REVIEW ON DESULFATION OF LEAD-ACID BATTERY FOR HEV

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Abstract
In today's world, Electric Hybrid Vehicle (EHV) is a prevailing vehicle technology in that the major part is electric battery.Lead-acid battery is the widely usable battery in the EHV because of its cost and efficiency. The real disadvantage in lead-acid battery is that it easily sulfates because of improper charging or discharging. Hence, desulfation circuit or charge controller is placed along with the rechargeable lead-acid battery for proper charging and subsequently sulfation gets reduced. Numerous research techniques are proposed for this desulfation or charge controlling are inspected in this paper. The desulfation or charge controlling of lead-acid batteries done based upon various techniques and our audit made according to various methods such as pulse width modulation (PWM), pressure feedback, resonant frequency, chemical reaction and artificial intelligent. Eventually, the direction for the future research is talked about in view of the survey investigation.

Keywords: electric hybrid vehicle, lead-acid battery, sulfation, desulfation, pulse width modulation, electric vehicle.

1. Introduction

Due to increased fuel price, global warming, population EV technology is coming into picture as have improved performance so becoming suitable for various automobile applications. Still EV has range problem due to limitation of low energy density and specific energy [1-4]. The problem in batteries compared to gasoline engine can be resolved using Hybrid Vehicle (HV) technology with various drive trains, configurations to maximize fuel efficiency and battery life [5-11]. EV/PHEV is also gaining lot of attraction to give pollution free environment.[12] but are a long way from ideal. An immaculate battery has high specific energy, great force abilities, snappy charging time, lifetime, well being, and low cost. Some of these prerequisites are found in Li-ion technology and the cost is still high. In [13] the creators created all the advancements, the expense of the lead-acid battery makes it focused with the future (modest) Li-ion technology (for distances of 200 km) with a condition of five year's battery lifetime.

Sulfation is a real issue in lead-acid batteries for hybrid vehicle and it happens when a lead-acid battery is deprived of a full charge [14] and is basic with starter batteries in cars driven in the city with burden hungry accessories. A motor in idle or at low speed can't charge the battery sufficiently and using little sulfate precious crystals form in lead-acid batteries are ordinary and are not destructive. During prolonged charge deprivation, the amorphous leadsulfate converts to a stable crystalline that store on the negative plates and this prompts the improvement of substantial gems, reduce the battery's active material that is responsible for high capacity and low resistance. Sulfation brings down charge acknowledgement and charging take longer raise internal resistance [15-17].

The two sorts of sulfation are reversible (soft sulfation), and permanent (hard sulfation). If the battery is adjusted early, reversible sulfation is remedied by applying a cheat to a completely charged battery as a controlled present of around 200mA. The terminal voltage of a battery is rise to 2.50 and 2.66V/cell (15 and 16V on a 12V mono block) for around 24 hours. Expanding the battery temperature to 50–60°C (122–140°F) aides in dissolving the crystals and permanent sulfation sets in when the battery has been in a low condition ofcharge for weeks or months and at this stage, rebuilding is not conceivable [18, 19].

There is an almost negligible difference in reversible and non-reversible sulfation, and both happen in practically batteries. Great results are achievable if the sulfation is few weeks old and reclamation gets to be more troublesome when the battery is permitted to stay longer in a low SOC. A sulfated battery enhance barely when applying a desulfation administration and a lead-acid recuperated is obvious on the voltage discharge bend. On the off chance that a completely charged battery holds a stable voltage profile on discharge, possibilities of reactivation are better if the voltage drops quickly with burden [20, 21].

A few organizations offer hostile to sulfation gadgets that apply pulses to the battery terminals to prevent and reverse sulfation. Such innovations have a tendency to lower sulfation on a healthy battery nevetheless can't adequately switch the condition once exhibit. Producers offering these gadgets take the "one size fits all" methodology and the technique is unscientific. An irregular service of pulsing or indiscriminately applying an overcharge hurt the battery in advancing matrix consumption. Advances are being created that measure the level of sulfation and apply an ascertained cheat to break down the precious stones. Chargers offering this strategy just apply de-sulfation if sulfation is available and just for the time required [22-25].

