



THE STUDY AND ANALYSIS OF CELL PHONE CHARGING MODULES IN NIGERIA

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Cellular phones require frequent charging with the aid of modules known as chargers. The performance of chargers in Oleh, a community in the Niger Delta area of Nigeria as a case study were investigated with a view to proffering solutions arising from the conventional act of disposing failed chargers without attempted remedies by users. Twenty (20) chargers were sampled and examined to determine the electronic components most likely prone to failure in the modules and possible reactivation. Also, experiments were performed to compare charging rates to initial specifications by manufacturers for the sampled chargers. The results show that the components most likely prone to failure from the sampled chargers in order of frequency of failure were circuit breakers, capacitors, switching rectifier and switching power transistors. Furthermore, one of the reactivated chargers model, Infinix of initial specification mostly available in Nigeria with open-circuit voltage of 5.00V and short-circuit current of 1500mA, recorded 4.50V, 800mA and was able to charge Samsung A12 phone to full capacity (100%) in twenty(20) minutes at a charging rate of 0.01V.min or -4.67A/min respectively. Similarly, reactivated Oraimo charger recorded 4.70.00V, 2500mA as against 5.00V, 900mA specifications when charging the Tecno Pop2 phone. The results show that the reactivated modules charging performances were comparatively enhanced at current delivery to loads as shown by the two cell phones. Therefore, it is recommended that Engineers and Technicians skills be chanelled towards local design and reactivation of failed charging modules in Nigeria.

1.0 Introduction

Technological innovations have introduced much improvement in the performance of charging modules to consumers using cell phones and other related devices. European Commission in 2019 state that for effective charging, a charging solution which has three main elements must be temporally interconnected, to satisfy devices demands referred to as charging profile. These elements are the external power supply (EPS), a cable assembly connectivity and the battery in the device. The charging profile is the variation of current and voltage during charging which depend on battery type and recharge time. Charles River Associates (2015), put world charging modules purchase at 18-34 million while Frick and Bott, (2009), put the reasons for these purchases include module failure, desire to have multiple modules, forgetting module whilst travelling and loss of module. Sudeep. (2004), put the causes of failures in electronic devices which include charging modules as components failure, improper circuit design, manufacturing deficiencies, improper handling and operations, as well as environmental factors. Mandeep and Supreet. (2015), states that charging modules performs charging operations in two circuit modes known as linear regulated power supply (LRPS) and switched mode power supply (SMPS). Robert *et al.* (2009), described the linearly regulated power supply as a circuit with an input ac voltage that is stepped down, rectified, and then filtered using a capacitor. Modern cellular charging modules employ the switched-mode power supply mode in circuit design.

Jagannathan, (2011), described the switched-mode power supply (SMPS) as a high-frequency operation device with a small size and light weight that is capable of providing a ripple-free and constant output voltage. Yates, (2010), presented the advanced technology of wireless chargers that operate under the principle of power transfer by magnetic induction while Beasley, (2008), described the underlying engineering concept for the wireless power cellular charging module as similar to electronic toothbrush chargers. Limited research had been carried out on the study of energy consumption of mobile phones, reactivation of mobile phones and charging modules. Etoh et al. (2008), put an average customer’s phone consumption at 0.83 Wh per day while mobile network consumes 120 Wh per day per customer by the largest mobile telecommunications operator in Japan in the year 2006. Similarly, Schaefer et al. (2003), put an average customer’s phone consumption at 79.5 Wh per day per subscriber in 2000 by German mobile telecommunications sector. The variation between these two studies illustrates the challenges of estimating the power consumption of mobile telecommunication technologies. Ferreira et al. (2011), examined only limited details of recharging behaviour of a large sample of Android phones while Heikkinen and Nurminen, (2010), examined smaller sample of module chargers operations and failures. Poonam and Rajat, (2017), looked at wireless charging system using the principle of electromagnetic induction. It is a power transfer technology that eliminates the current wired power transfer technology. S. Sheik Mohammed et al. (2013), put some of the advantages of wireless charging transmission technology to include reduction in power losses, reduction in cost and power transmission to a remote area as well as higher efficiency than the wired transmission system. Vikash et al. (2014), also state that wireless charging system eliminates faults due to absence of linkage cables associated with wired charging system. This study therefore look at reviving fail charging modules which leads to cost reduction associated with the normal practice of disposed-off instead of attempted remedy in Nigeria.

