Optimized connection for faster battery charging and longer working time

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ABSTRACT

Considering the increase in energy consumption and issues related to air pollution by chemical residues and global warming caused by the consumption of fossil fuels resulting from that combustion, many approaches have been considered to reduce the use of fossil fuels and the use of renewable energies at this time. Efficient use of energy, energy storage and management is critical because portable power sources are environmentally friendly as well as provide economic cost and reduce dependence on fossil fuels. One of the most important commodities available for energy storage is the battery. Various electrochemical lithium batteries are used in series to achieve the voltage required for applications such as electric vehicles, industrial power systems, military purposes, etc. Batteries used in a series will have differences in capacity due to factory conditions, the environment, the chemical involved in its manufacture, especially lithium, and the number of times of charging and discharging, this series of batteries will move towards an imbalance of voltage and capacity. This is an incentive to create and develop battery power system management and an integrated charging system, to balance batteries and increase their capacity, efficiency and life.
The purpose of this research is to stimulate the establishment and development of an integrated charging system for the lithium-ion battery, and to balance the batteries and increase their capacity, efficiency and life,
In addition, proposals will be presented to design a high-efficiency charger with typical electrochemical components and standard specifications, to provide an optimal solution for those battery chargers.

Keywords: battery charger , lithium battery, renewable energy, electric vehicles, vehicle-to-grid

I - Introduction

Recently, it has been noted that governments, organizations, and investors have resorted to many methods to reduce the use of fossil fuels and use renewable energies through alternative sources due to the increase in energy consumption and issues related to air pollution and global warming resulting from the consumption of fossil fuels.[1] And since batteries are one of the most important elements of energy conservation, therefore, the effective use of energy, its storage and management is crucial because portable energy sources are environmentally friendly in addition to providing economic cost and reducing dependence on fossil fuels. Battery chargers are usually used for the purpose of charging used batteries to a fully charged state after they have been used and discharged. Rechargeable batteries, as well as secondary cells, differ in terms of design and the chemicals used to manufacture them[2] .

And because the battery is one of the most important commodities available for energy storage. Several electrochemical batteries are used in series to achieve the required voltage for applications such as electric vehicles, industrial power systems, military purposes, etc. Chargers and batteries used in series vary in capacity due to factory and environment conditions, and several times of charge and discharge, this series of batteries will move toward voltage and capacity imbalance [3] . This is an incentive to create and develop battery power system management and an integrated charging system, to balance batteries and increase their capacity, efficiency and life. It is necessary to know the batteries and chargers, as detailed below:

1- Batteries [1]:[3][29][30]

Batteries Types

1. Rechargeable batteries differ in terms of the chemicals used to manufacture them[.

A. The first type: lithium battery designed to support backup power sources for most electronic equipment.

B. The second type: ferrous electrode batteries, which are a type of battery that occupies 60% of the batteries sold worldwide, which can be recharged and are characterized by (low self-discharge and good energy density) , but they are (more expensive than lead-acid batteries, and they provide poor performance in extreme temperatures)

C. The third type, the common type is rechargeable zinc, alkaline and manganese dioxide batteries, as they are considered good and new alternatives because they are (low in cost and Battery chargers for these products are commonly available) , but their useful capacity does not exceed two thirds of the capacity of the primary cells.

D. There are other types of batteries that can be recharged, such as:
- air or metal batteries,
- Ni-Cd batteries .
- Batteries that include chemicals in their manufacture, such as:
- Nickel Hydrogen (Ni-H2)
- Nickel Metal Hydride (NiMH)
- silver oxide (Ago)
- Nickel, Zinc (Ni-Zn)

2. Rechargeable batteries in terms of styles, design and physical form .

As for the cell size, the cell varies according to standard or non-standard battery styles, namely

1 - Standard patterns: and divided into

A - cylindrical styles (4), having a positive top; negative bottom. The standard cylindrical patterns are:
- Pattern with code (A) (AAAA, AAA, AA, 1/3 AA, 2/3 AA, 1/2 AAA, 2/3)
- The model bearing the symbol (C): (C, C, 4/5 C)
- inscribed with the symbol (D): D and 1/2 D
- the form with the symbol (N): (1 / 2N, N)

B- The rectangular battery No. (5) is a standard type of battery with a voltage of (9 volts). It is rectangular in shape with positive terminals and negative terminals located on the upper side of the battery.