The rest of the paper is organized as follows: - the so far research works in the field of desulfation or charge controlling for the lead-acid battery are listed in section 2. The performance of various research works is analyzed in section 3. The conclusion and future direction is given in later sections.

2. Review on Desulfator for Lead-acid Battery which is Capable of Hybrid Electric Vehicle

In lead-acid battery the sulfation is the real issues, corrupts the life time of the Lead-acid battery. Sulfation happens due to inappropriate charging and discharging which is frequently seen in cells that work in the low state of charge (SOC) for no. of time.Various literature shows about sulfation process and methods for desulfating it.[26-30]..

Consequently keeping in mind the end goal to improve the life of lead-acid battery in cross breed vehicle a desulfator is put alongside the battery, the correct charging is attained to. In this paper we audit the strategies for the desulfation of lead-acid battery. Various strategies for desulfation are Pulse Width Modulation, Pressure Feedback, Resonant Frequency, Chemical Reaction and Artificial Intelligent. In this paper our audit is taking into account these five methods.

2.1. Review on Desulfation by Pulse Width Modulation

Pulse Width Modulation (PWM) charging mode is the best intends to steady voltage battery charging by exchanging in the middle of on and off with certain recurrence and a variable obligation cycle the yield present of Generating point (GP) modules to the batteries. The outcome is higher charging proficiency, quick energizing, and solid battery at full limit. The charge controller, as demonstrated in fig. 1, permits the battery to be charged at full charging exhibit present from the lower set-point battery voltage (LVD) up to the gassing set-point, Vg, where the framework then uses PWM to control the charging current. At high voltage disconnect (HVD); the era point is detached to keep the battery from being over-charged. The high and the lower set-point are not much kept consistent yet controlled by the product for enhanced operation. On the other hand, the heap is separated, if the voltage of discharging battery falls beneath LVD, the heap is separated. Load reconnect voltage set-point (LVR) permitted to gather enough charge for the following discharge cycle [31].

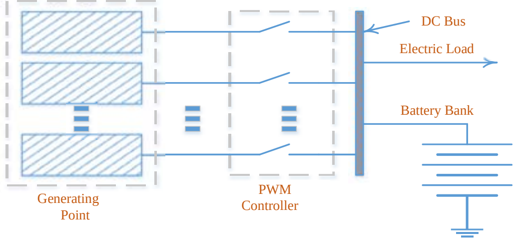

Figure 1: Charge control by Pulse Width Modulation

Michael J. Rolfes [32] has displayed a technique and mechanical assembly for charging a battery. A voltage controlled charger applies an introductory charging flag and measures the battery terminal voltage. Accordingly, the charger generously keeps the charging signal from surpassing the battery gassing potential amid the charging procedure. The strategy and mechanical assembly likewise desulfate profoundly discharged batteries. The strategy and device screen a swell voltage connected with the battery terminals to evaluate battery charge acknowledgement and battery quality. The measure of average swell voltage ideally diminishes as the charging method moves ahead.

J. Marcoset al. [33] has talked about the quick charge procedure because of the way that one of the limits of the lead-acid batteries is the long charging time without focusing life of battery. In the first stage consistent high present and as a part of the second stage is current heartbeats controlled by a PID controller. Nitin Bhiwapurkar *et al.* [34] have proposed two control methods for battery SOC control were assessed for streamlining mileage and depth of discharge (DOD) of battery for extent extender vehicle. Counselor model with leadcorrosive battery is to assess and think about efficiency and DOD of battery in city drive cycle.

The charge and discharge qualities of lead-acid battery and LiFePO4 battery is proposed by A. ChihChiang Hua *et al*. [35]. The work lies in offering the pulse current charger of higher crest for the charging time to achieve the objective of quick charging furthermore evades the polarization phenomena delivered charging the voltage and current flag at the same time, administering entire charging course of the battery, staying away from the circumstance of unreasonable charging, and guaranteeing the life of battery. Jae-Hak Yoon *et al*. [36] has displayed the continuous reproduction of the battery charging attributes controlled by the 12-stage generator framework. The vitality collecting from activity bike is proposed by Suchart Jan jornmanit *et al*. [37]. The proposed topology is in view of lead-corrosive battery charge controller for photovoltaic framework. The changed steady voltage charging control, is prescribed by IEA, is adjusted and actualized in this research. CUK converter is to convey the vitality; from bike mounted the battery is charged appropriately by charging voltage and current. Wujong Lee *et al*. [38] have proposed a battery swells current diminishment strategy and outline of three-stage interleaved dc-dc converter for 5kW battery charger. The charger comprises of three-stage interleaved dc-dc converter, DC connection and a matrix joined inverter.

