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RESEARCH ARTICLE

Design and Simulation of Cellphone Charging System for a Shop in Nigeria

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ABSTRACT

The increase in mobile phone usage in Nigeria has been significant over the past few years, this increase is because of the growing population of Nigeria and high demand for connectivity. Mobile phones cannot be used effectively without charging their batteries whenever they are low or else they will be useless when the battery is flat. Power interruptions in Nigeria are frequent and unplanned. Charging cellphones from solar systems at private charging facility has proven to be the best option in the absence of power supply. This paper presents an overview of different types of mobile phone chargers used in Nigeria; it also presents a design of private cellphone charging system that can be installed in shops. Dynamic modelling and simulation results of the designed system are included in this paper.

Keywords: Charging efficiency, charging station, fast charging, hybrid power system.

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1. Introduction

The use and purchase of mobile phones in Nigeria is growing tremendously with android devices dominating the market followed by Apple phones. Nigerian telecommunication has evolved from NITEL phonebooths to Nokia 3310, Sony Ericsson, Java phones, Symbian phones, blackberry, android phones, apple phones etc. There has been a surge in the use of smart phones among Nigeria population mostly the youths, the increase in the usage of smart phones among the youths is because of the numerous opportunities that comes with the use of internet which includes e-commerce, freelancing jobs, remote jobs, entertainment, education etc. The benefits of using mobile phones cannot be overstated, it has helped in the globalization and digitalization of the world which all of us are enjoying today. To make maximum use of these phones, the batteries need to be charged whenever it is low or flat. Charging of phones in Nigeria faces the challenge of unreliable power supply, to mitigate this challenge, cellphone charging stations that makes use of alternative energy must be built across the country to ensure steady and dependable access to electricity for charging phones and other gadgets.

Mobile phone chargers that are used for charging phones have become an essential part of our modern-day life. Chargers work by converting the alternating current from the socket to direct current that is needed to charge the batteries of our mobile phones. Phones and other gadgets will be useless without recharging their dead batteries [1]. To charge a phone, it is advisable for users to check compatibility between the mobile phone and the charger. Checking phone and charger compatibility involves making sure that their voltage, charging current, polarity and shape match. The issue of incompatibility between mobile phones and chargers has led to overheating of phones, damage to phone batteries and pollution to the environment. The invention of different types of mobile phone chargers and the need for compatibility, efficiency and fast charging has brought about an evolution in the mobile phone industry. The latest mobile phone chargers are designed to be compatible, efficient, faster and portable while maintaining high safety standards [2]. In this review, different types of mobile phone chargers will be examined, and their technology and specifications will be compared.

1.1. Base Plug Chargers

Motorola invented the first mobile phone, Motorola DynaTAC 8000X in the year 1983. The mobility of this invention brought about the break away from the constraint of direct power connection for charging phones. Motorola DynaTAC 8000X was equipped with a base-plugged charger that is portable and mobile just like the first invented mobile phone, Motorola DynaTAC 8000X shown in Fig. 1. The base plug charger took more than 10 hours to charge a battery that will last only for 30 minutes talk time. The base plug charger could not stand the test of

Fig. 1. Motorola base plug charger.

Fig. 2. Integrated charger.

time because it lacked advanced features like fast charging and efficiency, it was only able to give an output of 5 V and 2 A.

1.2. Integrated Chargers

A Finnish multinational company, Nokia corporation made available its first portable phone, Nokia 1011 in 1992. The first portable Nokia phone is measured 195 mm × 60 mm × 45 mm, its 900 mAh nickel-cadmium battery was able to provide 90 minutes talk time. In the integrated charger design as shown in Fig. 2, the charging cable and plug were inseparable, the major drawback of the integrated charger by Nokia was that it could only charge batteries of specific sizes, it also restricted its usage to Nokia users only because of its non-compatibility to other phone products. The integrated chargers operated with a voltage of 5 V and current range of 350 mA–500 mA which makes charging time longer.

