International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 2 ‖ February. 2013 ‖ PP.60-73

Mathematical Modeling for Reliability Assessment of Uninterruptible Power Supply System in Sokoto State, Nigeria

M.B. Adamu[1], M. Momoh[2], I.G Saidu[3], N.S. Jega[4], M.I. Ilyasu[5], A. Tukur (MIEEE, MIET, MITP)[6], S. Buda[7]

[1,2,6]*(Physics department, faculty of science, Usmanu Danfodiyo University, Sokoto- Nigeria)*
[3,5]*(Physics unit, Sokoto state polytechnic, Sokoto- Nigeria)*
[4]*(School of nursing and midwifery Binin Kebbi, Kebbi state-Nigeria)*
[7]*(Renewable energy research centre, Usmanu Danfodiyo University, Sokoto-Nigeria)*

ABSTRACT: *Uninterruptible Power Supply (UPS) is a system which is designed to provide a short-term power supply for our constant power demanding electronic equipment. This research paper presents a mathematical modeling for the reliability assessment of UPS system in Sokoto State, Nigeria, using part stress method. Data on failures of APC BG650MI in Sokoto were used as a case study, with special consideration given to factors like environmental impact, quality of power supply, service personnel, human factors (over and under usage). A comparative assessment was made on the reliability and reliability indices of the UPS when operated within Sokoto environment and when operated within the environment for which it was planned (USA). The result shows that lower reliability level is associated with the use of the UPS in Sokoto State of Nigeria, as compared with the country for which it was designed.*

Keywords: *Availability, failure rate, Maintainability, Modeling, MTBF, MTTF, Reliability,*

I. INTRODUCTION

1.1 Background to the study

To help us better understand our world, we often describe a particular phenomenon mathematically by means of a function or an equation called model. Such mathematical model is an idealization of the real-world phenomenon and never a completely accurate representation [1]. Hence model can only approximate real-world behavior. However most models simplify reality, a good one can provide valuable result and conclusions. Also mathematical model can help us understand a behavior better or aid up in planning for the future. The model allows us to reach mathematical conclusions about the behavior of system as illustrated in fig. 1.1 [13]

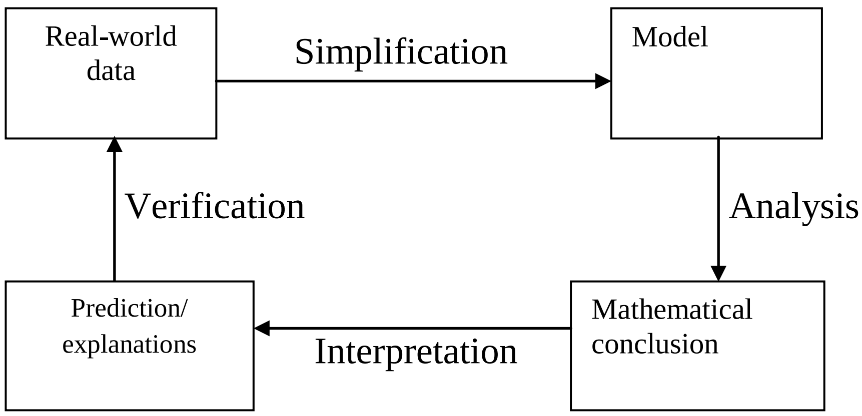

Fig 1.1: A flow of the modeling process beginning with an examination of the real-world data.

Reliability is the ability of an apparatus, machine, or system to consistently Perform its intended or required function or mission, on demand and without degradation or failure. It can also defined as the probability of failure-free performance over an item's life, or a specified timeframe, under specified environmental and duty-cycle conditions; often expressed as mean time between failures (MTBF) or reliability coefficient [18][19], also called quality over time [16]

II. FAILURE RATE PREDICTION

Prediction model

The failure rate of the system is calculated by summing up the failure rates of each component each category (based on probability theory). This applies under the assumption that a failure of any component is assumed to lead to a system failure. [4][9][17].

Failure rate prediction at reference conditions (part count)

The failure rate for equipment under reference conditions is calculated as follows:

$$\lambda_{s,i} = \sum_{i=1}^{n} (\lambda_{ref})_i$$

Where

$\lambda_{s,i}$ is the failure rate of equipment made up of several components

λ_{ref} is the failure rate under reference conditions

n is the number of components

The reference conditions adopted are typical for the majority of applications of components in equipment. Reference conditions include statements about [5]

- Operating phase
- Failure criterion
- Operation mode (e.g. continuous, intermittent)
- Climatic and mechanical stresses
- Electrical stresses.

It is assumed that the failure rate used under reference conditions is specific to the component [7][8]

Failure rate prediction at operating conditions (part stress)

Components in equipment may not always operate under the reference conditions. In such cases, the real operational conditions will result in failure rates different from those given for reference conditions. Therefore, models for stress factors, by which failure rates under reference conditions can be converted to values applying for operating conditions (actual ambient temperature and actual electrical stress on the components) a uired.

$$\lambda_{s,i} = \sum_{i=1}^{n} (\lambda_{ref}\ \pi_u\ \pi_I\ \pi_T)_i$$

Wher

λ_{ref} is the failure under reference conditions

π_u is the voltage dependence factor

π_I is the current dependence factor

π_T is the temperature dependence factor

n is the number of components [6][8][12].

The factors should be used for converting reference failure rates to field failure rates. The stress models are empirical and allow fittings of observed data [17].

The failure rate prediction process

The failure rate prediction process consists of the following steps.

- Define the equipment to be analysed

- Understand system by analyzing equipment structure
- Determine operational conditions: operating temperature, related stress.
- Determine the actual electrical stresses for each component.
- Select the reference failure rate for each component from the database.
- In the case of a failure rate prediction at operating conditions calculate the failure rate under operating conditions for each component using the relevant stress level.
- Sum up the component failure rates
- Document the results and the assumptions.

The following data is needed

- Description of equipment including structural information
- All components categories and the number of components in each category.
- Failure rate at reference conditions for all components

Relevant stress factor for the components.[6][9]

Types of power problems and effect on critical load (UPS)

There are many types of power disturbances that cause electronic equipment like UPS to malfunction. These disturbances include [14] sag, noise, surge, brown-out etc. fig 2.1 below shows how the above mentioned disturbances are manifested [11].