Nosh K. Medora *et al.* [39] has proposed a battery model, which allows the client to utilize the makers' electrical determinations and discharge bends to create battery yield attributes for diverse working profiles. The model additionally incorporates cycleby-cycle charge or discharge characteristics.T.L. Tiang *et al.* [40] has exhibited a bum based proportional integral (PI) controller for stand-alone single stage voltage source inverter battery cell as essential vitality sources. The framework comprises of the lead-acid battery, third request Butterworth low pass DC channel and AC channel, H-span inverter, venture up transformer, furthermore a variety of loads and sinusoidal pulse widthmodulation (SPWM) deadbeat-based PI controller.

Adithya Rajeev *et al.* [41] have utilized the sun based vitality for fueling little loads. The system consisting of exchanging controller and a battery charging area utilizing microcontroller.

Electric Vehicles are the perfect street transportation device to moderate air contamination and carbon dioxide outflows. The current vitality sources are not met all requirements for EVs on vitality thickness, power thickness and cycle life. Flywheel battery is another idea battery for putting away vitality in mechanical structure. Xiong Xin FU *et al.* [42] have proposed a complex vitality sources for EVs in light of battery and flywheel battery. Created the model of flywheel battery and proposed the charging and discharging control methodologies of it.The charging procedure joined Fuzzy-PI controller was utilized, and at the discharging process, the PWM method was to control the yield voltage and force of flywheel battery to meet the driving engine's necessity.

2.2. Review on Desulfation by Pressure Feedback

Valve Regulated Lead-Acid batteries debase because of a mixed bag of instruments, including erosion, hard sulfation, water misfortune, shedding, and dynamic mass debasement. Hard sulfation is the predominant maturing instrument for some phones. The desulfation accusing calculation begins of constant current (CC) charge to 2.40V. Right now, the cell is near to full SOC and gas era produces interior cell weight, P (t) that is measured and bolstered back to conform current. The desulfation charging controller minimizes gassing by directing the weight era rate to a little esteem. A PID controller guarantees that the gassing weight rate tracks. The goal of the desulfation control calculation is to pump charge into the cells minimizing water misfortune. A dead battery is completely charged and discharged a straight intensifier. Amid full charge or discharge testing, the battery is discharged from 100% SOC until a cutoff voltage of 10V is arrived at. The battery rests for less than 24 hours and is then charged until a cutoff voltage of 15V is arrived at. Five bars, strung to a profundity of pretty nearly 0.5 inches into the highest point of every phone current gatherer, empower individual cell voltage estimations amid testing. Openings were penetrated into every individual cell and joined with weight sensors fixed tubes. In fig 2, the voltage signals from the sensors are read by the DAQ to quantify the phone weights as demonstrated.

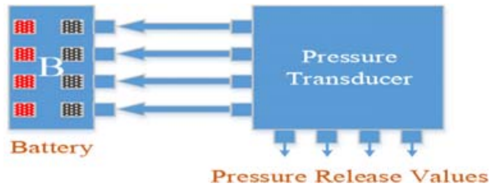

Figure 2: Desulfation by Pressure Feedback

Ying Shi *et al*. [43] have weight input to minimize water misfortune amid low ebb and flow energizing intended to break hard sulfate and recuperate limit. A cell of this battery that was diagnosed with sulfation debasement was desulfated for 313 hrs at present of 0.2 A. The limit of the cell was recouped by 41% with insignificant water misfortune, exhibiting the adequacy of the desulfation charge controller. Jay L. Chamberlin [44] have depicted the vitality stockpiling model in PVFORM the deliberate execution in frameworks intended to boost the show vitality use, if legitimate info parameters for the battery's ability and efficiencies.

2.3. Review on Desulfation by Resonant Frequency

Alastair Couper [45] has refined and rearranged different methods, and made a fundamental circuit that keeps little to medium estimated batteries in desulfated condition. It accustomed to bring old, sulfated units over into administration. Fig 3 demonstrates the circuit diagram for desulfation using the resonant frequency technique.

