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A Statistical Approach to the Modified Impress Current Cathodic Protection (ICCP) for Pipeline Systems.

[1]Ariavie G.O, [2]Ariavie S.S and [1]Olagbegi P.O
[1]Mechanical Engineering Department
University of Benin
P.M.B 1154, Benin City, Edo State, Nigeria.

[2]Statistic Division, Nigerian Oil Palm Research
Km 7, Benin-Akure Road
P.M.B 1030, Benin City, Edo State, Nigeria.

Abstract

An attempt to predict theoretically, the corrosion protection of oil pipelines by Impressed Current Cathodic Protection (ICCP) was embarked upon using data from an ICCP system in practice for three years (2004 through 2006). The concepts and principles used in Cathodic protection is briefly explained with a discussion of the forecasting models employed. The forecasting methods employed include the Simple Moving Average Method, the Simple Exponential Smoothing Method and the Double Exponential Smoothing Method. The forecasting models were applied on the collected data and results obtained and tabulated. The forecasted results were plotted and superimposed on the actual (collected data) and observations made. The results show that the forecasted results followed closely to the actual data, confirming that forecasting results can only be relied upon in ICCP monitoring if there are no coating damages, interference problems and other anomalies.

Keywords: Impressed Current Cathodic Protection (ICCP), Simple Moving Average Method, Simple Exponential Smoothing Method and the Double Exponential Smoothing Method.

Introduction

The two known methods of Cathodic protection widely used are the Sacrificial Anode Cathodic Protection (SACP) and the Impressed Current Cathodic Protection (ICCP) [2], [9], [8] and [12]. The Sacrificial Anode Cathodic Protection (SACP) involves the placement of two dissimilar metals in an electrolyte and joined by a conductor allowing electric current to flow from the less noble metal to the other increasing the corrosion of the less noble metal and reducing that of the nobler one. In the impressed current method, the equipment that is to be protected is placed in an electric circuit with a direct-power supply and an earth system or ground bed. And throughout the world, impressed current cathodic protection (ICCP) systems have been used to provide cathodic protection for pipelines, ship hulls, offshore production platforms, water and wastewater treatment equipment, tank farms, and underground storage tank systems where corrosion protection is desired for poorly coated or bare structures [2]. The impressed current cathodic protection (ICCP) method is flexible, has wide applicability, can adjust and use unlimited current output , not constrained by low driving voltage, possesses comparative lower cost of ampere per of cathodic protection current and very effective in high resistivity soils.

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

Theory of ICCP Systems

Monitoring an ICCP system involves traversing the right of way of the pipeline. This is a long and tedious task. Therefore if an alternative method of tracking monitoring parameters (current and voltage) can be developed, it would go a long way in assisting the corrosion engineer in managing his ICCP system. ICCP protected pipelines are fitted with permanent test posts that may be at regular intervals from each other along the length of the pipeline.

Test posts are not usually fitted with a permanent reference cell. The potential readings taken from the test posts give a general indication of the performance of the CP system at that point. They do not give detailed information concerning anomalies on the line. It is sometimes desirable to obtain more detailed information on CP performance along the line. This can be done by using Close Interval Potential Survey (CIPS).

Information provided from an ICCP monitoring exercise include

- The detection of intermittent stray current interference problems
- Indication of the level of protection
- Current-on and Current-off potentials

In this paper, attempts to use statistical models to track the measured readings and infer on any correlation, similarity or relationship; in order to know if forecasted results can be relied on in ICCP monitoring. The methodology would involve

- Collect data (readings from a monitored ICCP system)
- Study the trend to determine the most appropriate forecasting model to be employed
- Apply the model on the collected data to give forecasted results
- Compare the forecasted results with the collected data
- Make an inference from result obtained

We considered and applied the Simple Moving Average, Single Exponential Smoothing and Double Exponential Smoothing forecasting techniques and infer on correlated and inferred values.

Review of Statistics Smoothing Technique

The simple moving average technique is used to forecast demands or events by calculating an average of the actual demands or events from a specified number of prior periods. Each new forecast drops the demand in the oldest period and replaces it with the demand in the most recent period thus the data in the calculation "moves" over time. Expressed mathematically, the simple moving average is given by [1]:

$$MA_n = \frac{\sum_{i=1}^{n} D_i}{n} \quad (1)$$

Where n = number of periods in the moving average and D_i = demand in period i

A higher value of n lowers the responsiveness and increases the smoothing while a lower value of n lowers the smoothing but increases the responsiveness. This implies that the more periods (n) over which the moving average is calculated, the less susceptible the forecasting is to random variations, but the less responsive they are to changes. A large value of n is appropriate if the underlying pattern of demand is stable while a smaller value of n is appropriate if the underlying pattern is changing or if it is important to identify short-term fluctuations. The Moving Average method seeks to smooth out past data by averaging the last several periods and projecting that view forward periods to be averaged. Moving averages rank among the most popular methods for the processing of time series. But it should be noted that the simple moving average can be used to predict only one step ahead.

Single exponential smoothing methods are conveniently written as recurrence relations i.e. the next value is calculated from the previous one (or ones). Expressed mathematically, the single exponential smoothing is given by [1]:

$$F_{t+1} = \propto D_t + (1 - \propto) F_t \quad (2)$$

Where F_{t+1} = the forecast for the next period

D_t = actual reading in the present period

F_t = the previously determined forecast for the present period

$\propto$ = a weighing factor referred to as the smoothing constant

Simple exponential smoothing is an averaging method that weights the most recent data strongly and works well for time

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

series without an overall trend as only forecast for the current period and a smoothing factor, $\propto$, are required. A higher $\propto$ makes implies forecast is more sensitive to changes in recent data, and the smoothing will be less. The closer $\propto$ is to zero, the greater will be the dampening, or smoothing, effect. As $\propto$ approaches zero, the forecast will react and adjust more slowly to differences between the actual data and the forecasted data. The most commonly used values of $\propto$ are in the range 0.01 to 0.50. However, the determination of $\propto$ is usually judgmental and subjective and is often based on trial and error experimentation. An inaccurate estimate of $\propto$ can limit the usefulness of this forecasting technique.