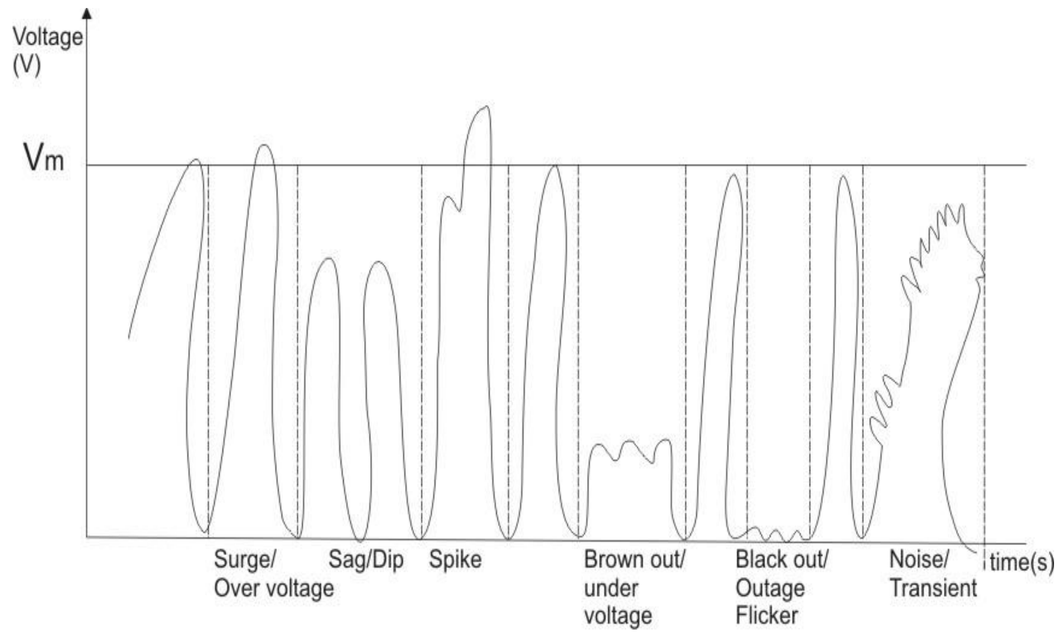

Fig.2.1: disturbance on the ac line

III. ASSUMPTIONS

As stated earlier, failure rate predictions and hence, the reliability assessment of a system demand that certain assumptions must be made. In this research, the following, assumption were made in the mathematical modeling for reliability assessment of the UPS under consideration

1. The components are assumed to be working at maximum rated power (maximum watts). It is generally assume therefore that weighting factor due to rating W_R for capacitor, transistor diode and resistor are 6.0, 2.0 and 1.0 respectively [9][15][19][21]
2. The Operational environment is at normal room temperature of 28^{O}C and there is no mechanical motion/vibration or shock experienced by the UPS.
3. No specific value is usually allotted to the derating factor of items such as crystal connector and heat sink, in the literature [19]. They are generally assumed to be unity in the computation of the overall failure rate. Thus is to be adopted in this thesis.
4. Electronic components may be connected either in series or parallel. While reliability prediction techniques such as similar complexity and prediction by function techniques take the method of connections into consideration, the parts stress method does not [9]. In this research, reliability is evaluated strictly and only on the basis of operational stress of the component parts of the system

3.3 Reliability Indices

Two of such parameters that are commonly used according to Susan, (2010) are the
Mean time before failure (MTBF) and Mean time to failure (MTTF)

3.3.1 Mean Time before Failure (MTBF)

For a repairable system, mean time before failure (MTBF) is the mean or average time before successful failures of the system [10]. The MTBF can be obtained by running a system for a predetermined length of time under specified conditions. Hence for the failure race λ, which is the number of failure per unit time, MTBF is given by [9][15][19][21]

$$MTBF = \frac{1}{\lambda} \qquad (3.1)$$

3.3.2 Mean Time to Failure (MTTF)

The mean time to failure (MTTF) is used for component or items that are not repairable example filament lamps, resistors, capacitors and so on, which are disposed off as soon as they fail.[19][21].
MTTF can be computed after testing a numbers of items, N in a specified way (example by applying certain electrical, mechanical, heat or humidity conditions) until all failed.

If the times to failure are (t_1, t_2, t_3…..t_n) then the observed MTTF is given [19] as $MTTF = \frac{\sum_{t=1}^{n}(t_i - t_0)}{N}$

i.e. $$MTTF = \frac{(t_1 - t_0) + (t_2 - t_0) + \cdots + (t_n - t_0)}{N}$$

where t_0 = starting (reference time)
($t_1 - t_0$) = period to 1st failure
($t_2 - t_0$) = period to 2nd failure
($t_n - t_0$) = period to nth failure
N = total number of failure components.
Consider the case in which a fixed number N_0 of identical components are tested.
Let N_s = number surving up to time t.
N_f = number failed up to time t.
$N_0 = N_s + N_f$ = total number in operation at t=0
∴ Reliability at any time t becomes

$$R(t) = \frac{N_s}{N_0} \qquad (3.2)$$

The failure rate λ(t) is normally defined by the mathematical relation

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{1}{N_s} \times \frac{\Delta N_f}{\Delta t}$$

$$\lambda = \frac{1}{N_s} \times \frac{dN_f}{dt} \qquad (3.3)$$

where N_s = number of serving items after a life test
ΔN_f = number of failure item during the time interval, Δt.
Consider the case in which a fixed number N_0 of identical components are tested,
Let N_s = number surving up to time t
N_f = number failed up to time t
$N_0 = N_s + N_f$ = total number in operation at t=0
∴ Reliability at anytime t becomes

$$R(t) = \frac{N_s}{N_0}$$

and failure rate (for constant failure rate)

$$\lambda = \frac{1}{N_f} \times \frac{dN_f}{dt} \quad \text{from Equation (3.3)}$$

$$\lambda = \frac{1}{N_0 - N_s} \times \frac{dN_f}{dt}$$

or $$\int \lambda dt = \int \frac{1}{N_0 - N_s} dN_f$$

introducing the limits

$$\int_0^t \lambda dt = \int_0^{N_f} \frac{1}{N_0 - N_s} dN_f$$

$$\lambda t = -\left[\log_e\left(N_o - N_f\right) - \log_e\left(N_o - 0\right)\right]$$

$$-\lambda t = \log_e\left(\frac{N_0 - N_f}{N_0}\right)$$

Thus $$e^{-\lambda t} = 1 - \frac{N_f}{N_0} \qquad (3.4)$$

But from Equation (3.3)

$$R(t) = \frac{N_s}{N_o} = \frac{N_0 - N_s}{N_0} = \left(1 - \frac{N_s}{N_0}\right) \qquad (3.5)$$