2 - Non-standard rechargeable styles include:

- Coin cells or buttons similar to the buttons of a robe or a circulating coin.
- Prismatic cells.
- Lantern batteries
- Crystalline cells
- and battery packs

3 - Lithium Polymer Battery (LiPo)

- This battery is from the (lithium-ion) family, but it is distinguished because of its special structure. This battery uses lithium polymer cells instead of lithium bulk electrolyte in solid polymer compounds. [3]:[6] [29][30].

Advantages of lithium polymer batteries [29][30] :

1 - Lithium polymer battery has the highest amount of specific energy compared to other batteries.
2- It is of high quality.
3- Packaging flexibility.
4- It is the most suitable choice for portable equipment such as mobile phones and laptop computers.

Disadvantages of Lithium Polymer Battery In comparison to other batteries of the lithium ion family [29][30],

1- Lithium polymer battery has a shorter life cycle and the number of cycles.
2- It cannot be used in places such as connecting to the national grid or manufacturing electric cars.

2- Battery charger

Definition of battery charger:

A device used to put energy into rechargeable batteries or a secondary cell by passing an electric current through it. The charging protocol depends on the type and size of the charged battery [16]:[20][29][30] .

Applications of battery chargers :-

1- IN the ships as:_

A- As a backup charger (12/24V) for the main control of the ship's engine
B- As a charger to control the propulsion and moving process (48 volts).
C- Control radio stations for ships (12/24 volts) and communication systems (satellite 12/24 volts)
D - As a backup emergency charger, (UPS 12/24 volts)
E - Use in fire alarm and extinguishing systems (12/24 volts), etc.

2 - IN the airport Use as a 110V DC source for SWGR control power fuel supply system. - (24VDC) and (48VDC) for field instrument, main console on platform and aircraft fixtures.

3- Use as a regenerator for dead lead-acid batteries. The process takes place with a mixture of the solution and DC generators.

4- For battery powered vehicles such as (Vehicles, remote control car, electric/hybrid cars, and fork lift trucks, agricultural equipment, HVAC spray units.),
For DC standby power applications telecom.

5 - Instrument battery chargers, two-way radio battery charging, rechargeable battery flashlights, battery-powered household, office and industrial tools, remote control, telephone, cameras, scientific instruments, computers, inverters and electronic devices .

- As for the Display screens, and the display method is in the form of (dot matrix or segmented) that provides alphabetical or digital representation, light-emitting diodes (LED) are mostly used , and there are three main types, which are:

1. Analog screens

2. Digital
3. LED screens. in most uses.

II. LITERATURE REVIEW

Due to the possibility of developing traditional devices to charge batteries with alternative and new sources used in many industrial and technological fields. Through the introduction of these technologies in the field of renewable energies and electric cars, which it is hoped will be together in the new future, many comprehensive researches and tests have been conducted with the aim of keeping pace with global developments, as follows:

A . Literature review of electric vehicle (V2G) battery chargers.

Based on several of the previous studies at the electric vehicle (V2G) battery chargers and Due to legislation, high energy costs, environmental issues, climate change, concerns about the security of fossil energy and its reserves, and the number of consumers that are increasing daily, electric vehicles called hybrids (PEVs) have been spread all over the world [1] - [3]. And since electric cars have not spread widely, due in part to social obstacles, technical limitations, and cost when compared to vehicles powered by (conventional) internal combustion engines [4], and based on these moderate expectations, experts predicted within a year By 2020, up to 35% of all vehicles in the United States will be hybrid PEVs as determined by the Electric Powers Research Institute (EPRI) [5]. It was found that there is an adequate generating capacity in the United States of America to accommodate more than one million electric vehicles without problems [6]. Governments, most of the automotive sectors, and many organizations such as (IEEE), as well as (Society of Automotive Engineers) (SAE) and (Electric Energy Research Institute) (EPRI) are working on preparing specifications, codes, and standards that meet customer demand. PEVs have many advantages when compared to autonomous (hybrid) electric vehicles (HEV) as well as vehicles with internal combustion engines (ICE): When connected to the national electric power grid. The PEVs then operate in unloaded mode as a vehicle-to-V2G power generator. In the charging mode, the process is reversed, as devices from the electricity grid to a vehicle (G2V) [7]. The concept of V2G has caught the attention of vehicle owners and grid operators. However, in order to achieve the benefits of V2G capabilities, available electricity supplies, as well as convenient recharging, are necessary. were identified for research purposes and are summarized in the first table. , "(V2G)" is used generically for both energy streams (V2G and G2V). A number of proposed V2G concepts were discussed including charge/trans charge strategies, individual structures and features, services, power flow technologies and component assembly.