Double exponential smoothing smoothes (averages) both the series average and the trend. It correlates the forecast with itself which makes it more sensitive to the numerous changes and fluctuations. It is useful where the historic data series is not stationary. Expressed Mathematically, Double Exponential Smoothing is given by [1]:

$$F_{t+1}(D) = \left(\frac{2+\propto T}{1-\propto}\right) F_{t+1} - \left(\frac{1+\propto T}{1-\propto}\right) F_{t+1}(2) \quad (3)$$

Where, $F_{t+1} = \propto D_t + (1-\propto)F_t$

$F_{t+1}(2) = \propto F_{t+1} + (1-\propto)F_t(2)$

T= Trend Factor

Both the simple and double exponential smoothing largely overcomes the limitations of moving averages or percentage change model by automatically weighting past data with weights that decrease exponentially with time (that is, the more recent the data value, the greater it's weighting).

Historical Data

Historical data obtained from a pipeline operating company operating in the Niger Delta region of Nigeria for the years 2004 to 2006 for resistance, voltage and current values are shown in tables 1 – 3 and figures 1 – 9. For each of the graphs in figures 1 to 9, the parameters (i.e. resistance, voltage and current) were plotted against months on the horizontal axis for the current year while the last column for January, shows the reading for the next year.

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

Table 1 Company Readings for Year 2004

MONTH	RESISTANCE	VOLTAGE	CURRENT
JAN	2.63	21	7.98
FEB	2.63	21	7.98
MAR	2.63	21	8
APR	2.63	21	8
MAY	2.63	21	8
JUN	2.63	21	8
JUL	2.63	21	8
AUG	2.68	21.29	7.96
SEPT	2.58	20.65	8
OCT	2.63	20.5	7.81
NOV	2.59	20.5	7.9
DEC	2.52	20.6	8.19

Table 2 Company Readings for Year 2005

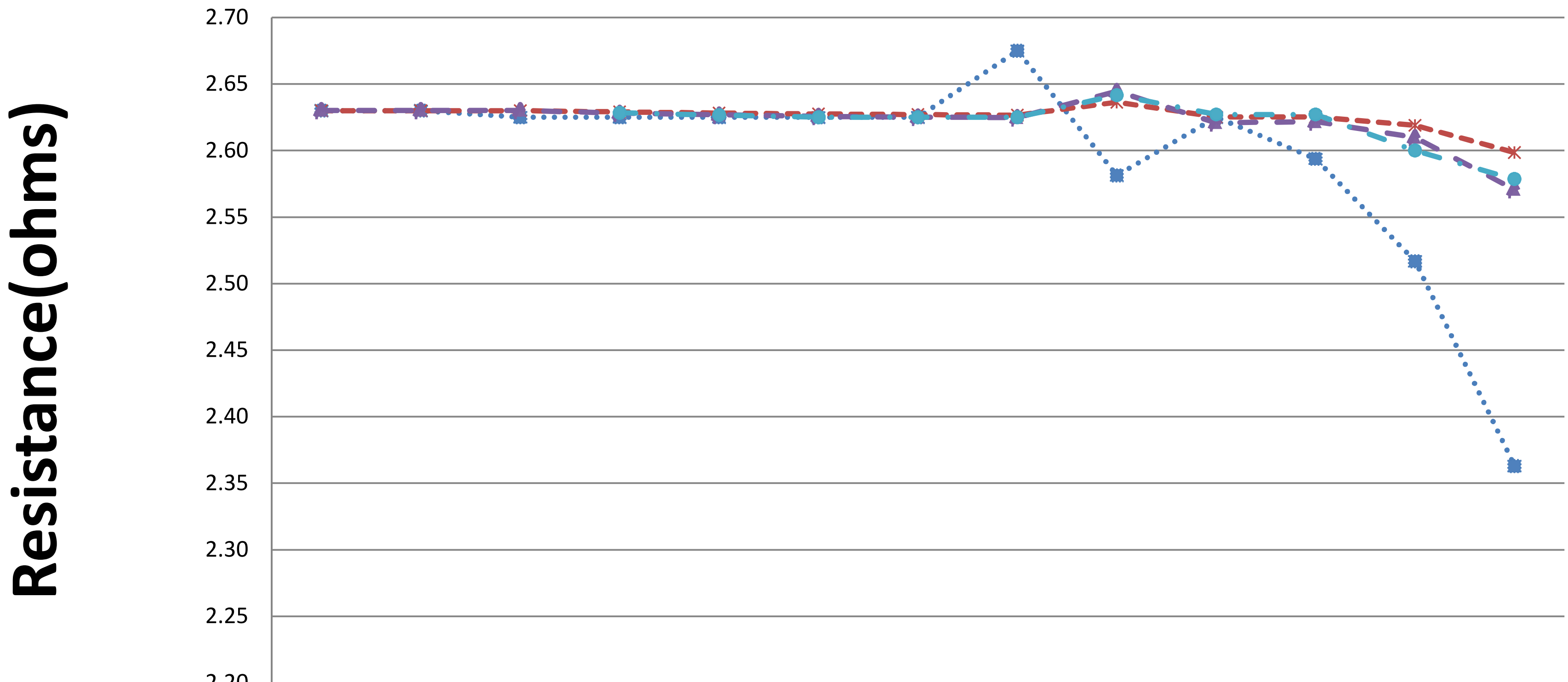
MONTH	RESISTANCE	VOLTAGE	CURRENT
JAN	2.36	20.63	8.73
FEB	2.36	20.63	8.73
MAR	2.32	20.5	8.85
APR	2.1	20.5	9.75
MAY	2.17	20.5	9.43
JUN	1.38	20.63	15
JUL	1.34	20.38	15.17
AUG	1.67	22.5	13.44
SEPT	1.43	20.88	14.63
OCT	1.27	20.3	16
NOV	1.1	20.13	18.35
DEC	1.13	20.75	18.42

Table 3 Company Readings for Year 2006

MONTH	RESISTANCE	VOLTAGE	CURRENT
JAN	1.03	20.5	19.66
FEB	1.01	20.25	20.81
MAR	1.01	20.2	21.81
APR	0.83	20.9	22.74
MAY	0.44	19.75	23.27
JUN	0.33	19.5	24.58
JUL	0.34	19.67	25.96
AUG	0.36	19.85	26.92
SEPT	0.36	19.93	27.83
OCT	0.36	19.84	28.72
NOV	0.35	19.63	29.84
DEC	0.34	18.5	30.83

