument, against loss of vital information and life as the case may be.

UPS is a set of batteries, an inverter that transforms the low-voltage direct current of the batteries into standard alternating current used by computer and a battery charger that assures that reserve power is always available inside the batteries. In other words, it is a power storage system (battery) with interface to match it to utility power and the computer system. [1960].

Many organizations in Nigeria use imported units of UPS operating at various power levels, but they come with neither functional circuit diagrams nor circuit analysis of any kind. Therefore, we cannot claim that we have sufficient knowledge of the design, operation and control of these systems. Also, "run time" for these imported UPS is very short while those with longer backup time are very costly. Those of very short backup time cannot satisfactorily be efficient to suit the situation in Nigeria where power supplied is not free of pollution and prolonged outages. Also, some of the components that made up these UPS are not readily available to effect repairs in case of any damage.

It is important to note that this study carried out experiments to determine the characteristics of a locally designed and fabricated UPS and compared it with international standards. The study also considered the affordability of this locally produced UPS in terms of sales cost as compared with the imported. UPS comes in different shapes, some look like flattened outlet strips, others fit neatly in racks with platoons of

network servers. The most common form, however, is the bulky type, rectangular box type, meant to sit on the floor beside the computer system unit.

Due to the deplorable power condition in Nigeria, effort has been locally made towards the design and construction of UPS that is suitable and affordable to Nigerian. Ihemelandu, (1995) developed 15.2VA prototype UPS that can be used for a low power demanding machines/equipment. Martin (1997) designed and constructed a 400VA UPS, which was an improvement over that of 15.2VA. Also, Ogungbemi, [2000] designed and constructed 600VA UPS, the designed circuit used the same power transformer to supply both the inverting mode and the charging circuit, and this cause operational stress on the transformer and eventually shortens the unit life span. Ibehaga, [2002] designed and produced 1kVA UPS with 12volts D.C supply, in her work, the system cannot be used while the battery is being charge, this run down the battery and may not support a prolonged power outage also it lacks voltage and frequency control. Kareem/Adeoti (2015) designed and fabricated 2kVA UPS to be used for computer centers, business premises and domestic loads. This is the sample of locally produced UPS used for this study and was compared with the four available imported types.

Definition of Terms

- **UPS**: Uninterruptible Power Supply
- **Run time/Backup time**: is the number of minutes /hours that the UPS will be able to provide power from the battery for a given load when the utility power is off.
- **Transfer/Changeover time:** is the time taken by the UPS to switch over power to the load when utility power is off.
- **Force outage rate (FOR):** this is the rate at which the forced outage occurs on the system.
- **Mean time between failures (MTBF):** this is he applicable to repairable items and can be defined as the mean value of the length of time that elapses between failures.
- **Mean time to repair (MTTR)**: is the mean of the time requiring to perform maintenance action or to clear a fault on equipment.
- **Failure rate ():** this is the rate at which the system fails i.e. the number of failure occurring per unit time.
- **Repair rate (λ):** this is the number of repair that can be carried out on the system per hour.
- **Availability (μ)**: the probability that the system when used under given conditions, will perfotin satisfactorily when called upon.
- **Reliability (R)**: is the probability that the system will perform as required, under stated conditions, for a stated period of time.
- **PC:** Personal Computer

2 METHODOLOGY

This work determined the characteristics and features of a locally produced UPS. The apparatus used and their ratings are stated below:

Apparatus:

Battery: (Automotive battery), Boost 2xl2volts, 60AH

Load: IPC 330W

UPS: 2kVA

Printer: 352W

Experiment: Run time/Load Capacity

One computer system was set up, and the UPS was connected to it, and supplies the entire system with alternating current (A.C) supply from the utility power.

The A.C supply was Switched ON and the battery was fully charged, after which the A.C was switched off and allowed the UPS to supply the load from the storage battery until battery low alarm came up. The duration between the A.C was switched OFF and low battery alarmed; the battery voltage level and the A.C output hourly were recorded (Table 1). This experiment was recorded by increasing the follows: 2PC, IPC+1 Printer, 2PC + 1 Printer up to 2000 VA load.

Experiment: Transfer time/Change over Time

The UPS was connected to a computer system and powered by A.C utility supply, the system was allowed to boot and worked for some minutes.

The A.C supply was switched off the system to observe interruption to the operation of the system

Experiment: Battery Charging Time

A computer system was connected to the UPS with partially discharged automobile battery, the A.C supply was switched ON.

The computer system was allowed to run for some minutes (10 minutes) after which the A.C supply was switched off and allowed the computer system to run on the stored power from the UPS until battery low alarm/indicator came on.