2.0 Materials and Methods

The work was carried out through the study of selected charging modules and the verification of major components prone to failure. Reactivation on identified components was performed on failed chargers with the modification of circuit components. An experiment was performed to determine the amount of charging current and voltage demand for two reactivated cellphones.

2.1 Examination of cell phone charging modules

The study looked into various cell phone charging modules with a view to attempting a remedy.

Table I: Charger components and nature of faults

S/N	Component	Fault
1	Capacitors (CPT)	Short-Circuit
2	Opto-Couplers (OCL)	Short/Open-Circuit
3	Pulse-Width Modulators (PWM)	Open/Short-Circuit
4	Switching Rectifiers (SRF)	Short-Circuit
5	Resistors (RST)	Open-Circuit
6	High Frequency Switching Transformers (HFT)	Open/Short-Circuit
7	Switching Power Transistors (SPT)	Short-Circuit
8	Metal-Oxide Varistors (MOV)	Open-Circuit
9	Circuit Breaker (CBR)	Open-Circuit
10	Inductors (IDT)	Open-Circuit

Table 1 presents the basic and identified switch-mode power supply circuit components in chargers and the nature of faults associated with the component while Figure 1 is a photo-view of some sampled failed charging modules examined by us.



Figure 1: Sampled failed charging modules

2.2 Modules with faulty or malfunctioning components

Table 2 presents the tabulation of some chargers with respect to the various faulty or malfunctioning components. The mark (√) indicated a representation of a faulty component in a charger as well as its rate of failure in chargers as examined by us.

Table 2: Sample of failed chargers and components

Charger Model	Component									
	CP T	OC L	PW M	SR F	RS T	HF T	SP T	MO V	CB R	ID T
Oraimo (OCW-U63D)	√						√		√	
Million Power (T5)				√			√		√	
Amazon	√			√			√	√	√	
Infinix (OD-5509)	√	√	√	√					√	
Itel (IMU05)			√			√	√		√	√
AG (IC988)	√	√	√	√	√				√	
Desktop	√			√	√				√	
Tecno	√		√						√	
Apple USB	√	√		√			√			√
Samsung Super										
Anker 747		√		√		√		√	√	√
Belkin Dual USB	√	√	√			√	√			√
iPhone 13			√	√		√		√		√
Cheeteh 3		√		√		√		√		
Apple Magsafe	√		√		√		√		√	
Dual Port USB Wall	√	√		√	√		√	√		
Amazon Basics	√	√	√	√			√	√		√
Apple MFI	√			√	√	√		√	√	
Booster Magnetic	√	√	√	√		√			√	
iPhone Fast			√	√		√				√
Component Failure Rate (CFR)	13	9	10	14	5	1	9	7	11	7

2.3 Modules and Reactivation

Figures 2 and 3 are samples of two cell-phone charging modules with physically identified failed component(s) as indicated by the arrow signs.