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

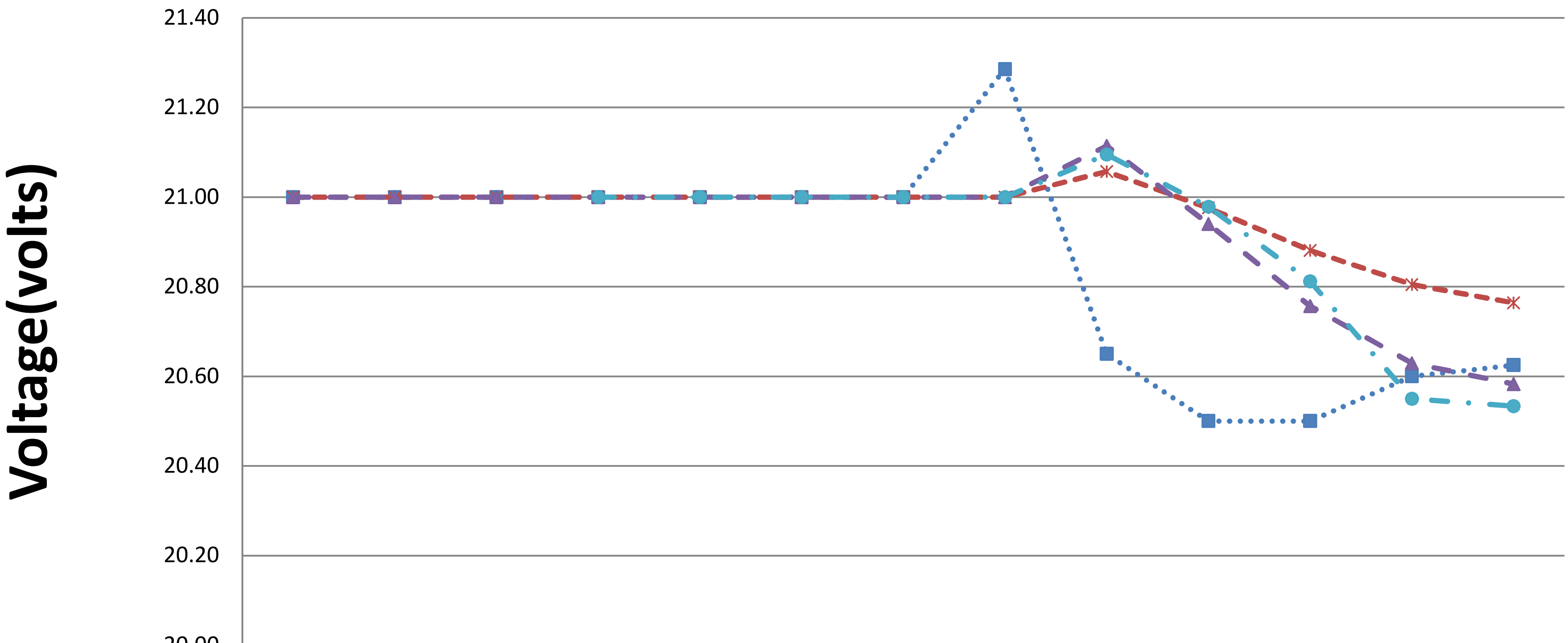
Figure 1:Resistance Values for year 2004



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Resistance BnYt	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.68	2.58	2.63	2.59	2.52	2.36
Resistance Ft+1	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.64	2.63	2.63	2.62	2.60
Resistance Ft+1(D)	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.62	2.64	2.62	2.62	2.61	2.57
Resistance SMA				2.62833	2.62666	2.625	2.625	2.625	2.64166	2.62708	2.62708	2.6	2.57847

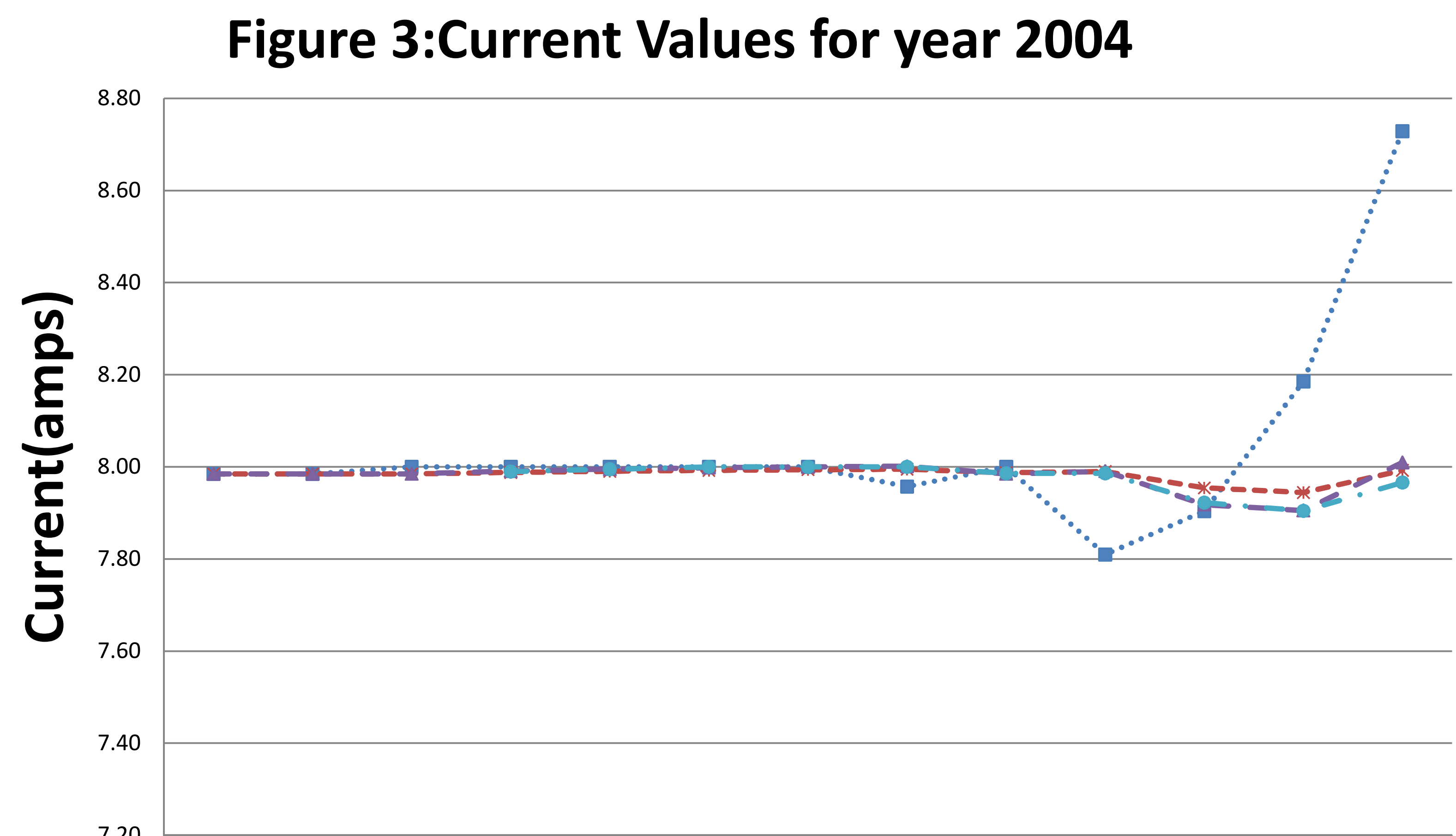
*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