The battery voltage level was recorded; the A.C power was then switched ON to allow the charging unit of the UPS charged the battery, the timing was started immediately until the fully charged indicator came on. The voltage at fully charge was measured. This process was repeated twice.

3 Performance Measurement

The UPS was placed in operation for 672 hours and the failure data were recorded. The data were used to solve some mathematical equivalents for the performance criteria to characterize the UPS: Meantime between failure, Failure rate, Meantime to repair, Availability, Cost/effective hour and Cost/effective load. The mathematical expression to describe functions is Exponential model (Oroge, (1991), Elwood, S.B and Rakesh, K.S (1987)).

FOR = (forced outage hour (FOH))/ Hours of continuous operation (1)

MTBF = Service hour/No of failure recorded in 672 hours (2)

MTTR = Forced outage hour / No of failures (3)

$\lambda = (MTBF)^{-1}$ (4)

$\mu = (MTTR)^{-1}$ (5)

A = MTBF / (MTBF+MTTR) (6)

$R = e^{-\lambda t}$ (7)

Where t is the operating time = 672hours.

Cost /effective run time = cost of item/ Run time (Hour) (8)

Cost/effective load= cost of item / Load capacity (9)

4 RESULT AND DISCUSSION

RESULT

The results of the experiment are shown in Tables as follow:

Table 1: Run-time for connecting 1 PC

Time (Hrs)	Battery voltage (D.C)	AC Output (V)
00.00	28.00	243
01.00	27.30	242
02.00	26.80	240
03.00	26.40	238

04.00	26.00	236
05.00	25.60	235
06.00	25.10	235
07.00	24.00	227
08.00	23.80	223
09.00	23.40	220
10.00	23.00	219
11.00	22.6	213
Runtime =10 Hrs		

Table 2: Run-time for connecting 1 PC and 1 Printer

Time (Hrs)	Battery voltage (V)	AC Output (v)	Remark
00.00	28.00	243	The printer was engaged three times within this period of operation. (3 minutes each Time.)
01.00	27.00	240	
02.0	26.40	238	
03.00	25.60	235	
04.00	24.00	227	
05.00	23.40	220	
06.00	23.00	219	

Table 3: Run-time for connecting 2 PC and 1 Printer.

Time (Hrs)	**Battery voltage D.C(V)**	**A.C Output (v)**	**Remark**
00.00	28.00	243	The printer is first switched ON before
01.00	26.10	236	

02.00	24.10	227	the two systems.
03.00	23.40	220	The printer was
04.00	22.60	213	engaged in operation (3 minute each time)

Table 4: UPS Load Capacity

Load (VA)	Battery voltage (V)	AC output (V)	Current output (A)
0.0	28.00	240	0.00
100	27.80	240	0.40
500	27.00	235	2.12
1000	26.00	235	4.25
1500	25.00	230	6.52
2000	24.00	230	8.60
2100	24.00	225	9.21
2200	24.00	000.00	UPS tipped on overload

Table 5: Charging Time

Time (Hours)	Battery Voltage (V)
0.00	19.00
0.70	20.00
1.40	20.45
2.10	22.00
2.80	23.00
3.50	24.50
4.20	25.00
4.90	26.00
5.70	27.00
6.42	28.00

Table 6: Characteristics of a locally produced and some selected foreign UPS

NAME	**Toutch-mate**	**APC**	**Maxima**	**Blue-Gate**	**Okin Sonic**
SPECIFICATION					
Power rating	2KVA	2kVA	2kVA	2kVA	2kVA
Input voltage (A.C volts)	150-275	170-270	150-275	150-270	190-240
Output voltage (AC volts on inverter)	220+/-5%	220+/-5%	220	220	230
Frequency	50Hz	50Hz	50Hz	48-60Hz	48-60Hz
Battery voltage	24V D.C	24V D.C	24V D.C	24V D.C	24V D.C
Recharge time	1 01-lours	Not specified	8Hours	Not specified	7Hours
Wave-form	Quasi-sine	Quasi-sine	Quasi-sine	Quasi-sine	Quasi-sine
Transfer time	1.5ms	1.5ms	1 .3rns	1.0ms	I .3ms
Load capacity	8 P.C	7 P.C	8 P.C	8 P.C	8 P.C
Run time	1 Hour	1 Hour	50 minutes		1 ½ Hours
Availability of material	Not all is locally available	Not all is locally available	Not all is locally available	Not all is locally Available	All is locally Available
Portability	10Kg	11Kg	9Kg	10Kg	12Kg
Efficiency	Not given	Not given	Not given	Not given	90%
Cost of production	Not given	Not given	Not given	Not given	N55, 000
Sales cost	NI 00, 000	N114, 000	N120, 000	N 100, 000,	N65, 000
Name of manufacturer	Touch-mate electronic Industry, Indonesia	American Power Converter, USA	Maxima Industry, China	Blue-Gate Industry Ltd.	Kareem & Adeoti
Year of manufacturer	April, 2014	December, 2013	February, 2014	Not indicated	\August, 2015