1.3. Universal Chargers

Universal chargers flooded into the market in the year 2003, the invention came because of non-standardization in the chargers made by phone industries. The invention of universal chargers helped to solve the non-compatibility in the chargers produced by phone industries. The universal charger as can be seen in Fig. 3 is made up of two adjustable metal contact springs and a transparent clip that will position the battery to be charged, a red light will blink steadily if the battery to be charged is correctly positioned. Universal chargers work with a voltage range of 5 V–20 V and current range of 1 A–5 A.

1.4. USB-A Chargers

USB–A (Universal Serial Bus) charger is a type of charger that is directed towards the host, it has a plug on each head. USB technology has been selected as the standard charging format for mobile phones thereby reducing the proliferation of proprietary chargers. USB–A charger is compatible with many mobile devices; it works with 5 V and current range of 0.5 A to 2.4 A [3]. A typical cable used for such a charger is shown in Fig. 4.

Fig. 3. Universal charger.

Fig 4. USB-A charger.

Fig. 5. USB–C charger.

1.5. USB–C Chargers

USB–C charger is a type of charger with a 24-pin connector that provides power to modern phones, laptops and handheld devices. USB–C is used by both USB technology and other protocol used in connecting and sending data [4]. USB-C technology was developed in 2012 by a group of companies (Intel, Microsoft, HP Inc and USB implementers forum). The user of USB–C can interchange either end of the cable when charging or transferring data, the receptacles or connector measures 8.4 mm wide, 2.6 mm high and 6.65 mm deep. USB–C operates with an amperage of 5 A and a maximum voltage of 20 V, it charges a smartphone in less than 30 minutes with its cable having a data transfer speed of 40 gigabits per second. A USB-C charging cable is shown in Fig. 5.

Fig. 6. USB 3.0 charger.

Fig. 7. Mobile phone charged with a wireless charger.

1.6. USB 3.0 Chargers

Modern electronic devices come with USB 3.0 chargers which is the 3rd version of Universal Serial Bus (USB), it is known as Super Speed USB because of its fast-charging capability. Its architecture is still the same with USB 2.0 model except that USB 3.0 has a new lane that provides a full-duplex data transfer [3] which requires five additional wires and pins, while also providing a new signal coding scheme (8b/10b symbols, 5 Gbps; that is known as Gen 1). The data transfer rate of USB 3.0 is 5 gigabits per second with a charging current of 900 mA, the data rate is 10 times faster than that of USB 2.0 model. In the family of USB 3.0 series is USB 3.1 which has an Enhanced SuperSpeed System with a new coding schema. USB 3.0 charging cable is shown in Fig. 6.

1.7. Wireless Phone Charging Technology

Wireless phone charging is a type of technology that functions by transferring energy from a charging pad to a compatible device [5]. For a wireless charging process to be complete, a charging pad/station that contains a coil of wire that generates magnetic field will be present, a receiver which is the phone that contains a built-in-coil that captures the energy from the electromagnetic field and converts it to charging energy. The commonly used wireless charging format used in the mobile phone industry is the Qi charging technology [6]. The Qi technology uses electromagnetic induction to achieve wireless charging that supports low and medium charging. The major drawback in this technology is low charging speed, poor conversion efficiency and heat loss. Wireless charging offers convenience in charging phones and gadgets which is its main advantage. A typical wireless charger is shown in Fig. 7.

1.8. Fast Charging Technologies

Fast Charging Technologies came to light because of the need for shorter and faster charging times, built-in chips in the phone are designed to regulate the in-rush current to provide faster, cool and safe charging. Some of the technologies used in the fast charging includes PD Power Delivery which is used across many mobile phones and can deliver up to 100 watts of charging through USB-C. Quick Charge 5 (QC 5) by Qualcomm is their latest technology in QC series and it can deliver power of up to 100 W. Oppo, Realme and Oneplus developed VOOC/Dart charging which can deliver power of 240 W. PPS technology (Power Programmable Supply) which is a part of Power Delivery (PD) achieves efficiency and fast charging by tuning voltage and current.

1.9. Gallium Nitride Chargers (GaN)

The latest chargers now incorporate Gallium Nitride technology for faster charging speed and portability. The recent use of gallium nitride is because of its superior properties when compared to silicon. GaN can handle higher voltages and currents in a compactible form which makes them ideal for building portable devices. It also produces less heat which helps in preserving both the charger and the device that is charged. Chargers using gallium technology can output a maximum power output of 240 W.