Comparing equations (3) and (4), we have

$$R(t) = e^{-\lambda t} \qquad (3.6)$$

The general expression for MTBF, m is [9][19][21]

$$m = \int_0^\infty R(t)dt \qquad (3.7)$$

For the case when λ is constant from equation (3.6)

$R = e^{-\lambda t}$ so equation (3.7) becomes

$$m = \int_0^\infty R(t)dt$$

$$= -\left[\frac{1}{\lambda} e^{-\lambda t}\right]_0^\infty$$

$$= -\frac{1}{\lambda}\left[e^{\infty} - e^{0}\right]$$

$$m = \frac{1}{\lambda} \qquad (3.9)$$

If failure are due to chance and if the failure rate λ is constant, then

$\lambda = \frac{1}{MTTF}$ for non-repairable items

$\lambda = \frac{1}{MTBF}$ for repairable items

3.3.3 Equipment Availability

Equipment availability is the probability that an equipment will perform its required function at a stated instant of time or over a stated period of time [19]. Availability is a function of the utilization factor (μ). The utilization factor of a unit or system is defined as the ratio of the operating time (t_{op}) to the sum of maintenance time (t_m), idle time (t_{id}) and operating time (t_{op}), which may occur between completion of maintenance and the use due to administrative reason [22]

Mathematically,

$$\therefore \quad A = \frac{MTBF}{MTBF + MTTF} \qquad (3.10)$$

3.4 Failure rates of Electronic components
The general expression for the failure rate of the parts stress method is given as;
$\lambda_i = \lambda_B \pi_E \pi_A \pi_Q \pi_N \ldots /10^6$ hrs (3.11)
Where
λ_i = The failure of the i[th] part
λ_b= The basic failure rate obtained from derated data for each generic part against normalized stress and temperature factor.
π_E= Account for the environmental factors other than temperature
π_Q= Account for the quality factor
π_N= Account for the any additional factor that has not been taken care of above [17]

Reliability in UPS design
In each UPS design, it is possible to obtain the system reliability in Sokoto as compared to designed reliability for the target environment. Part stress method is used in this work to obtain the failure rate. Two failure rates therefore, will be estimated.
(a) Designed failure rate- as will be applicable to the system operating in the environment for which it was designed for.
(b) Relative failure rate- as will be applicable to the system operating in the Sokoto.

The conclusions arrived at can be used as guide lines for optimal design of system operating in the region of interest and hence assess the reliability of any UPS model operating in the region.

3.4.1 Program Organization
The main program are in six parts, namely the effective failure rate of UPS for designed country, effective failure rate of UPS in Sokoto State, reliability, Mean time to repair (MTTR), Availability of the UPS components and finally the redundancies of the parallel component in the UPS.

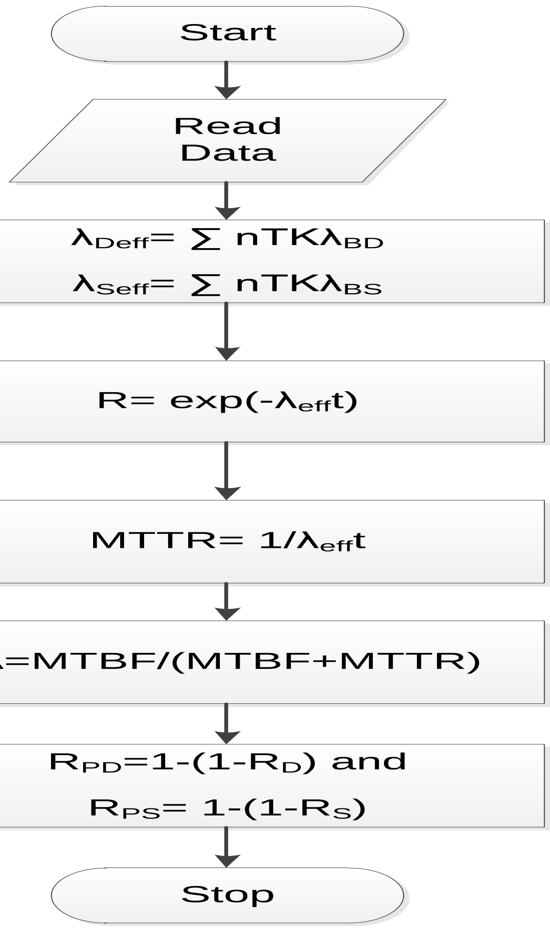

Fig3.1 flow chart

IV. RESULTS AND DISCUSSIONS

4.1 Failure rate results

Tables 4.1 and 4.2 shows the failure rate results obtained for each component in the UPS under consideration.