Figure 2: Voltage Values for year 2004



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Voltage BnYt	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.29	20.65	20.50	20.50	20.60	20.63
Voltage Ft+1	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.06	20.98	20.88	20.80	20.76
Voltage Ft+1(D)	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.11	20.94	20.76	20.63	20.58
Voltage SMA				21	21	21	21	21	21.0952	20.9785	20.8119	20.55	20.5333

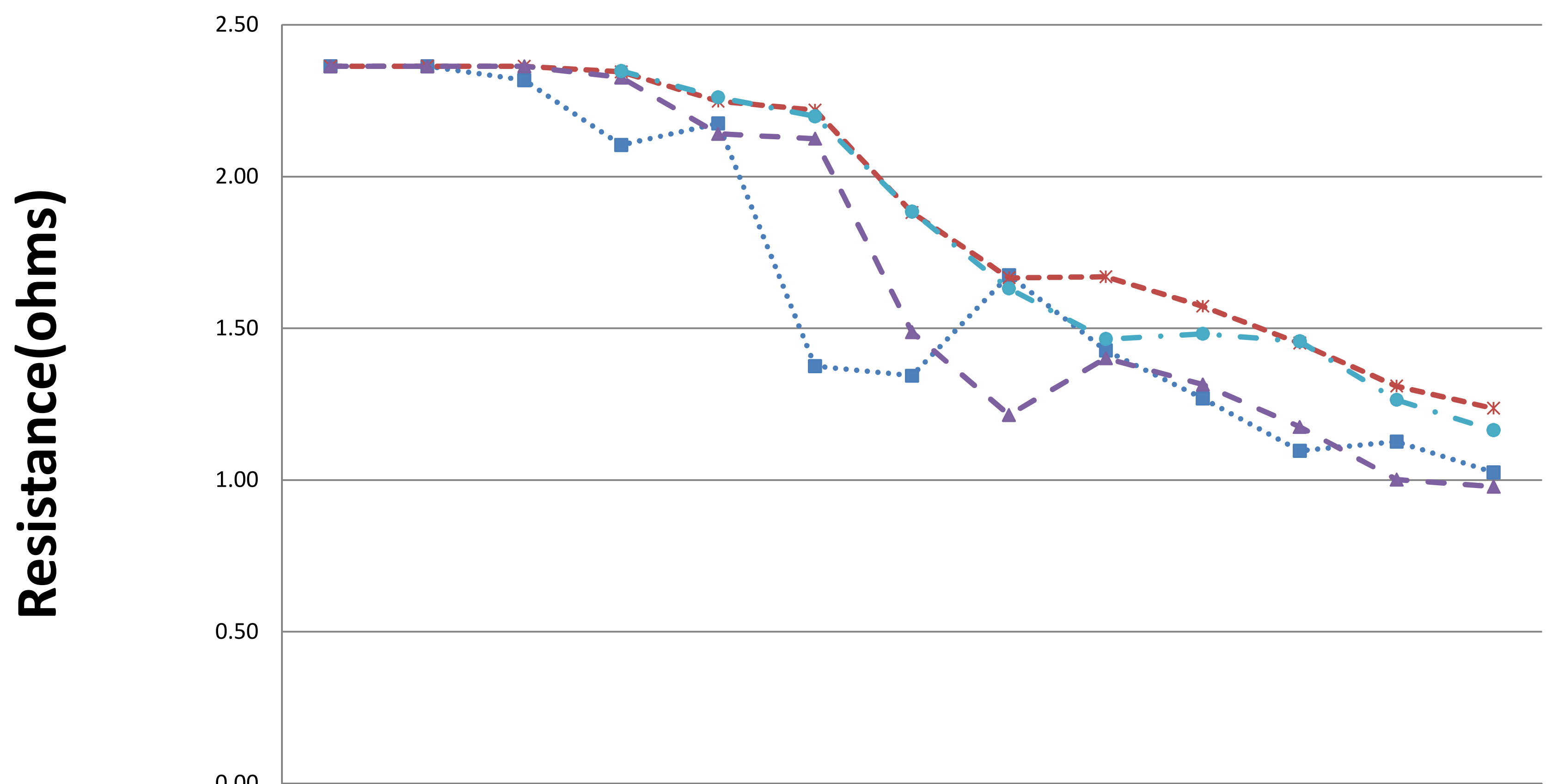
*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Current BnYt	7.98	7.98	8.00	8.00	8.00	8.00	8.00	7.96	8.00	7.81	7.90	8.19	8.73
Current Ft+1	7.98	7.98	7.98	7.99	7.99	7.99	7.99	8.00	7.99	7.99	7.95	7.94	7.99
Current Ft+1(D)	7.98	7.98	7.98	7.99	8.00	8.00	8.00	8.00	7.98	7.99	7.92	7.91	8.01
Current SMA				7.9898	7.9949	8	8	8	7.9857	7.9857	7.9222	7.9043	7.9661