In Nigeria, people still use all kind of cellphones, and they need different chargers, in case of no power they can go to some shops to charge their cellphones.

2. Modelling of Cellphone Charging Circuit

The design of the charging circuit of the cellphone charger was done in Matlab/Simullink environment. The cellphone charging station is part of the electrical system of a supermarket as can be seen in Fig. 8. The hybrid power system at Better Mart consists of 76.8 kW rated capacity of Trina Duomax PEG14 320 W solar panels, 50 kVA Caterpillar generator that runs on diesel, Grid system, 24 kW Fronious Symo Inverter, Charge controller, 30 pieces of EnerSys PowerSafe SBS 1800 battery storage with a capacity rating of 12 V/220 Ahr each, and a 39.59 kW peak load. The dispatch strategy used in the design is a cycle charging dispatch strategy whereby whenever a generator needs to operate to serve the primary load, it operates at full output power [7]. The cellphone charging system is directly connected to the 360 VDC of the overall system as can be seen in the system block diagram in Fig. 8.

The design of the cellphone charging circuit in Fig. 9 was carried out using MATLAB Simscape. The circuit has 3 similar sections that have different DC regulated outputs (5 V, 9 V, 12 V) which is used for cellphone charging. The Zener diode in each section of the circuit design produces a stable reference output voltage of 3.2 V, which is used to compare the feedback voltage from the voltage divider setup. The voltage divider setup of the circuit (R2, R3, R5, R6, R8, R9) feeds a fraction of the output voltage to the input of the Operational Amplifier. The feedback voltage is them compared with the reference voltage (3.2 V) from the Zener diode, the difference of the comparison

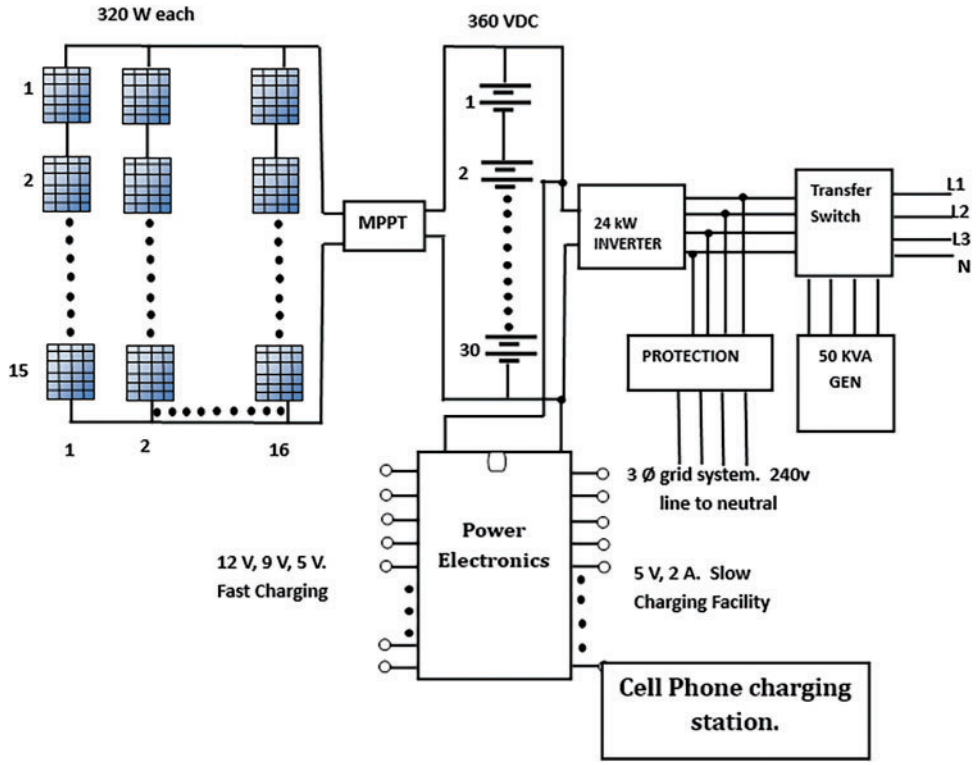

Fig. 8. System block diagram of the cellphone charging system connected to the solar system.