Circuit Components	Description of components	No. of component (n)	Room tempt in USA (TD)	Room tempt in Sokoto (T(s)	Base failure rate for components in USA (λBD ×10-6)	Base failure rate for component in Sokoto (λBS×10 -6)	Voltage stress ratio (K)	Effective failure rate in USA (λBDeff)	Effective failure rate in Sokoto (λBSeff)
F3	AC FUSE (1A,239V)	1	21	28	0.02	0.02	0.94	0.3948	0.5264
F2	1A,125V	1	21	28	0.02	0.02	0.96	0.4032	0.5376
F1	30A, 32V	1	21	28	0.02	0.02	0.375	0.1575	0.21
F4	30A, 32V	1	21	28	0.02	0.02	0.375	0.1575	0.21
IC1	LM78DN (REGULATORS)	1	21	28	0.007	0.91	0.125	0.018375	3.185
IC3	CD40106BCN	4	21	28	0.01	0.91	0.81	0.6804	10.8864
IC4	LM339N	3	21	28	0.007	0.12	0.81	0.35721	61.9164
IC5	CD4011BCN	3	21	28	0.01	0.19	0.8107	0.510741	8.1719
IC6	CD4066BCN	2	21	28	0.01	0.12	0.8107	0.340494	5.4479
IC7	SG3542BN	1	21	28	0.011	0.12	0.3875	0.0895125	1.6275
C5	FILM CAPACITOR	1	21	28	0.0008	0.15	0.22	0.003696	0.6776
C21	FILM CAPACITOR	1	21	28	0.0008	0.011	0.1167	0.0019606	0.03594
T1	LOW POWER TRANSFORMER	1	21	28	0.019	0.011	0.9435	0.376457	9.2463
T2	HIGH POWER TRANSFORMER	1	21	28	0.003	0.35	0.1043	0.0065709	0.13726
D4-D7	BRIDGE RECTIFIER	1	21	28	0.0066	0.047	0.0192	0.0026611 2	0.2742
D8	DIODE	1	21	28	0.0066	0.51	0.0052	0.0007207 72	0.074256
D47	DIODE	1	21	28	0.0066	0.51	0.0066	0.0009147 6	0.09423
RY1	RELAY	8	21	28	0.44	0.51	0.272	2.51328	21.3248
FET	INVERTER CIRCUIT	1	21	28	0.046	2.8	0.2143	1.6561106	76.80512
J3	TOGGLE	1	21	28	0.035	0.61	1	0.735	17.08
R51	WIRE WOUND RESISTOR	1	21	28	0.0085	0.078	2.77	0.49445	6.04968
R56	WIRE WOUND RESISTOR	1	21	28	0.0085	0.078	0.3	0.5355	0.6552
R53	WIRE WOUND RESISTOR	1	21	28	0.0085	0.078	2.7	0.48195	5.8958
R59	WIRE WOUND RESISTOR	1	21	28	0.0085	0.078	1.54	0.27489	3.36336
VR2	VARIABLE RESISTOR	1	21	28	0.086	1.3	0.5097	0,9.20518 2	18.55308
R60	WIRE WOUND RESISTOR	1	21	28	0.0085	0.078	0.5	0.08925	1.092
R38	FILM RESISTOR	1	21	28	0.0051	0.0066	2.45	0.262395	0.452776
R22	FILM RESISTOR	1	21	28	0.0085	0.078	0.55	0.098175	1.2012
VR3	VARIABLE RESISTOR	1	21	28	0.0051	1.3	0.3333	0.6019398	12.13212
R14	WIRE WOUND RESISTOR	1	21	28	0.0085	0.078	2	0.336	4.368
R15	WIRE WOUND RESISTOR	1	21	28	0.086	0.078	0.41	0.073185	0.89544

R16	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**0.61**	**0.108885**	**1.33224**
R20	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**0.07**	**0.012495**	**0.15288**
R17	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**0.04**	**0.00714**	**0.08736**
VR4	**VARIABLE RESISTOR**	**1**	**21**	**28**	**0.0085**	**1.3**	**0.7618**	**1.3758108**	**27.72952**
VR18	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**0.45**	**0.080325**	**0.9828**
R19	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.086**	**0.078**	**0.88**	**0.15708**	**1.92192**
R127	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**0.18**	**0.03213**	**0.39312**
R27	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**11.5**	**2.05275**	**25.116**
R126	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**0.18**	**0.03213**	**0.39312**
R28	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**11.5**	**2.05275**	**25.116**
RC1	**CHOKE RESISTOR**	**1**	**21**	**28**	**0.072**	**0.045**	**0.044**	**0.066528**	**0.5544**
BATTERY	**6V, 11AMPS BATTERY**	**2**	**21**	**28**	**1.9**	**2.58**	**1**	**79.8**	**144.48**
TOTAL								**97.8714308**	**500.777966**

TABLE 4.1 Failure for the BG650MI (series components)

Circuit Components	**Description of components**	**No. of component (n)**	**Room tempt in USA (T_D)**	**Rom tempt In Sokoto ($T_{(s)}$)**	**Base failure rate for components in USA (λ_{BD} X^{10-6})**	**Base failure rate for component in Sokoto (λ_{BS} X^{10-6})**	**Voltage stress ratio (K)**	**Affective failure rate in USA (λ_{BDeff})**	**Affective failure rate in Sokoto (λ_{BSeff})**
C3	**ELECTROLYTIC CAPACITOR**	**1**	**21**	**28**	**0.0047**	**0.025**	**0.5148**	**0.05081076**	**0.36036**
C27	**ELECTROLYTIC CAPACITOR**	**1**	**21**	**28**	**0.0047**	**0.025**	**0.7613**	**0.07514031**	**0.53291**
C23	**CERAMIC CAPACITOR**	**1**	**21**	**28**	**0.011**	**0.047**	**0.0002**	**0.0000462**	**0.0002632**
C49	**CERAMIC CAPACITOR**	**1**	**21**	**28**	**0.011**	**0.047**	**0.043**	**0.009933**	**0.0565588**
C19	**CERAMIC CAPACITOR**	**1**	**21**	**28**	**0.011**	**0.047**	**0.0466**	**0.0107646**	**0.0613256**
C4	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.1145**	**0.0019236**	**0.035266**
C9	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.011**	**0.0001848**	**0.003388**
C10	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.034**	**0.0005712**	**0.010472**
C8	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.0348**	**0.00058468**	**0.0107184**
C6	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.528**	**0.0088704**	**0.0162624**
C17	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.02262**	**0.000380016**	**0.006967**
C18	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.0267**	**0.00044856**	**0.008224**
C22	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.0002**	**0.00000336**	**0.0000616**
C45	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.617**	**0.00103656**	**0.019004**
C46	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.617**	**0.00106356**	**0.019004**
C7	**FILM CAPACITOR**	**1**	**21**	**28**	**0.0008**	**0.011**	**0.024**	**0.0004032**	**0.007392**
J15,14,11,4,2,1	**TOGGLE**	**6**	**21**	**28**	**0.035**	**0.61**	**1**	**4.41**	**102.48**