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

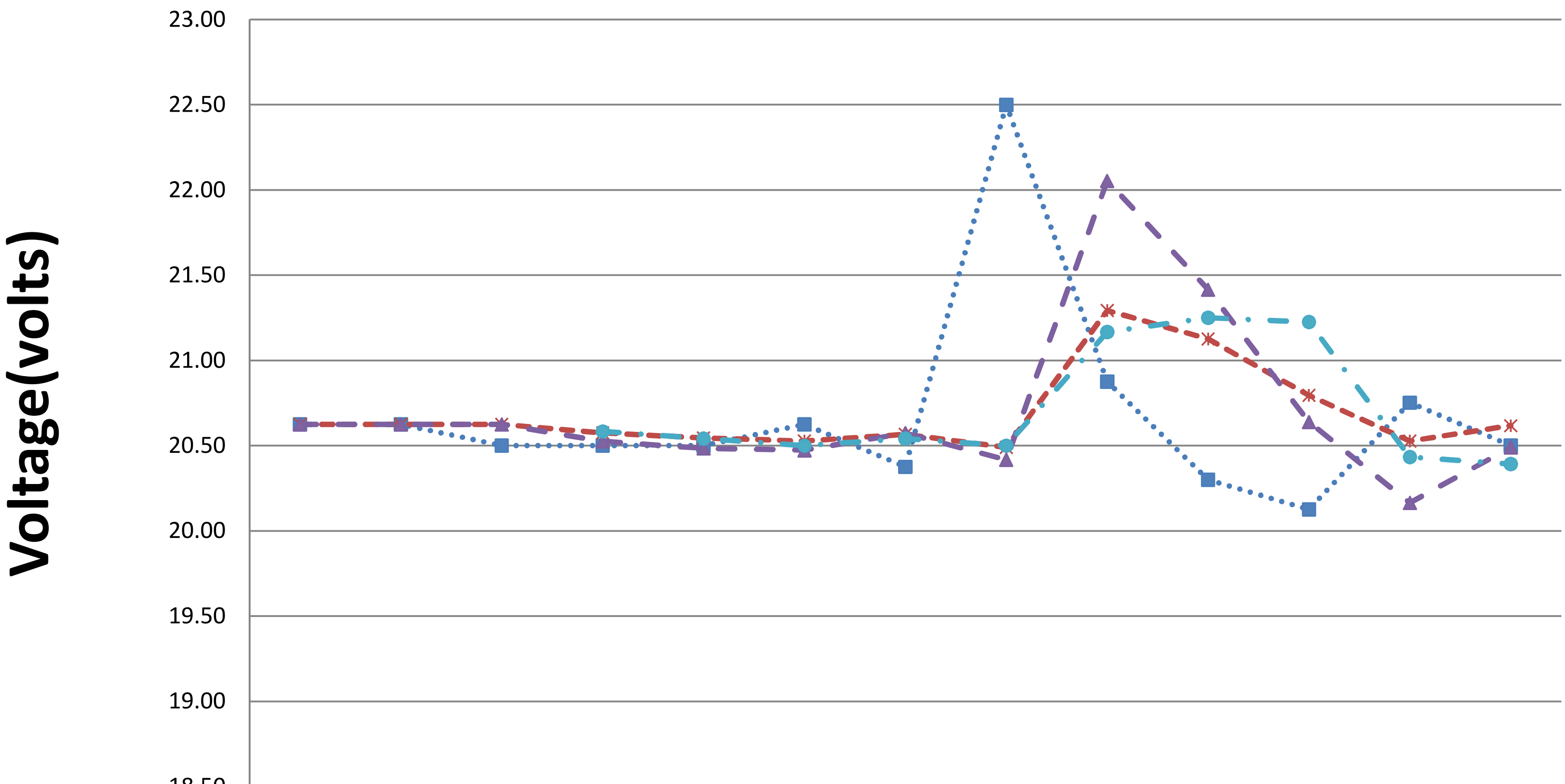
Fiigure 4: Resistance Values for year 2005



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Resistance BnYt	2.36	2.36	2.32	2.10	2.17	1.38	1.34	1.67	1.43	1.27	1.10	1.13	1.02
Resistance Ft+1	2.36	2.36	2.36	2.34	2.25	2.22	1.88	1.67	1.67	1.57	1.45	1.31	1.24
Resistance Ft+1(D)	2.36	2.36	2.36	2.33	2.14	2.12	1.49	1.21	1.40	1.31	1.17	1.00	0.98
Resistance SMA				2.34743	2.26083	2.19796	1.88410	1.63092	1.46429	1.48153	1.45661	1.264	1.16385