B . Literature review of electric vehicle chargers (EV).

This paper presents a compact charger connected on board electric vehicles (EVs) containing an asymmetric machine that relies in its operation on additional degrees of freedom present in those machines [7] . For vehicles using grid power to charge the battery, traction circuit components are not engaged during the charging time, so there is a possibility to use them in the charger circuit to have an onboard integrated charger. The battery charger can be galvanically isolated or nonisolated from the grid , The proposed charger is a bidirectional high-power charger with a unity power factor operation capability that has high efficiency[8]. In this paper, we investigated the EV charging problem at an intelligent parking garage subject to the real TOU electricity pricing. We designed a multi charging system for the garage charging operator to effectively provide charging services by jointly considering the charging station profit and customer satisfaction. Besides, we analyzed the battery charging characteristic change during the actual charging process and applied it into the EV charging problem . With it, the charging operator can achieve the best performance compared with other existing algorithms, which is promising for the parking garage charging service proliferation. And How to schedule the charging activity according to different pricing schemes and how to integrate the incentive mechanism to achieve a win-win solution for both the customers and the charging operator are some further directions for us to consider[10].

C . Literature review of lithium-ion battery chargers .

IN this study Lithium-Ion batteries and super capacitors traditional energy storage systems(ESSs) need a voltages balancing circuit to remove voltage imbalance and one bidirectional dc-dc converter to control the charge process. In this paper, a self-equalized charger for lithium-ion batteries is proposed which consists of a phase-shifted full bridge dc-dc converter for charging operation and a voltage multiplier for eliminating voltages imbalance. Owing to integrated structure of the proposed circuit, complexity and volume of the system are reduced. By using phase-shifted method, the converter experiences ZVS operation which gives rise to high efficiency and control simplicity. a high power high efficiency self-equalized battery charger by using phase-shifted full bridge converter and voltage multiplier for lithium-ion batteries has been presented [1] . In this paper , a new technique is introduced for increasing the battery cells balancing process speed. The proposed algorithm causes the cell with minimum voltage to be disconnected from the common capacitor and remain with the same charge in the first switching cycle. This algorithm significantly increases the balancing speed of the cells [2] .

III - Challenges of battery chargers-:

With the recent increase in demand for clean energy, including devices that operate on storage energy in batteries, many challenges have emerged, including the challenges of charging the battery[28] , and it had to be mentioned because of its importance And as mentioned below-:

* The first challenge: minimizing unjustified energy losses.

The primary challenge is to achieve a longer total runtime after fully charged. In A- Use in heavy equipment, 12 and 24 volt systems,

B- Use in marine equipment this case, the longer overall runtime translates to the number of cycles the battery charger can charge. throughout its useful life. Ultimately, achieving highly efficient charging while minimizing energy loss from the charger case.

*The second challenge: reducing the overall size of the charger without removing the features:

It is called the Global Challenge, where designers compete to design batteries and chargers - with a smaller size and greater functionality. Devices with the most integrated components should be selected. For example:

- A high-performance linear charger is a good option because it integrates additional power rails that supply the main system blocks of the device (such as a headset.(
- Switch bars are the best choice for low-voltage and power-hungry blocks, such as in wireless communication units and processors, being efficient and low-noise.
- You also need the sensors for measuring blood oxygen and heart rate. A boost adapter that enables power rails to be integrated into the charger in a smaller form factor.

*The third challenge: extending the waiting time

An important issue is the standby time because consumers expect their devices to be ready to run even after a long idle time outside. Li-ion cell chargers are higher in energy density, and thus pack more power. Note that a full charge will also increase standby time. The battery charger with small termination current with high accuracy will help to extend the standby time as well.