L1-2	**FIXED COIL INDUCTOR**	**2**	**21**	**28**	**0.44**	**0.048**	**11.7**	**0.78624**	**31.4496**
RY1	**RELAY**	**1**		**28**	**0.44**	**2.8**	**0.08**	**0.7392**	**6.272**
RY2	**RELAY**	**1**	**21**	**28**	**0.086**	**2.8**	**0.00112**	**0.0103488**	**0.087808**
VR1	**VARIABLE RESISTOR**	**1**	**21**	**28**	**0.1**	**1.3**	**0.5653**	**1.0209318**	**20.57692**
MOV1-2	**VARIABLE RESISTOR TRIMMER**	**2**	**21**	**28**	**0.1**	**1.2**	**0.8667**	**3.64014**	**58.24224**
MOV3	**VARIABLE RESISTOR TRIMMER**	**1**	**21**	**28**	**0.0066**	**1.2**	**0.0975**	**0.20475**	**3.276**
D48	**DIODE**	**1**	**21**	**28**	**0.0066**	**0.51**	**0.0036**	**0.000049896**	**0.051408**
D44	**DIODE**	**1**	**21**	**28**	**0.0066**	**0.51**	**0.0018**	**0.000024948**	**0.025704**
D9	**DIODE**	**1**	**21**	**28**	**0.0066**	**0.51**	**0.0018**	**0.000024948**	**0.025704**
R123	**DIODE**	**1**	**21**	**28**	**0.0005**	**0.51**	**0.0066**	**0.00091476**	**0.09428**
R9	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**0.81**	**0.008505**	**0.149688**
R11	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**8.75**	**0.091875**	**1.67**
R57	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**1.54**	**0.1617**	**0.284592**
R122	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**1.35**	**0.014175**	**0.24948**
R39	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**1.35**	**0.014175**	**0.24948**
R23	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**2.45**	**0.025725**	**0.45276**
R58	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**10.7**	**0.11235**	**1.97736**
R21	**FILM RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**2.93**	**0.030765**	**0.541464**
R10	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0005**	**0.0066**	**3.65**	**0.038325**	**0.67452**
R55	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**3.3**	**0.03465**	**7.2072**
R50	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**3.34**	**0.59619**	**7.29456**
R52	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**2.77**	**0.494445**	**6.04968**
R61	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**8.35**	**1.490475**	**18.2364**
R63	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**11.8**	**2.1063**	**25.7712**
R54	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**2.74**	**0.048909**	**5.98416**
R62	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**2.77**	**0.494445**	**6.04968**
R125	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**1.76**	**0.31416**	**3.84384**
R24	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**2.13**	**0.380205**	**4.65192**
R26	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**1.11**	**0.198135**	**2.42424**
R12	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**4.07**	**0.726495**	**8.88888**
R13	**WIRE WOUND RESISTOR**	**1**	**21**	**28**	**0.0085**	**0.078**	**4.09**	**0.730065**	**8.93256**
BATTERY	**6V,11AMPS BATTERY**	**2**	**21**	**28**	**1.9**	**2.48**	**1**	**79.8**	**144.48**
TOTAL								**98.74155349**	**479.7935342**

The results in Tables 4.1 and 4.2 are obtained using equation (3.11)

4.2 Reliability assessment for BG650MI APC UPS
The effective failure rate of the BG650MI UPS in USA for which it is designed is
λ_{BDeff} (series) + λ_{BDeff} (parallel)
$\lambda_{BDeff} = 1.9661\times10^{-4}$
Hence reliability $R = e^{-\lambda BDefft}$
Reliability of the BG650MI UPS for first year in USA is
For one year ⇒ 365days×24 hours= 8760 hrs
$R= e^{-1.9661\times.0001\times8760} = 0.1787 \cong 17.9\%$
Similarly, effective failure rate of the BG650MI UPS in Sokoto, Nigeria, environment is
λ_{BSeff} (series) + λ_{BSeff} (parallel)
$\lambda_{BSeff} = 9.8057\times10^{-4}$
Reliability of the BG650MI for the first year in Sokoto is:
Hence reliability $R = e^{-\lambda BSefft}$
Reliability of the BG650MI for the first year in Sokoto is;
For one year⇒ 365days×24hours= 8760hrs
$R = e^{-9.8057\times10\text{-}4\times8760} = .00185991 \cong 0.19\%$

TABLE 4.3 Reliability result for five years

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
DESIGN	**1.786548E-01**	**3.191753E-02**	**5.702218E-03**	**1.018728E-03**	**1.81997E-04**
SOKOTO	**1.85991E-04**	**3.4E-08**	**6.433966E-12**	**1.196710E-15**	**2.225578E-19**