Figure 2: Failed pulse generator in AG charger

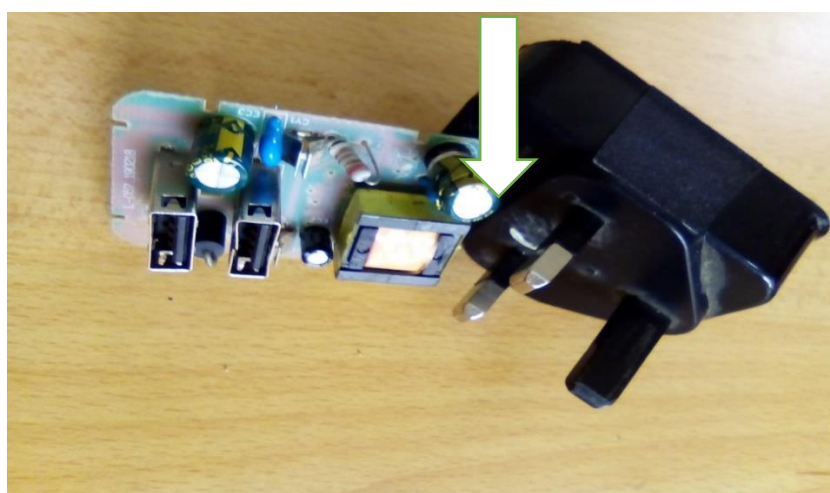


Figure 3: Failed capacitor in Amazon charger

The failed components in Figures 2 and 3 as identified were isolated from circuits, and the nature of faults associated with the components and specifications are presented in Table 3.

Table 3: Chargers failed components and specifications

S/N	Component	Specification	Fault
1	Electrolytic Power Capacitor	10.0V, 1000 μ F	Short-circuit
2	Transistor	2N3904 ($V_{CEO}=40V_{dc}$, $I_C=200mA$)	Nil
3	Fuse	1.0A,	Open-circuit
4	Rectifier	SCH25000 (0.36-1.5A, 100-1000Vdc)	Short-circuit

2.1 Experiment on reactivated chargers

Figure 4 is a circuit diagram of an experiment performed by us to ascertain the amount of charging current drawn to charge cell phones with respect to their voltages by using one of the reactivated charging modules. The diagram consists of an ammeter connected in series with the cell phone to measure charging current, while a voltmeter is placed in parallel with the cell phone. The experiment was repeated for each cell phone, and the voltage and current values were recorded. Table 4 presents selected charging modules with their specifications used in

carrying out the experiment while Table 5 presented the charging power, voltage and current with time to charging rates of Infinix module in terms of power, voltage and current. Figure 5 presents the photo-view of the experimental setup.

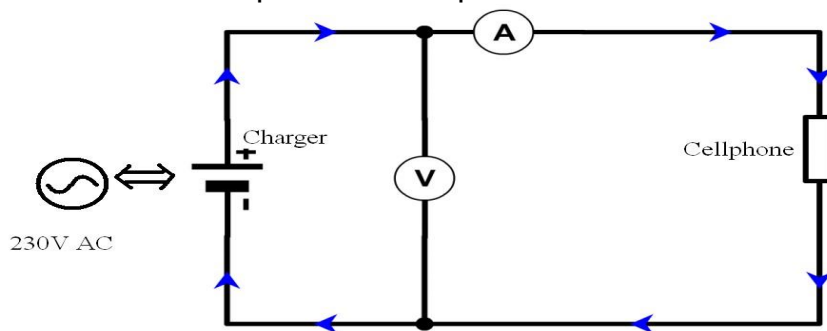


Figure 4: Circuit diagram of the charging process



Figure 5: Photo-view of laboratory setup for the experiment

Table 4: Sampled models of charging modules with specifications

Module Model	Output Current	Output Voltage	Interface
Oraimo (OCW-U63D)	340mA	5.0V	USB
Million Power (T5)	360mA	5.0V	USB
Amazon	500Ma	5.0V	USB
Infinix (OD-5509)	2500mA	5.0V	USB
Itel (IMU05)	1000mA	5.0V	USB
AG (IC988)	200mA	5.0V	USB
Tecno	3500mA	5.0V	USB
Apple USB C	4500mA	5.0V	USB
Samsung Super	4200mA	5.0V	USB
Anker 747	3700mA	5.0V	USB
Belkin Dual USB	3500mA	5.0V	USB
iPhone 13	4000mA	5.0V	USB
Cheeteh 3	3500mA	5.0V	USB
Apple Magsafe	1000mA	5.0V	USB
Dual Port USB Wall	4100mA	5.0V	USB
Amazon Basics	2400mA	5.0V	USB
Apple MFI	4000mA	5.0V	USB
Booster Magnetic	5000mA	5.0V	USB
iPhone Fast	3000mA	5.0V	USB

Table 5: Infinix module charging Techno POP2 phone.