***The fourth challenge**: security and safety measures:

The safety guidelines and procedures followed by charger and battery pack manufacturers must be available at different temperatures, and it is essential that chargers and battery packs remain in safe operating areas during use. Some require a standard profile where charging stops outside specified hot and cold temperature limits, and this requires specific ITA profiles to be compatible with these temperature profiles.

***Fifth challenge**: ensuring system reliability

This is rare, but it requires studying and setting the power of the system microprocessor so that it can return to normal and reboot.
Some microprocessors can malfunction due to low system reliability, and when the consumer plugs in the charger. Some battery chargers incorporate a timer to monitor the devices.

***Sixth challenge**: Catastrophic errors caused by incorrect use of the battery charger [27] which will be summarized below:

- Use of low voltage decoupling (LVD) can result in intermittent DC output. This can harm the operation of communications equipment; Especially the remote protection equipment for high voltage overhead lines.
- Most problems are caused by poor battery maintenance. Connecting a battery charger with too high a voltage to a battery can cause the battery to overheat and explode.
- Wrong polar connections, for example, the positive pole is black and the negative pole is red.
- Under-rated chargers (called "profitable") lead to complete failure of the entire system with the consequences of connecting expensive components that are triggered.
- Customers have a bad cell or jar. And she takes out this jar and does not adjust the float effort .
- Disconnect the current if the charger is connected to basic devices that will stop if the power line is cut off.
- Polarity 2- Capacity 3- Using the charger as a power source 4- Grounding is very important especially if you change the polarity by mistake. harms the hardware.
- A Li-ion battery will deteriorate and melt when connected to a cheap unbranded charger.
- Gel batteries explode from a high charge rate.
- Current and voltage over ranges .

IV - Suggestions Designs

The synchronous charger is designed to fit the electrochemical components of the lithium-ion battery, this is a high-efficiency design with standardized configurations, error handling and return to work, and reduces energy loss. Experimental results can be achieved in the future, which confirm the feasibility of the proposed scheme. It has the following specifications:

1 <u>The Specifications of the designed charger:</u>

1- High efficiency - exceeding (90%) with typical loads .
2- small size ,Small filter components, resulting in a smaller plate
3- Complete error protection.
4- Space and cost reduction materials list.
5- Small filter components, resulting in a smaller plate
6- Equipped with integrated power switches
7- Contains an interface through which programming is achieved and
8- Statement of charging status.
9- Ease of use and can work with related smart energy products.
10- .Complete protection against the risk of over-current, charging time-out, over-voltage and over-temperature,

2- Independently adjust the regulation voltage according to the temperature range .

There are temperature ranges through which the regulation voltage can be set, as mentioned below:

1. The first range: temperatures range from (0 to 9.9) ^{o} Celsius.
2. The second range: temperatures range from (10 to 44.9) ^{o} Celsius.
3. The third range: temperatures range from (45 to 99.50)^{o} Celsius.
4. The fourth range: temperatures range from (50 to 60) ^{o} Celsius.

3- Practical specifications of the design structure:

1. User programmable charging current: (from 50mA to 1500mA)

2. Wide input voltage range: (from VBAT + 0.3V to 7.2V)
3. Withstands the operating temperature of the intersection: - (39.9°C to 124.9°C) with Frequency (megahertz per minute)
4. Possibility • PWM current mode control, at constant voltage
5. C™ program interface with EEPROM registers
6. Protection from high voltage and heat
7. Design dimensions: 16-tooth PQFN (4 mm x 4 mm).

4- Battery charger and its typical applications

1. smart phones
2. . electronic readers
3. Portable battery chargers
4. Tablet devices
5. Laptops .