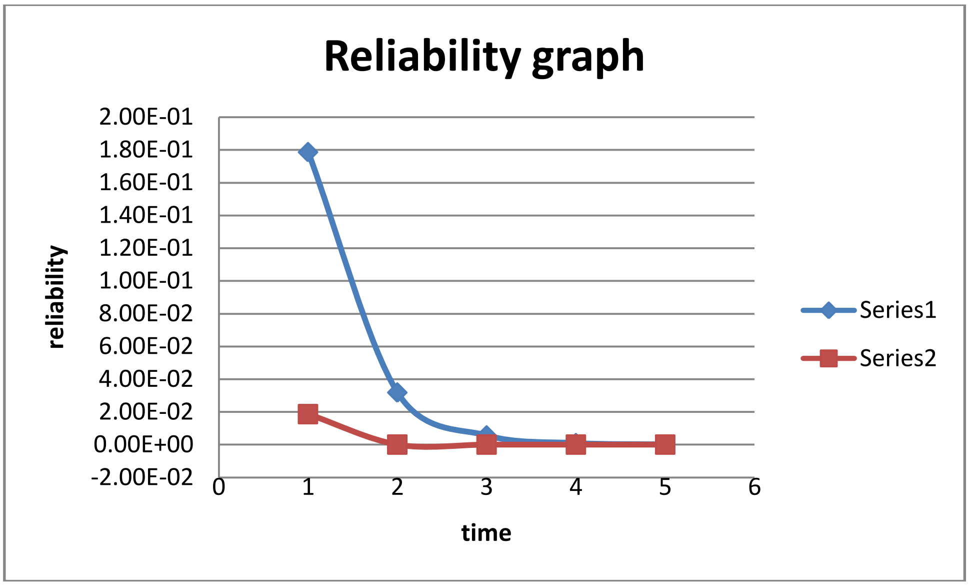

Fig.4.1: Reliability against time graph

From fig. 4.1: we can appreciate and compare the reliability of the UPS in country which the system was designed for USA (series1) and that of Sokoto State (series 2) and see that the UPS under consideration is relatively higher in reliability in the country which the system was designed for than in the applied State. The reliability exponential decaying function graph shows that the UPS has a higher failure rate in Sokoto State, due to factors which are associated with them like voltage fluctuations, very high dust, surge frequency, high relative humidity, high temperature etc.
The ratio of the failure rate of Sokoto State to designed country is 9.8057×10^{-4}: 1.96613×10^{-4}
≅5:1.
Comparatively, the rate of failure of the UPS in the country which the system was designed for is very much less than Sokoto case.

4.3 Reliability Indices Results

MTTF Results

From the failure rate of the system obtained for the designed and applied country, we obtain the Mean Time To Failure (MTTF) of the system as follows.

$$MTTF= \frac{1}{\lambda Beff} \qquad (4.1)$$

$MTTF_D = \frac{1}{\lambda BDeff}$ (4.2)

The mean time the system is expected to function before failure (MTTF) in Sokoto state is 0.12yrs as against for the designed country which is approximately 0.58 yrs. The rate is about five times higher than the Sokoto case. It is possible to compare the result obtained for the failure rates obtained in computer model and the $MTTF_S$ of table 4.9 of the data collection from utility maintenance centre UDUSOK in Sokoto on BG650MI

The MTTF and the failure rate can be obtained as follows

$MTTF_{Data} = \frac{\Sigma MTTF}{N} = \frac{86}{60} = 1.43333 \cong 1.4yrs$

Failure rate Data

$\lambda_{Data} = \frac{1}{1.4 \times 365 \times 24} = 81.53 \times 10^{-6}$ hrs which can be compared modeled failure rate of 98.8057×10^{-6}

The table 4.4 below shows the MTTR of the country for which the system was designed (USA) for over a period of five (5) years. The same information is depicted in the fig4.2. It is observed that MTTR decreases as the number of years increases. This is to be expected, because there are adequate maintenance facilities and personnel.

Table 4.4: mttr for the designed country

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
DESIGN	0.580618	0.290309	0.193539	0.145154	0.116124

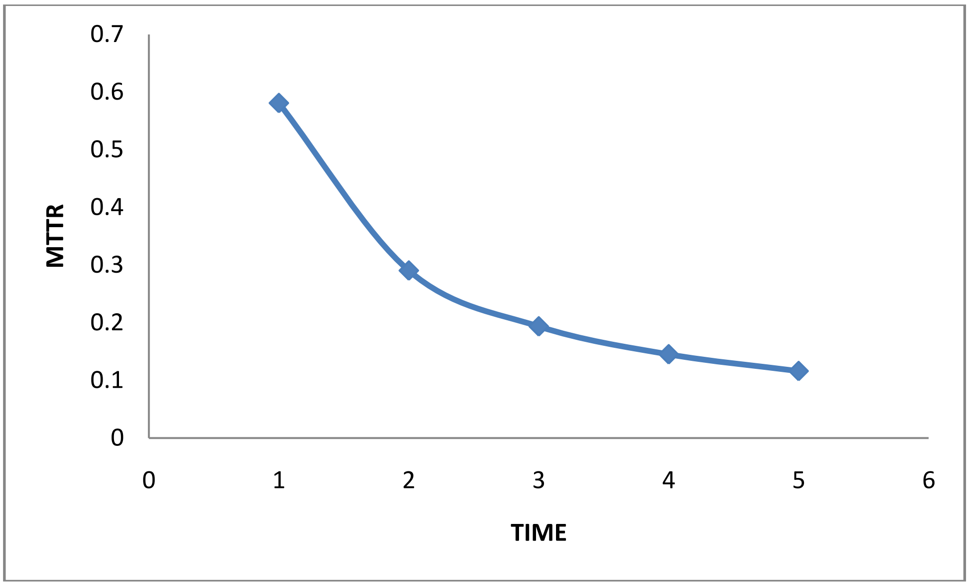

Figure 4.2: Mean Time to Repair against time graph

The MTTR for Sokoto cannot be obtained because of poor maintenance facilities, personnel and record keeping scheme common Nigeria.

Availability (A)

From equation (3.10)

$A = \frac{MTBF}{MTBF + MTTR}$

The above expression for the MTTR only hold for the designed country, where maintenance is regular and spare parts are readily available to put the system in order. Then the availability expression above will be true. This is however, not true for the Sokoto whose level of maintenance culture is low and the level of the maintenance personnel is very poor due to low technological know-how.

Table 4.3 and fig 4.3 gives the calculated values and graph respectively of availability of the design country for the period under consideration (5 years). The result shows that the availability of the equipment increases with the number of year. This could have accounted for the fact that maintenance is regular and spare parts are readily available.

Table 4.5 availability for the designed country

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
DESIGN	0.999885896	0.999942925	0.999961949	0.999971461	0.999977169