S/N	Techno POP2 Battery Capacity 4000mAH						
	TIME (t) min	CHARGE % mAH	I mA	Δ I mA	V Volt	Δ V Volt	POWER (P) mW
1	10	4	1279	11	3.812	0.131	4875.548
2	20	9	1268	16	3.943	0.027	4999.724
3	30	14	1252	12	3.97	0.026	4970.44
4	40	20	1240	27	3.996	0.014	4955.04
5	50	24	1213	43	4.01	0.012	4864.13
6	60	29	1170	26	4.022	0.014	4705.74
7	70	32	1144	12	4.036	0.004	4617.184
8	80	38	1132	9	4.04	0.018	4573.28
9	90	42	1123	96	4.058	0.04	4557.134
10	100	47	1027	27	4.098	0.025	4208.646
11	110	52	1000	19	4.123	0.035	4123
12	120	57	981	11	4.158	0.042	4078.998
13	130	62	970	6	4.2	0.038	4074
14	140	66	964	14	4.238	0.065	4085.432
15	150	70	950	29	4.303	0.04	4087.85
16	160	74	921	31	4.343	0.055	3999.903
17	170	79	890	28	4.398	0.022	3914.22
18	180	83	862	12	4.42	0.003	3810.04
19	190	87	850	29	4.423	0.029	3759.55
20	200	100	821	0	4.452	0	3655.092
	Total		21057	458	83.043	0.64	86914.951
	Average		1052.9	23	4.152	0.032	4345.748
	Charge Rate/Hour (CR/Hr)		315.86	6.9	1.246	0.01	1303.724

3.0 Results and Discussion

The result from the study is presented in various stages which include the findings on the most likely components prone to failure in chargers, the experimental determination of specified power ratings to maximum working values of a revived charger, time taken to charge a sample phone to its maximum value as well as determination of its charging rate. Figure 6 is the plot showing the components failure rate in charger circuits while Figures 7-10 are plots of module chargers current and voltage specifications to their maximum working current drawn by Samsung A12 and Techno POP2 phones respectively. Referring to Table 5, the data obtained by using Infinix charging module to charge Techno POP2 phone battery to 100% full capacity are employed in the plots of Figures 11-12.

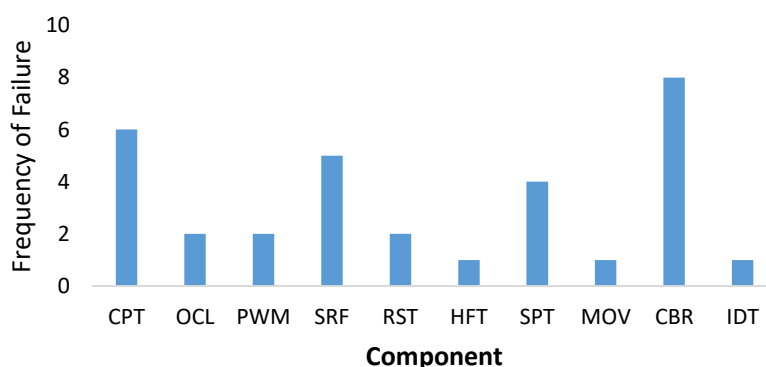


Figure 6: Frequency of component failure in charging modules

The components prone to failure as presented in Figure 6 are CBR (circuit breakers), CPT (capacitors), SRF (switching regulators), and SPT (switching power transistors). The reactivated chargers in Figures 6 and 7 were tested for power delivery, and it was confirmed that their charging time to full capacity with respect to a specific phone was reduced compared to its initial charging time. Finally, Figures 7–10 are plots showing the experimental results obtained from the performed experiment for the reactivated modules employed in the determination of the amount of current drawn at a specified voltage by two cell phones: the Tecno POP2 and the Samsung A12.