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

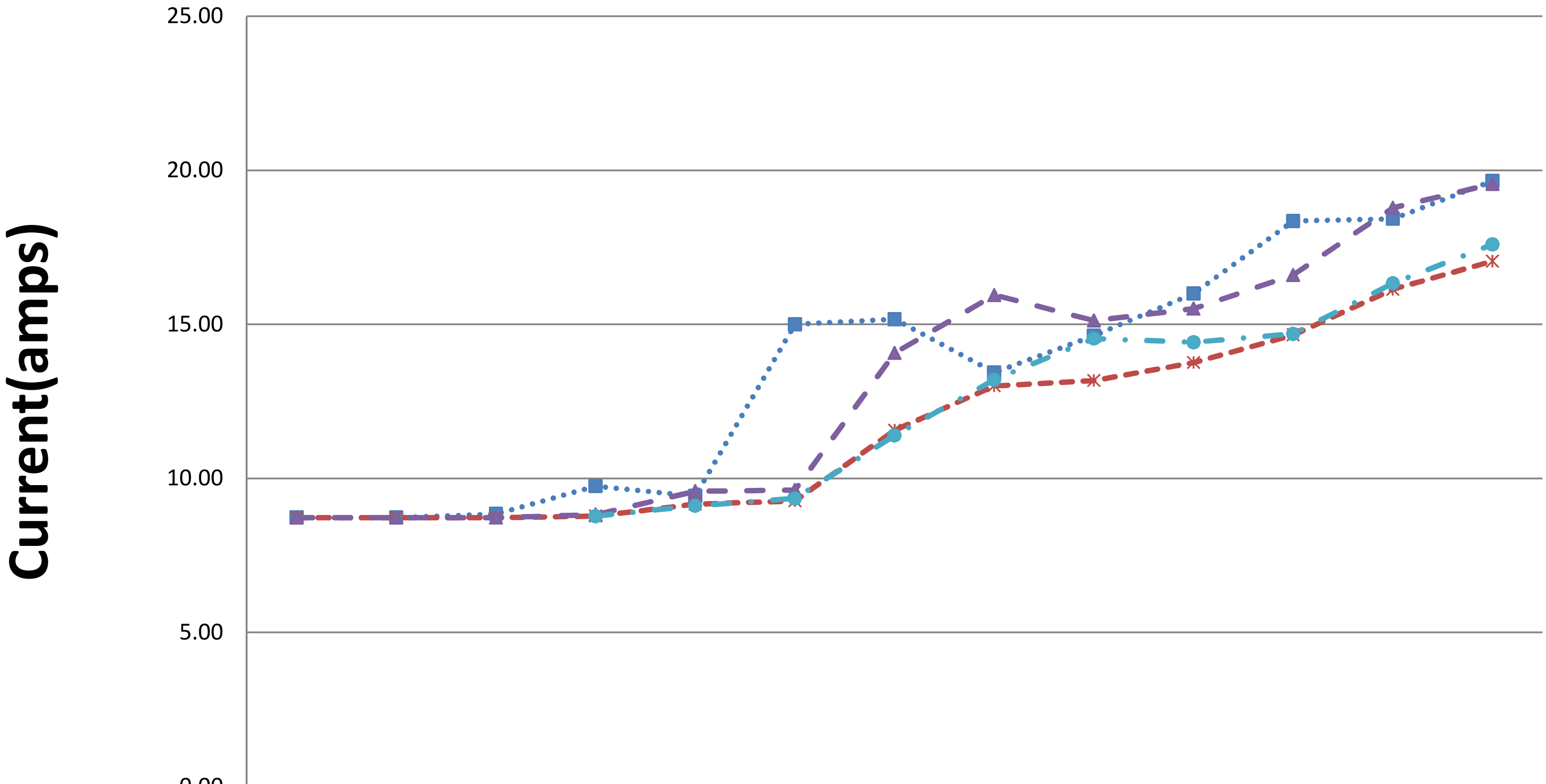
Figure 5:Voltage Values for year 2005



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Voltage BnYt	20.63	20.63	20.50	20.50	20.50	20.63	20.38	22.50	20.88	20.30	20.13	20.75	20.50
Voltage Ft+1	20.63	20.63	20.63	20.58	20.55	20.53	20.57	20.49	21.29	21.13	20.80	20.53	20.62
Voltage Ft+1(D)	20.63	20.63	20.63	20.52	20.48	20.47	20.57	20.42	22.05	21.42	20.64	20.16	20.49
Voltage SMA				20.5833	20.5416	20.5	20.5416	20.5	21.1666	21.25	21.225	20.4333	20.3922