Performance measurement

Availability (A%) = 99.80

Mean time to repair (MTTR) 0.83hours

Mean time between failure (MTBF) 672hours

Failure rate (λ) = 1 .48x 10^{-3}/Hr

Repair rate (μ) = 1.26/Hr

Cost/effective hour: ₦ 13,750

Cost/effective load: ₦ 55.00

DISCUSSION

The run time is the number of minutes the storage battery was able to provide power to the load when the utility power is switched off. Driving more load result to shorter runtime. A UPS with a larger battery capacity, or with an add-On battery pack, will provide longer run time for a given load size (Table 1,2, and 3).

The UPS maximum capacity is 2100VA, but going to 2200VA cause the UPS to be over loaded and shutdown. The reason for this maximum capacity is not just the batteries, it is also a function of the ability of the UPS's circuitry and it wires to handle a particular size of load. It is also a safety issue, as exceeding the current limit of the circuit will have a damaging effect on the UPS system (Table 4). Transfer time/change over time could not be measured, though no interruption of power to the system was observed and no information was lost. This indicates that a very fast switching device was used. (In the region of milliseconds)

The time it takes the battery to fully charged from it discharged voltage level of 19 volts is 6hrs 42mins. This charging time may vary, depending on; the voltage level supplied by the utility, the state/condition of the battery, the age of the battery and it capacity. The higher the voltage from the utility (not more Than 240V), the less the charging time. Also, battery in it newest stage charges faster than old ones. Meanwhile the higher the capacity of the battery, the longer the charging time at the normal supply voltage (Table 5).

A critical study of the sets of UPS imported and locally produced in Nigeria, reveals that those produced locally are cost effective and more easily affordable as against foreign UPS that are of the same capacity. A quick look at table 6 shows a wide difference in the sales cost between the few selected foreign and locally produced UPS. Furthermore, in Nigeria that is saddled with epileptic power supply and long duration of power outage, the locally produced UPS will support power sensitive equipment for a longer period of time. The duration of power supply can also be increased as may be demanded by the user, but this cannot be achieved using foreign UPS. Where foreign UPS, must be used, an additional cost will be incurred. Meanwhile, the incessant power outage in Nigeria easily damages the foreign UPS; because it is not designed for such power surge as obtained in Nigeria.

In addition, all the materials and component of the locally produced UPS could be obtained from the local market at lower prices; which makes it easier to repair in case of any damage, since the materials are readily available. Whereas, nearly all the components and materials of foreign UPS are custom built, they

are manufactured for their product alone. Also in debt knowledge of some of these components is exclusively reserve to the producer; this makes it difficult for technician to effect repairs, in case of any damage. However, both foreign and locally produced UPS are not technically different from each other in terms of; capacity, performance, protection against disturbances, short switching time, acceptable level of various form of risks, operating principle and acceptable quality of output power. Military components (i.e. component that has no moving part) are used in constructing both sets of UPS, giving it an assurance of longer life span (Table6). Most importantly, change- over time or switching time from the mains to the battery and vice-versa is within the standard.

5 CONCLUSION

The results of the study indicated that, locally fabricated UPS will be cost effective and affordable to the users if it is mass produced and, it will compete favorably with the available foreign UPS of the same rating. Moreover, it is fabricated to withstand abnormal power condition that may be found in Nigeria and elsewhere. In addition, based on the cooling system, it is made to suit the weather condition of the tropical region as found in Nigeria.

6 RECOMMENDATION

The following recommendation shall improve the effectiveness of the UPS system and reduce the cost of production; also it will make the unit more portable:

The use of circuit designing software, instead of the manual hand fills drawing of the circuit tracks. This reduces the size of the circuit board and makes it more sophisticated.

The iron-core transformer could be replaced with ferric core transformer, which is of higher efficiency. Replacement of iron core with ferric, will invariably reduce the size and cost of the casing. These make the unit portable and probably reduce the cost per unit when it is mass-produced.

The use of deep cycle/marine battery instead of automobile battery will drastically increase the runtime of the system.

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