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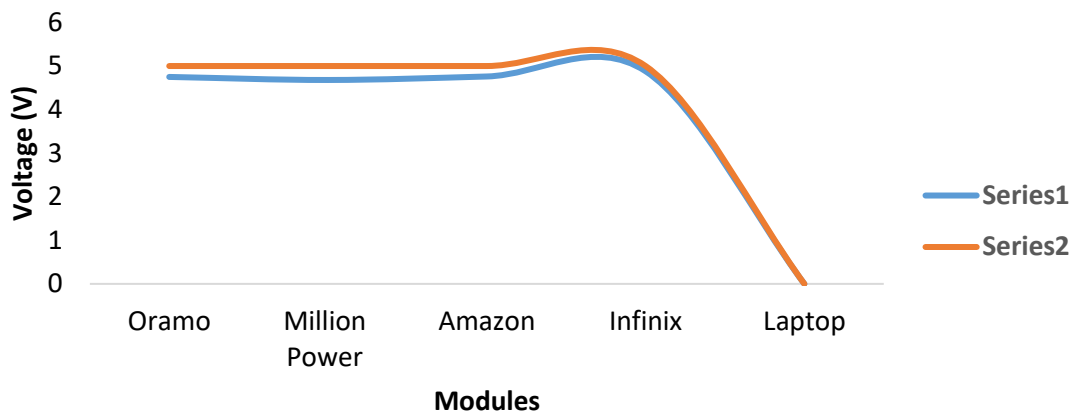


Figure 7: Module voltage specification to maximum working voltage for Techno Pop 2

Series 1 in Figure 7 indicate various reactivated modules working voltages when charging Techno Pop 2 while Series 2 indicate modules open-circuit rated voltages presented in Figure 4.

The open-circuit curve shows a unified average voltage of 5V indicating that most chargers output voltage specifications are 5V. The chargers load curve response show that the Infinix charger recorded a maximum voltage of 4.8V while the Million Power recorded a minimum of 4.6V.

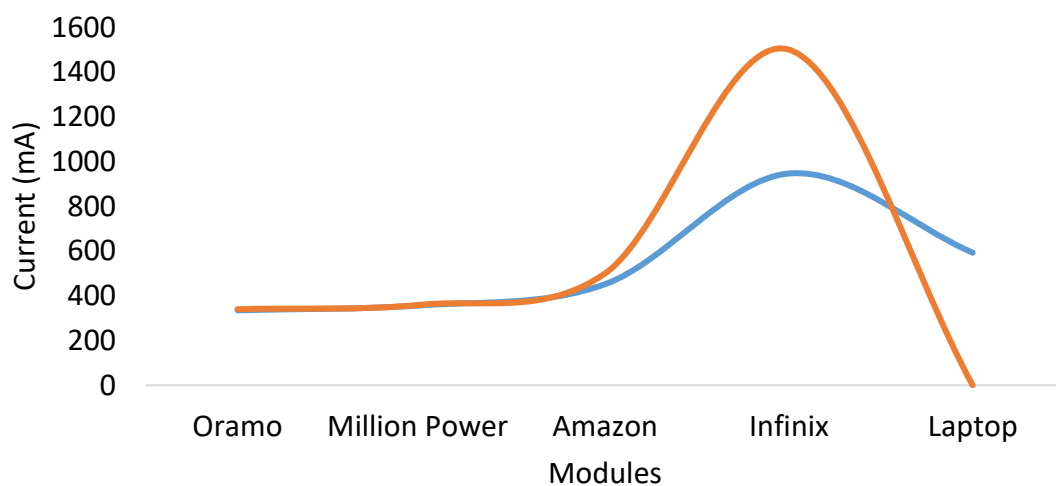


Figure 8. Module current specification to maximum current drawn by Techno Pop 2

The curves (series 1 and 2) of Figure 8 show that, Infinix charger recorded a current of 900mA drawn by Techno Pops during charging (series 1) as against its rated short-circuit current of 1500mA (series 2). This implied that the Infinix charger can accommodate the charging of two or more phones. Amazon charger recorded 400mA charging current as against short-circuit current of 450mA while Oramo and Million Power current drawn and short-circuit rated current are approximately same. The implication is that these model chargers of Oramo, Amazon and Million Power can only be employed for single phone charging at a time.