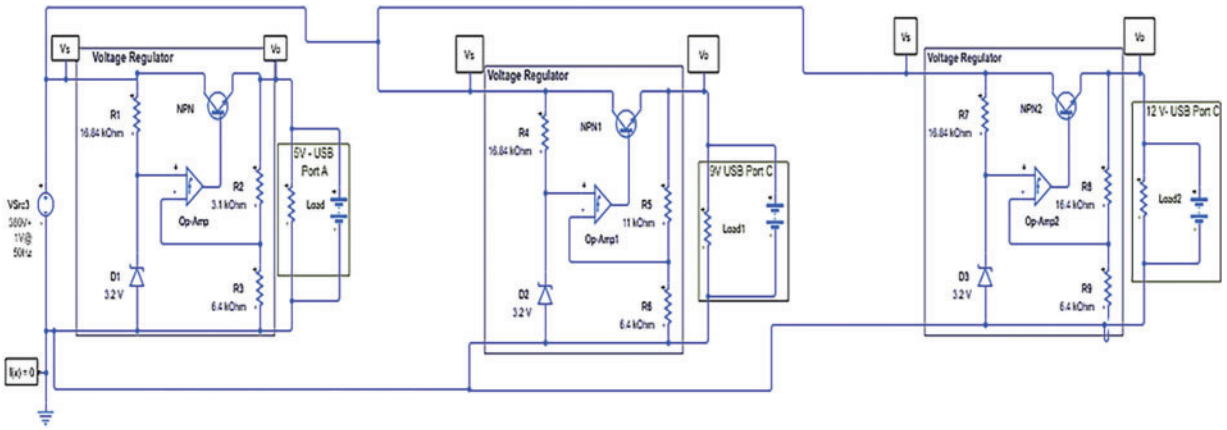

Fig. 9. Circuit diagram of a cellphone fast charger.

is augmented by the OP Amp and is used to control the base current of the NPN transistor. The increase in the conduction of the base current of the NPN transistor drives more current to flow from the 360 VDC to the load which is the battery of the mobile phone to be charged. In other hand, if the conduction current of the base current decreases, the NPN transistor will restrict current from flowing from the 360 VDC. The Operational Amp and the NPN transistor in the circuit work together to regulate the output voltage to maintain a stable output. The graph below shows the result of the stimulated charging circuit. In Fig. 10A, the source of the circuit is 360 VDC which is stepped down to a regulated output steady Direct voltages that is used for charging cellphones, the output voltages as can be seen in Fig. 10B are 5 V, 9 V and 12 V. Fig. 11 shows the output current of the stimulated circuit, the output current of 2 A is the same across the three voltage output.

3. Proposed Design of Cellphone Charging Station

Cellphone charging station is a critical infrastructure that is needed across Nigeria and other African countries where communication and mobile connectivity boosts economic activities and social development [8]. Nigeria experiences steady power outages especially in the rural areas where mobile connectivity is needed for smooth running of businesses. Cellphone charging stations are situated in public places where people easily come and charge their phones after paying a charge fee. Cellphone charging station business have proven to be beneficial, but it also comes with a lot of challenges like cellphone theft, frequent power outages which causes cellphone charging station operators to rely on alternative power sources like generators, high demand of cellphone users, lack of regulation on pricing and charging station facility failure because of wrong electrical connection [9]. Addressing these challenges with

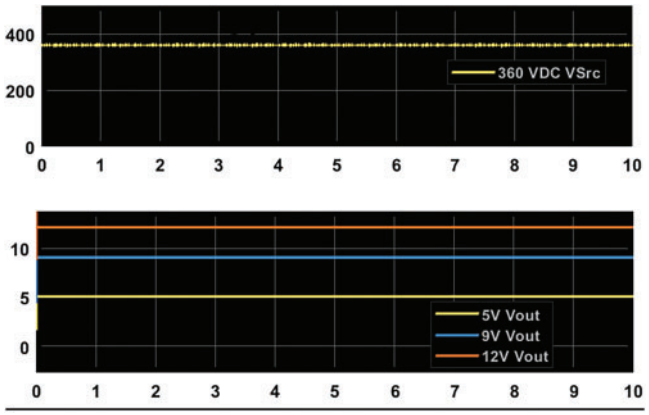

Fig. 10. Voltage input and output of the cellphone charger.