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

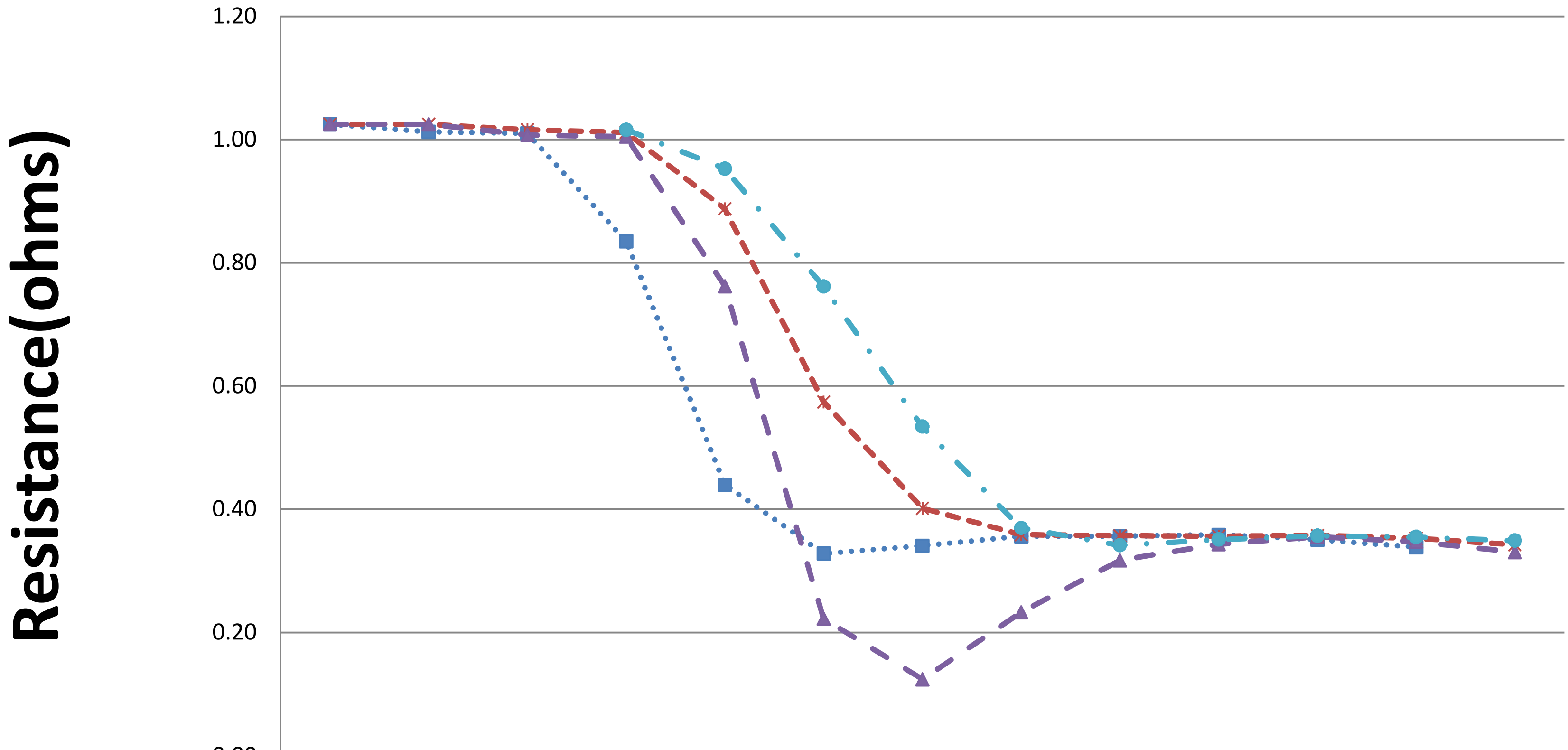
Fiigure 6:Current Values for year 2005



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Current BnYt	8.73	8.73	8.85	9.75	9.43	15.00	15.17	13.44	14.63	16.00	18.35	18.42	19.66
Current Ft+1	8.73	8.73	8.73	8.78	9.17	9.27	11.56	13.00	13.18	13.76	14.66	16.13	17.05
Current Ft+1(D)	8.73	8.73	8.73	8.83	9.58	9.63	14.07	15.95	15.12	15.51	16.60	18.78	19.55
Current SMA				8.76897	9.10857	9.34180	11.3920	13.1979	14.5344	14.4115	14.6898	16.3282	17.5927

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

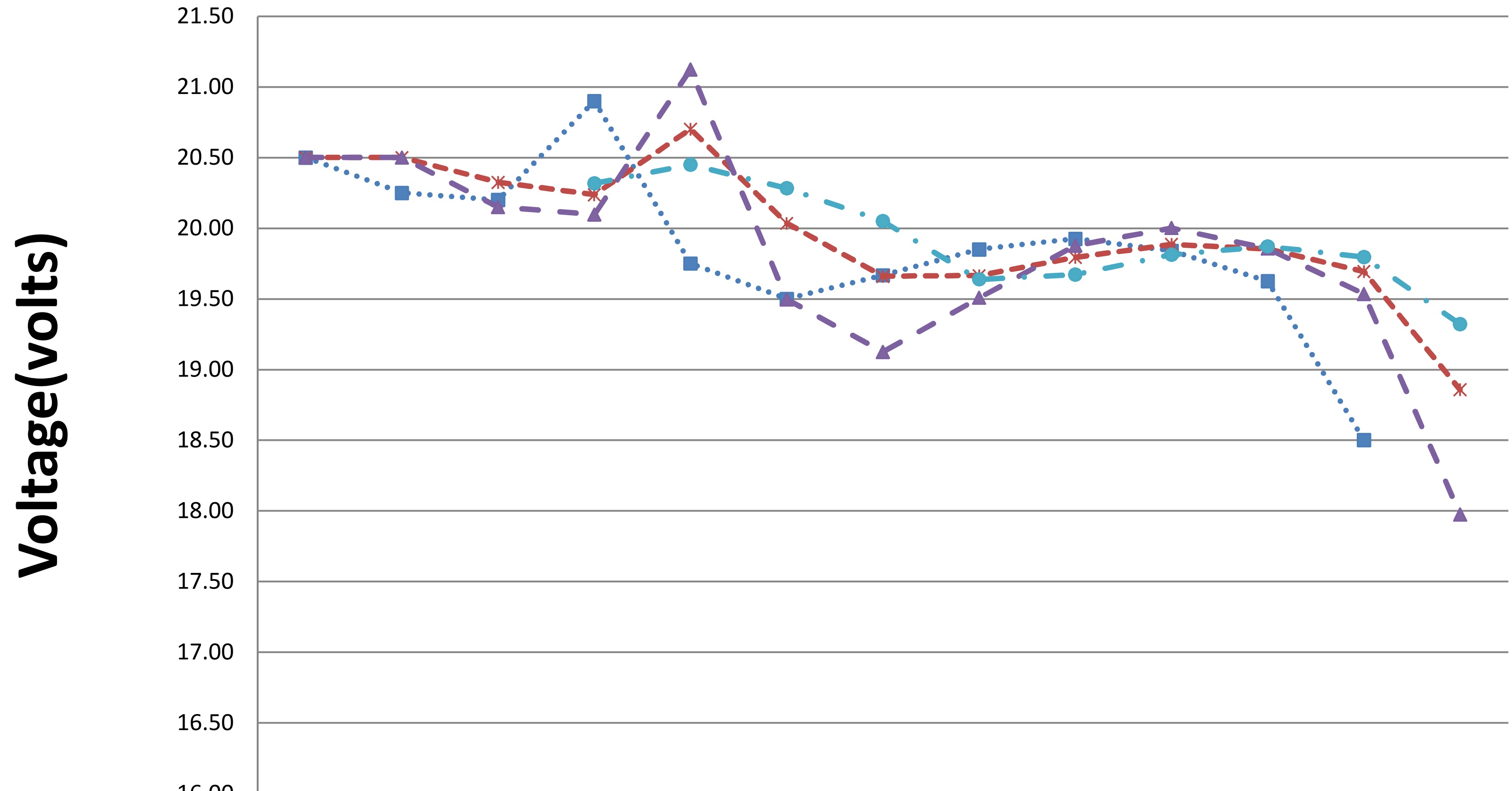
Fiigure 7:Resistance Values for year2006



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Resistance BnYt	1.02	1.01	1.01	0.83	0.44	0.33	0.34	0.36	0.36	0.36	0.35	0.34	
Resistance Ft+1	1.02	1.02	1.02	1.01	0.89	0.57	0.40	0.36	0.36	0.36	0.36	0.35	0.34
Resistance Ft+1(D)	1.02	1.02	1.01	1.00	0.76	0.22	0.12	0.23	0.32	0.34	0.36	0.35	0.33
Resistance SMA				1.01583	0.95249	0.76156	0.53416	0.36931	0.34144	0.35078	0.35668	0.35484	0.34889