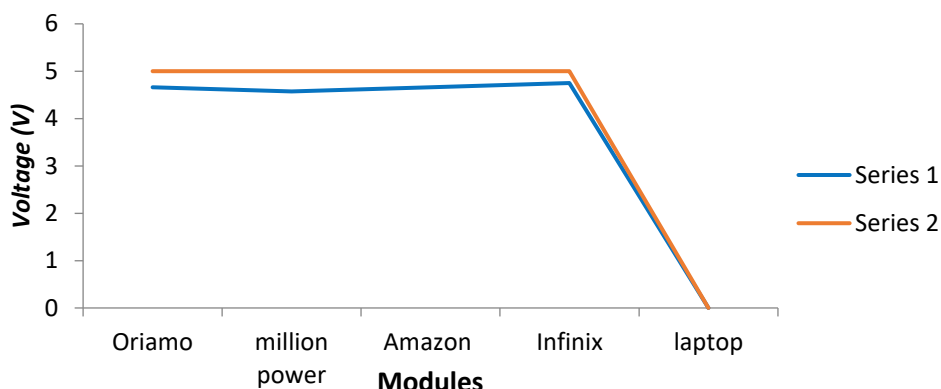


Figure 9. Module voltage specification to maximum working voltage for Samsung A12

Series 1 in Figure 9 indicate various reactivated modules working voltages when charging Samsung A12 while Series 2 indicate modules open-circuit specified voltages presented in Figure 4. The open-circuit curve shows a unified average voltage of 5V indicating that most chargers output voltage specifications are 5V. The chargers load curve response show that the Oriamo charger recorded a maximum voltage of 4.7V while the Million Power recorded a minimum of 4.5V.

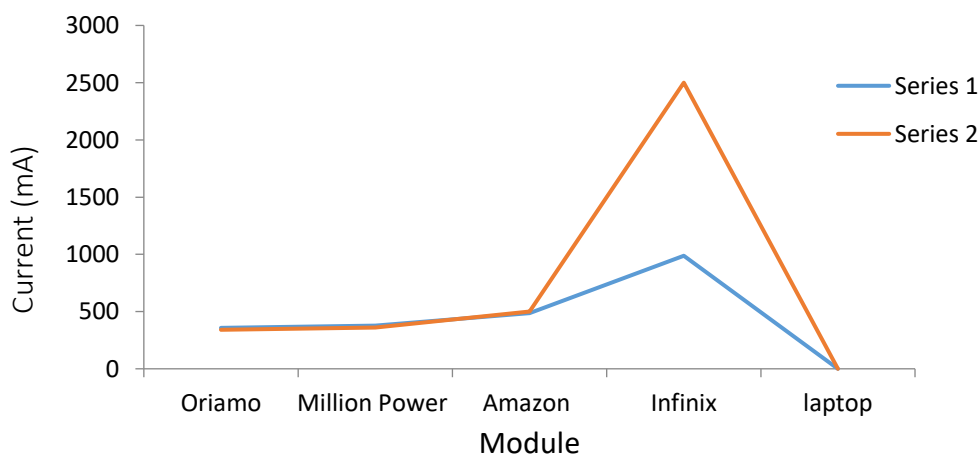


Figure 10. Module current specification to maximum current drawn by Samsung A12.

The curves (series 1 and 2) of Figure 10 show that, Infinix charger recorded a current of 950mA drawn by Tecno Pops during charging (series 1) as against its rated short-circuit current of 2600mA (series 2). This implied that the Infinix charger can accommodate the charging of two or more phones. Amazon, Oramo and Million Power current drawn and short-circuit rated current are approximately same. The implication is that these model chargers of Oramo, Amazon and Million Power can only be employed for single phone charging at a time.