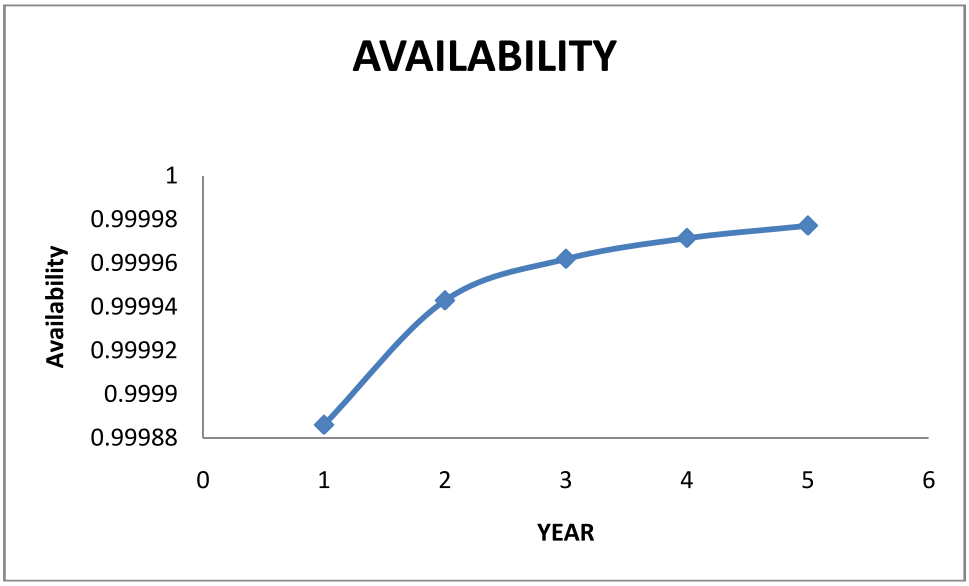

Figure 4.3 Availability against time

4.4 Fault analysis of BG650MI UPS

Sixty UPS were obtained from utility maintenance centre UDUS and considered for failure rate analyses, the fault that are associated with them hence obtained the components that are constantly prone to failure.

Table 4.6: Failure rate analysis of 60 BG650MI UPS

S/No	MODEL	YEAR OF MANUFACTURE (YM) YR	YEAR OF 1ST FAILURE (YFF) YR	MTTF YFF–YM) YR	DIAGNOSIS	REMARKS
1	BG650MI	2005	2007	2	Bad o/p Transfer	Repaired
2	BG650MI	2007	2009	2	Blown MOV	Repaired
3	BG650MI	2005	2006	1	Blown FET	Repaired
4	BG650MI	2005	2006	1	Blown FET	Repaired
5	BG650MI	2005	2007	2	Blown MOV	Repaired
6	BG650MI	2005	2006	1	Blown MOV	Repaired
7	BG650MI	2005	2006	1	Blown MOV	Repaired
8	BG650MI	2005	2006	1	Blown MOV	Repaired
9	BG650MI	2007	2008	2	Blown MOV	Repaired
10	BG650MI	2005	2006	1	Blown MOV	Repaired
11	BG650MI	2005	2006	1	Blown FET	Repaired
12	BG650MI	2007	2009	2	Blown MOV	Repaired
13	BG650MI	2007	2008	1	Blown FET	Repaired
14	BG650MI	2005	2006	1	Blown FET	Repaired
15	BG650MI	2007	2009	2	Blown FET	Repaired
16	BG650MI	2005	2006	1	Blown FET	Repaired
17	BG650MI	2006	2009	3	Bad o/p Transfer	Repaired
18	BG650MI	2005	2008	3	Bad battery	Repaired
19	BG650MI	2005	2008	3	Not charging	Repaired
20	BG650MI	2005	2007	2	Bad battery	Repaired
21	BG650MI	2005	2006	1	Blown board	Repaired
22	BG650MI	2006	2007	1	Blown FET	Repaired
23	BG650MI	2007	2009	2	Not charging	Repaired
24	BG650MI	2008	2010	2	Blown FET	Repaired
25	BG650MI	2009	2010	1	Blown MOV	Repaired
26	BG650MI	2005	2006	1	Blown MOV	Repaired
27	BG650MI	2005	2006	1	Blown MOV	Repaired

28	**BG650MI**	**2005**	**2006**	**1**	**Blown FET**	**Repaired**
29	**BG650MI**	**2005**	**2006**	**1**	**Blown FET**	**Repaired**
30	**BG650MI**	**2005**	**2006**	**1**	**Blown MOV**	**Repaired**
31	**BG650MI**	**2005**	**2007**	**2**	**Blown FET**	**Repaired**
32	**BK650MI**	**2007**	**2008**	**1**	**Blown Board**	**Repaired**
33	**BG650MI**	**2006**	**2008**	**2**	**Blown FET**	**Repaired**
34	**BG650MI**	**2006**	**2007**	**1**	**Not charging**	**Repaired**
35	**BG650MI**	**2006**	**2007**	**1**	**Bad o/p transfer**	**Repaired**
36	**BG650MI**	**2005**	**2006**	**1**	**Bad Battery**	**Repaired**
37	**BG650MI**	**2008**	**2010**	**2**	**Blown MOV**	**Repaired**
38	**BG650MI**	**2008**	**2009**	**1**	**Blown MOV**	**Repaired**
39	**BG650MI**	**2009**	**2010**	**1**	**Blown FET**	**Repaired**
40	**BG650MI**	**2008**	**2009**	**1**	**Blown FET**	**Repaired**
41	**BG650MI**	**2005**	**2006**	**1**	**Blown MOV**	**Repaired**
42	**BG650MI**	**2005**	**2007**	**2**	**Bad o/p transform**	**Repaired**
43	**BG650MI**	**2006**	**2007**	**1**	**Blown MOV**	**Repaired**
44	**BG650MI**	**2005**	**2007**	**2**	**Blown FET**	**Repaired**
45	**BG650MI**	**2007**	**2008**	**1**	**Blown FET**	**Repaired**
46	**BG650MI**	**2008**	**2009**	**2**	**Not charging**	**Repaired**
47	**BG650MI**	**2008**	**2009**	**1**	**Blown board**	**Repaired**
48	**BG650MI**	**2008**	**2009**	**1**	**Blown FET**	**Repaired**
49	**BG650MI**	**2009**	**2010**	**1**	**Not charging**	**Repaired**
50	**BG650MI**	**2005**	**2007**	**2**	**Blown MOV**	**Repaired**
51	**BG650MI**	**2005**	**2006**	**1**	**Bad battery**	**Repaired**
52	**BG650MI**	**2005**	**2007**	**2**	**Blown MOV**	**Repaired**
53	**BG650MI**	**2005**	**2006**	**1**	**Blown MOV**	**Repaired**
54	**BG650MI**	**2006**	**2007**	**1**	**Blown FET**	**Repaired**
55	**BG650MI**	**2005**	**2006**	**1**	**Not charging**	**Repaired**
56	**BG650MI**	**2006**	**2007**	**1**	**Blown MOV**	**Repaired**
57	**BG650MI**	**2005**	**2007**	**2**	**Blown MOV**	**Repaired**
58	**BG650MI**	**2005**	**2008**	**3**	**Blown FET**	**Repaired**
59	**BG650MI**	**2005**	**2006**	**1**	**Blown FET**	**Repaired**
60	**BG650MI**	**2006**	**2007**	**1**	**Bad battery**	**Repaired**