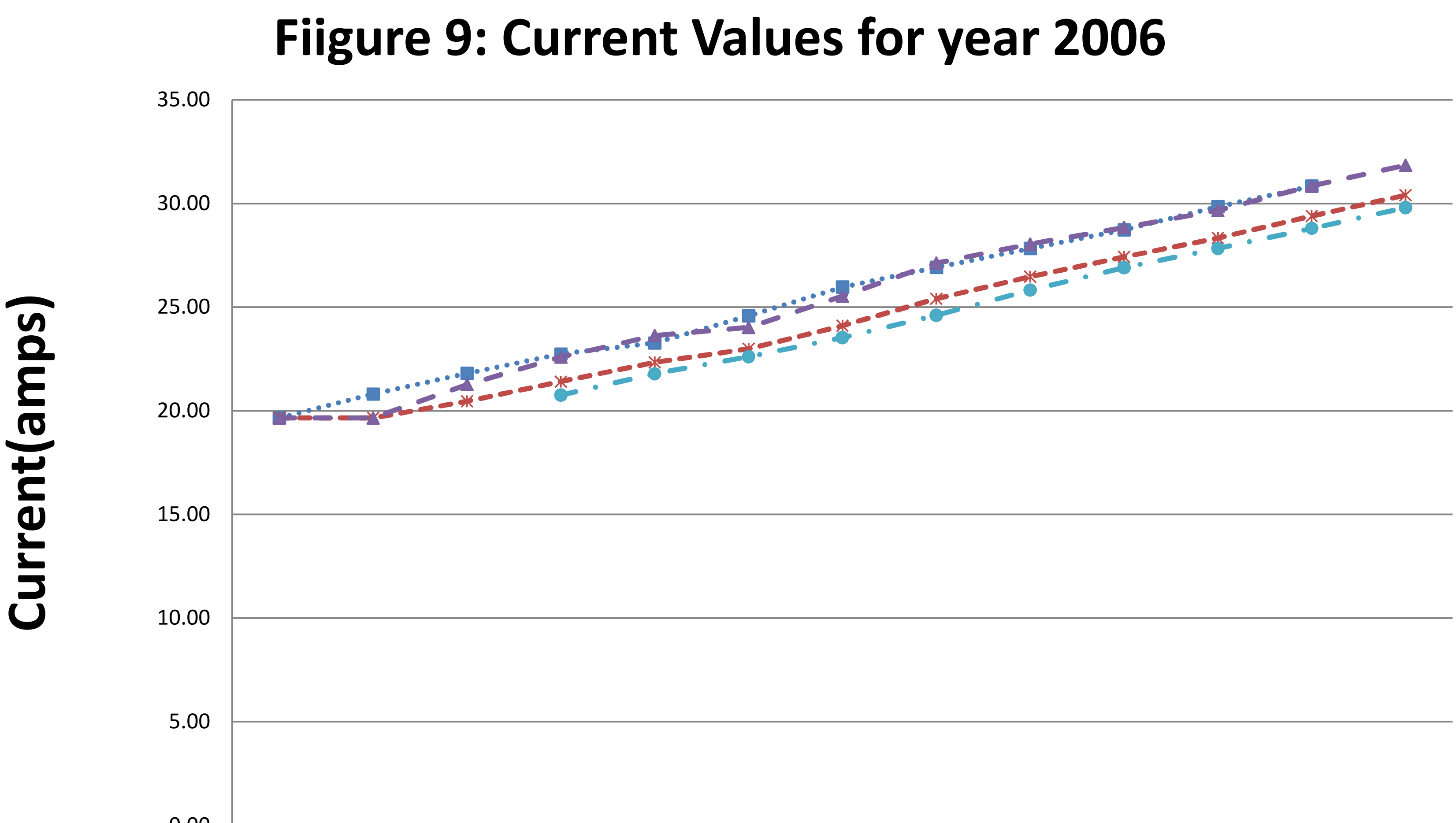
*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

Figure 8: Voltage Values for year2006



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Voltage BnYt	20.50	20.25	20.20	20.90	19.75	19.50	19.67	19.85	19.93	19.84	19.63	18.50	
Voltage Ft+1	20.50	20.50	20.33	20.24	20.70	20.04	19.66	19.66	19.79	19.89	19.85	19.69	18.86
Voltage Ft+1(D)	20.50	20.50	20.15	20.10	21.12	19.50	19.12	19.51	19.88	20.00	19.86	19.53	17.97
Voltage SMA				20.3166	20.45	20.2833	20.05	19.6388	19.6722	19.8138	19.8716	19.7966	19.3216

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN
Current BnYt	19.66	20.81	21.81	22.74	23.27	24.58	25.96	26.92	27.83	28.72	29.84	30.83	
Current Ft+1	19.66	19.66	20.46	21.41	22.34	22.99	24.10	25.40	26.46	27.42	28.33	29.39	30.40
Current Ft+1(D)	19.66	19.66	21.27	22.59	23.62	24.02	25.53	27.13	28.04	28.85	29.67	30.85	31.85
Current SMA				20.7583	21.7849	22.6044	23.5279	24.6024	25.8201	26.9025	27.8218	28.7966	29.7979

*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205

Result, Discussion and Conclusion

The readings used are data got from an Impressed Current Cathodic Protection System of a pipeline operating company in the Niger Delta region of Nigeria In this work the various parameters were forecasted and compared with the historical parameters. From the study of the graphs plotted for the forecasted results and super imposed on the collected data, it can be observed that the forecasted readings closely followed the trend of the actual (collected) readings for voltage, current and resistance. Finally, the use of forecasting in predicting the values of current, voltage and resistance for an ICCP system can only be relied on if and only if there are no unforeseen anomalies such as coating damages, human or environmental disasters, and interference problems. If such anomalies occur and forecasting models cannot account for them, then the practice of traversing the right of way in ICCP monitoring is still the only reliable method in ICCP monitoring.

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*Corresponding author: E-mail; ariaviefe@uniben.edu, Omonefe2000@yahoo.com, Tel. +2348035615205