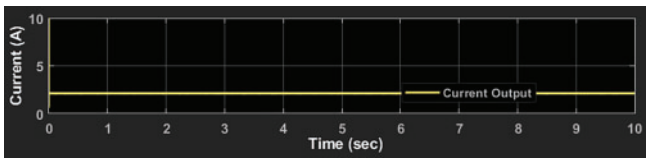

Fig. 11. Current output of the designed circuit.

cellphone charging station involves promoting the use of renewable energy in cellphone charging stations, improving security measures in cellphone charging stations to avoid cellphone theft and standardization of cellphone charging cost. In the proposed cellphone charging station, all the potential challenges faced with cellphone charging station were carefully addressed. The charging station will be built to help customers of better mart and the community of Badore, Ajah Lagos state, Nigeria to charge their phones at a subsidized price. The charging station will be positioned in front of Better Mart which is located at Remlek bus stop, Badore Road, Ajah, Lagos, Nigeria [10]. The cellphone charging station at Better Mart will help customers and the nearby community to effectively charge their cellphones. The input to the charging station is 360 VDC bus voltage of the supermarket while the current rating of the station is 150 A. The output voltages of the cellphone charging circuit is 5 VDC mini-USB cable and round connector cable, 9 VDC micro-USB and 12 VDC USB-C. The cellphone charging station contains 50 boxes and it is capable of charging 150 cellphone, each box will have one mini-USB cable, one micro-USB cable, one USB- C for fast charging and one round connector cable as shown in Fig. 2. Wireless charging pads will be included in 8 boxes for wireless phone charging. Each box will be provided with a reliable and a strong lock and key which can only be given to a customer when they must have paid the charging fees, the customer returns the key to cashier in charge of the cellphone charging station after plugging in their phone, the customer takes note of the number of the particular box their phone is plugged for easy collection after charging. Charging cellphones at the station is charged #100 per hour, the charging fee is used for the maintenance of the charging station. To further increase the security of the charging station, a CCTV camera that monitors the charging station is mounted above the station.

Cellphone charging stations are important infrastructure in a country like Nigeria where there is a frequent outage of electricity, charging stations are important in public places like the hospital, school and government places [11]. It is recommended for the government and private sector to embark on building cellphone charging stations across the country because of its importance.

Fig. 12. Architectural design of the charging station at Better Mart.

Picture in Fig. 12 is an architectural design that shows how the proposed charging station will look like after the implementation of the project.

4. Conclusion

A cellphone charging circuit for a charging station has been designed and simulated using MATLAB, the result of the design is presented in this paper. The input to the charging station is 360 VDC bus voltage of the supermarket. The result of the designed circuit is 5 VDC mini-USB cable and round connector cable, 9 VDC micro-USB and 12 VDC USB-C. The cellphone charging station contains 50 boxes and it is capable of charging 150 cellphones, each box will have one mini-USB cable, one micro-USB cable, one USB- C for fast charging and one round connector cable as shown in Fig. 2. Wireless charging pads will also be included in 8 boxes for wireless phone charging. Literature review of different cellphone chargers has also been presented in the paper to better understand the working principles of different types of cellphone chargers. It is recommended for phone users to always check compatibility between phones and chargers before charging to avoid overheating of phones, battery damage and phone explosion. Cellphone charging stations are important infrastructure in a country like Nigeria where there is a frequent outage of electricity, cellphone charging stations can be seen in public places like the hospital, school and government places, individuals can also build cellphone charging stations and commercialize it. The proposed cellphone charging station at Better Mart will help phone users to effectively charge their cellphones at the cost of #100 per hour.

Future work will include designing and incorporating wireless pads in the 50 boxes of the charging station.

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Conflict of Interest

The authors declare that they do not have any conflict of interest.

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