Table 4.7: fault analysis for 60 bg650mi ups

S/NO	**PARTS**	***NO. OF OCCURRENCE***	**% OF OCCURRENCE**
1	**Blown Metal Oxide varistor (MOV)**	**23**	**38.33**
2	**Blown FET (Field Effects Transistor)**	**18**	**30.00**
3	**Blown Board**	**4**	**6.67**
4	**Bad Output Transformer**	**3**	**5.00**
5	**Bad Battery**	**6**	**10.00**
6	**Charging Problem**	**6**	**10.00**
	TOTAL	**60**	**100%**

MOV faults forms 38.33% of the total faults, blown FET forms 30% of the total faults, blown Board forms 6.67% of the total faults, bad Output Transformer forms 5% of the total faults, bad Battery forms 10% of the total faults, Charging Problem forms 10% of the total faults
The result shows that Blown MOV and Blown FET accounts for the major faults that are associated with UPS in Sokoto. Anti surge suppressor and stabilizer will serve as a measure against these problems [2].

V. RECOMMENDATIONS

The following recommendations are derived from the research, to have high degree of reliability in Sokoto State:

a. Use of air conditioner as means of improving the environmental condition that are obtainable in the USA. This will provide a means of removing excess heat away from the system and appreciably reducing the dust deposited on it.
b. Use of stabilizers and voltage surge suppressor to reduce the operating stresses on the system.
c. Exposing maintenance staff to the importance of keeping data that will help to determine the reliability of design, MTTR and availability of the system.
d. Training in Reliability Physics and Reliability Engineering should be made part of science/engineering curriculum study so as to increase the number of expert in maintenance engineering in Sokoto State.
e. Availability of component- Components that have been discovered to be constantly failing should be made available to the maintenance engineers, so that the availability of the system can be increased.
f. From the result of this research paper, it is possible for the designer of UPS system to make a type that can work durably in Sokoto State and Nigeria at large.

5.1 Suggestion for further work

Given the rapid rate of power failure in Sokoto State, UPS will constantly be needed to provide a short-time back-up power supply. The following are recommended for further work on this paper.

1. Collection and keeping of relevant maintenance data which can be used for further reliability analysis of UPS in the State.
2. The design and construction of UPS system that will meet the demand of the State and Nigeria at large by derating all UPS components to address all the factors affecting reliability in the State.

REFERENCES

[1]. Ajibola S.O (2009), “Introduction Mathematical Modeling. Published by national open University of Nigeria.
[2]. Akinsanmi, O. (2003) “Assessing the Reliability of UPS system for medical operation in Zaria, Kaduna State”. The Information Manager, Vol.5, 2005. PP.1-11. Department of Library and Information science, Ahmadu Bello University, Zaria.
[3]. APC Power protection manual, (1995), Retrieved from http://www.goggle.com on September 9, 2010.
[4]. Ask.com, (2011), “Reliability prediction of Electronic equipment”. Retrieved January 17, 2011 from http://www.ask.com
[5]. Barlow, R.E. (1992) “Mathematical Reliability- An Historic perspective”, IEEE Transaction on Reliability, Vol. R33, PP.16-20.
[6]. Boston, B.M, (2004), “Reliability Predictions: part count, part stress and Dormant”. Reliability training course vol. 3 No. 5, September, 2004.
[7]. Bowels J.B. (1992) “A survey of reliability-prediction for microelectronic devices”, IEEE Transaction on Reliability, Vol.41, pp. 2-12.
[8]. Cadwallader, L.C.,(2007) “Failure Rate Data Analysis for High technology component”. Eighth international topical meeting on nuclear application and utilization of accelerators.
[9]. EPSMA, (2005), “Guidelines to understanding Reliability Prediction”. Retrieved August 8, 2012 from http://www.epsma.org
[10]. Gary, B. (2012), “Fundamentals; Understanding reliability terminology and factors that affect power supply reliability”. Posted on July 30, 2012. Retrieved on September 15, 2012 from www.xpower.com
[11]. Green, A.E (1978) “Electronic Reliability Appraisal”. The Radio and Electronic Engineers Journal, 48(7/8):321-330.
[12]. IEC61709, (1996), “Electronic Components- Reliability Reference Conditions for failure rates and stress models for conversion”
[13]. Ignou, O. (2009), “Mathematical modeling for school of science”. Published National Open University of Nigeria.
[14]. Joseph, S. (2001), “The Seven Types of Power Problems”, White paper 18, produced by Schneider Electrics Data Science Centre..
[15]. Liu, X, Guo-Quan, L., William, T.R, Carlos, S., Louis, G., Daanvan, W., and Dusan, B., (2001), “Processing and Reliability Assessment of Solder Joint Interconnection for Power Chips”. Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University, in partial fulfillment of the requirement of Doctor of Philosophy in Material Engineering and Science.
[16]. Michael, C. (2010) http://www.Bussinessdictionary.com/definition/reliability-coefficient.httm, “definition of terms”. Retrieved from goggle.com on January 5, 2010.
[17]. MIL-HDBK-217, (1995), “Reliability prediction of Electronic equipment”. Developed by Rome Laboratories, and the United States, Department of Defense.
[18]. Morris, S.F.; Reilly, J.F. (1998) “MIL-HDBK-217—a favourite target”, in Annual Reliability and Maintainability, pp. 503-509
[19]. Oroge, C.O. (1991) “Fundamentals of Reliability and Testing Methods”. Sooji press limited, Kaduna.
[20]. Reuben, T.E. (1997), “Advanced on-line UPS System”. Best power technology Ltd, Lagos Nigeria.
[21]. Susan, S. (2010) “MTBF, MTTR and FIT Explanation of terms”. Retrieved on July 8, 2011 from http://www.goggle.com
[22]. Taylor, P.F.U. (1989) “Reliability Assessment and Design of Microcomputers for Administrative purposes in Developing countries”, Ph.D Thesis ABU Zaria. Department of Electrical and Electronic Engineering.