5- Description of the battery charger, working principle, protection, faults and their treatment

Among the important things that have considerations for engineers when designing systems is to take into account the description of the device and protection systems, and to discover errors and how to treat them and get rid of them in order for the system to work as required. Which we will summarize below:

6- Description of the battery charger

1. It is a highly efficient and fully integrated Li-Ion battery charger.
2. It operates under different variables and conditions allowing optimal
3. charging conditions for the widest range of Li-Ion batteries
4. The internal conversion frequency is high.
5. Low cost due to easy LC filter installations

7- Working principle of designed battery charger:

1. -The charger starts the charging process when the lithium battery voltage is less than 3.00 volts.
2. When pre-charging, a programmable charging current is applied and the charging current is very small to complete the battery charging process safely.
3. A level at which the charging current can be fully applied must be reached.
4. When starting the charging process, the regulation will be for the continuous current.
5. The PWM loop will force a constant voltage across the battery, so the battery voltage increases enough to enter maintenance mode.
6. The current is always monitored to see if the battery is fully charged**.**

8- The internal protection of the device:

1. VIN lock under voltage
2. Thermal shutdown: The switch works to shut down if the temperature rises above the set limit (160), once the device cools down to a temperature of 160 degrees Celsius or less, the device will start operating again.
3. VBAT Over-Voltage Protection: Battery protection threshold is set and programmed to 2% higher than the termination voltage. So that turning off the charging profile does not result in an error condition.

9- Error handling

Errors detected in the charger are handled through the following:

A. (NFLT) pin : Its function is if an error is detected (excessive battery voltage, full charge timer expired, battery temperature outside the safe charging range, charging stopped) when the NFLT pin will be pulled low.

When the error condition is initialized and terminated, the device will enter the initialization state, and the status register (00HEX) is read, then the NFLT pin will rise and return to normal, until a new error condition is detected.

B. When the cases shown below are detected, charging stops, and initialization is carried out immediately until the state (00HEX) is reached. And the device returns to work until a new error is detected. The detected cases are:

1. Thermal closure
2. open thermistor
3. Low Voltage VIN
4. The upper stop times out
5. , charging stops immediately and the corresponding bit is set in the status register (00HEX). The device enters the initialization state until the error is detected.

10- Application circle:

11-The typical circuit and the selection of its physical components:

Output inductor (LOUT): It is recommended to use a low ESR (less than 35mΩ) ceramic capacitor for the output filter capacitor (4.7μF). The ESR should not exceed 100 cubic metres. This is to keep the output ripple low

1. Use a 4.7μF output capacitor (C OUT) and a 4.7μH output inductor (LOUT). Through which the internal compensation has been improved.
2. COUT Capacitor Output: Use an inductor with a saturation current rating higher than the maximum load requirement (VOUT) in order to obtain the best performance.
3. Bypass Capacitor (CIN): A low profile ceramic capacitor (ESR) was used for the input supply bypass capacitor (10μF) For best performance . We can add a ceramic capacitor (0.1μF) connected in parallel with (CIN) if we do not have a ceramic capacitor with a low (ESR).
4. Internal Reference Voltage Output (VDD) Bypass Capacitor (CVDD): For best performance, a low ESR ceramic capacitor should be used for the (100nF) bypass capacitor from the (VDD) pin to ground.
5. (RSENSE) Output Sensing Resistor: The value of the output sensing resistor (50mΩ) is chosen, which is the typical value.
6. Pull-up resistors: They are considered an element that performs the function of displaying the error warning signal, and they are connected to the (NFLT) pin on the one hand, and connected to a positive source (VDD).

Error handling

The detected cases that are dealt with immediately are:

A. Heat seal
B. Open thermistor
C. . Low Voltage VIN
D. . upper downtime
E. . Charging stops.

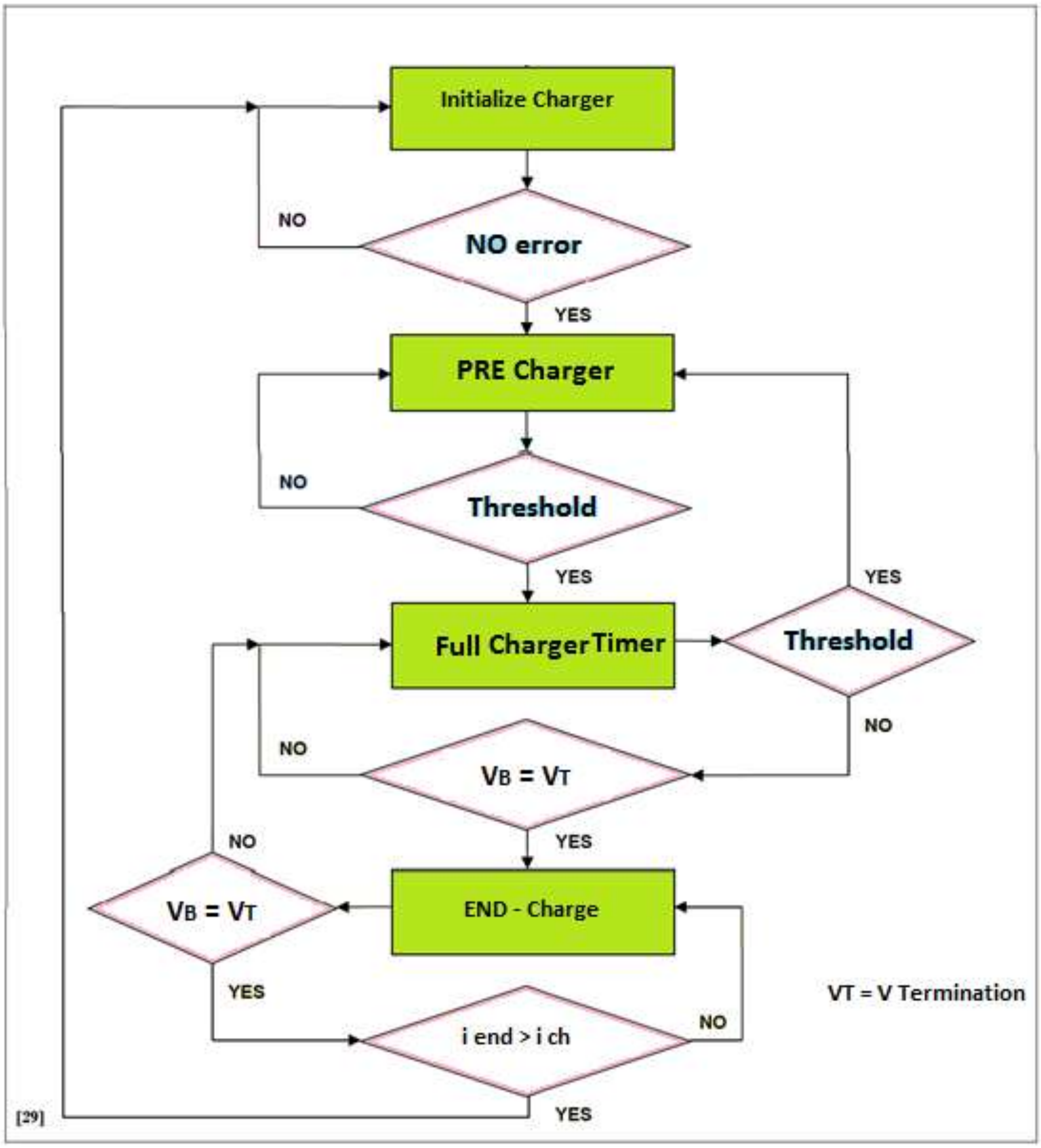

Fig (1) Charging State Diagram

V - Recommendations :.

From the foregoing, and in order to obtain the best performance of the proposed lithium-ion battery charger, the recommendations that we summarize must be followed as follows:

1. Use an inductor with a rating (saturation current) higher than the maximum load requirement (VBAT) plus ripple (inductor current).
2. The chemical is introduced to make a (ceramic) capacitor with (low ESR).
3. A capacitor of the type (ceramic 0.1 degrees Fahrenheit) is used to which (CIN) is added and connected in parallel with it. We follow this method in the absence of (ceramic) material with (low ESR).
4. - To be used in areas with stable electric current, and in the event that it is not available, it is preferable to connect it to areas fed by many sources, the best of which is alternative or renewable energies.
5. It must be of high reliability and correct performance to avoid inaccuracy and damage to the chemical substance (lithium) and thus damage to the battery system.
6. Monitor working conditions and temperatures within standard limits.
7. Proper use prolongs the life of the system in use.

8. Choosing the correct components (electrical and chemical) when designing and adhering to catalogs with standard specifications to obtain the required performance.
9. Presenting the recommendations contained in previous studies and benefiting from them for the purpose of developing the system for the better.

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