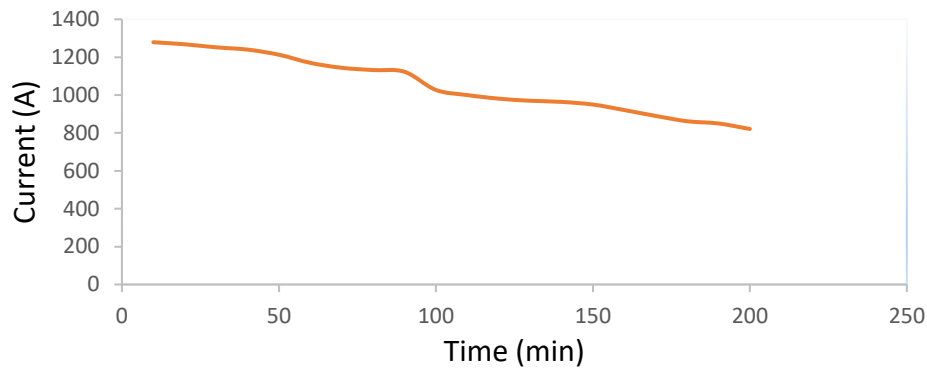


Figure 11. Plot of module charging current with time for Tecno Pop2.

The curve of Figure 11 shows a decrease in charging current during charging. At the first 10min, the charging current was about 1279mA. As charging progresses, the current reduces. It took 200min to charge Tecno Pop2 to full current of 821 mA. Taking some coordinates, the current charging rate can be deduced as follows.

$$\text{Current charging rate (CCR)} = \frac{1027 - 890}{100 - 170}$$

$$\text{CCR} = - .457\text{A/min}$$

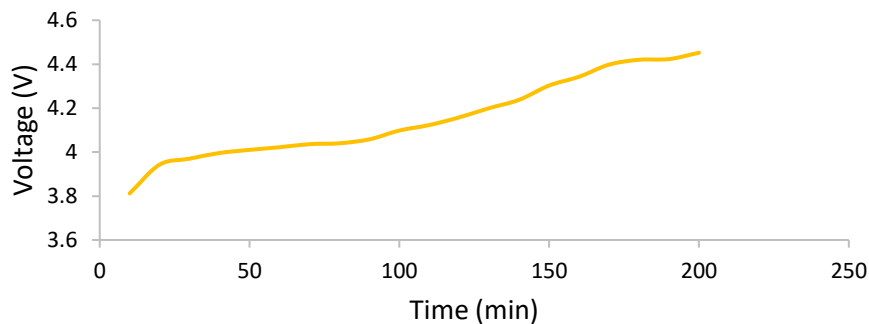


Figure 12. Plot of module charging voltage with time for Tecno Pop2.

The curve of Figure 12 shows an increase in voltage with time during charging. At the first 20min, the voltage was about 3.8V. As charging progresses, the voltage increases. It took 200min to charge Tecno Pop2 to full voltage of 4.55V. Taking some coordinates the voltage charging rate can be deduced as follows.

$$\text{Voltage charging rate (VCR)} = \frac{4.398 - 4.098}{170 - 100}$$

$$\text{VCR} = +.01\text{V/min}$$

4.0 Conclusion

The study, investigative analysis of cell phone charging modules in Nigeria using Oleh Community as a case study was successfully carried out. The main circuit components found in chargers were critically examined and recommendation on the most likely failed components was put forward from a sample of twenty (20) failed chargers. Reactivation of the sampled failed chargers were carried out using the necessary reactivation tools. Testing the reactivated chargers performance was proved to be adequate. In addition, the experiment performed on the reactivated failed chargers show enhanced power delivery and reduction in charging time compared to their initial specifications. Generally, based on the rising cost of chargers in Nigeria, there is an urgent need for local design or recovery of failed and malfunctioning chargers and urgent attention be focus in this direction. Further work should be done on the

energy usage of mobile networks and service infrastructure with regard to cell phones and chargers.

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