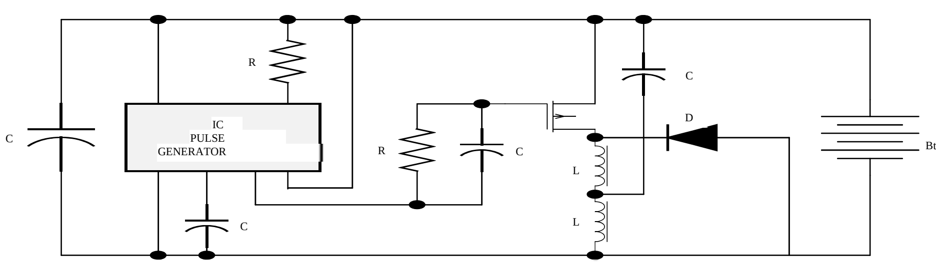

Figure 3: Desulfation by Resonant Frequency

Robert A. Gelbman [46] has displayed device for charging and desulfating lead-corrosive batteries gives a DC electrical charging present to the battery terminals to charge the battery to a completely charged voltage amid a mass charge mode. At the point when the battery achieves a completely charged voltage, the mechanical assembly changes to a float charge mode where the battery voltage declines to a float voltage not exactly the completely charged voltage and is kept up at this level. At the point when the mechanical assembly is in the float charge mode, the battery charging current is turned quickly on and off to keep up the battery at the float voltage and to desulfate the battery. At the point, the bulk charge mode reappears when the battery voltage drops to a predetermined value below the float voltage.

A multi-circle control framework for controlling a PV/battery cross breed framework has been produced and tried by Hisham Mahmood *et al.* [47]. The technique controls the PV power converter and the bidirectional battery power converter working imperatives under battery charging current and limits. S. G. Tesfahunegn *et al.* [48] have displayed another sun oriented or battery charge controller that joins both MPPT and over-voltage controls as single control capacity. A little flag model of lead-acid battery was determined in subtle element to outline the dual loop control design.

A necessity of a conservative, less expensive and proficient battery charger has gotten to be crucial in the advancement of HEVs. Chandrasekar V*et al.* [49] has made an endeavor to add to a disconnected from the net charger for lead acid batteries and meet the above necessities for a three wheeler arrangement HEV usage.in India.

2.4. Review on Desulfation by Chemical Reaction

Luiz C Ferracina [50] has introduced a procedure for Lead recuperation from the nonmetallic bit of depleted lead-corrosive batteries, was explored an electro hydro metallurgical methodology. Thirteen fluid arrangements mulled over in dissolvability tests, just the accompanying three were picked for the entire procedure (filtering and electro winning steps): tetra fluoroboric corrosive (200 g/L), glycerol (92g/L) +sodium hydroxide (120g/L) and sodium potassium tartrate (150 g/L)+sodium hydroxide (150 g/L). The tetrafluoroboric corrosive demonstrated an appealing execution as filtering electrolyte because of minimal effort and sensible draining quality. In the electro winning procedure in the arrangement acquired from the filtering of a desulfated slime with this acidic electrolyte, reduced, follower and immaculate lead stores were created at 250A/m2. Examining electron micrographs (SEM) of lead stores acquired at distinctive current densities in the scope of 250–500 A/m2 uncovered a stamp of the current thickness on the store morphology.

R.K.K. Mbaya *et al.* [51] have exhibited a technique for filtering of went through batteries powder with sodium carbonate and carbon dioxide. The transforming of lead from scrap lead-corrosive batteries by pyro metallurgical course is by and large joined by outflows of sulfur dioxide and high measure of slags. Thusly, lead is captured in the slags as xNa2S.yFeS.zPbS which makes the slag unacceptable to be arranged off as natural neighborly item. To defeat these troubles, a sodium carbonate draining methodology was explored. Results were examined from motor conduct perspective, particularly: filtering bends, stoichiometry of the response and X-beam diffraction investigation of the response items. Under these conditions, lead carbonate recuperation of 68 % was acquired in under around 40 minutes at room temperature.

2.5. Review on Desulfation by Artificial Intelligent

An insightful battery charger plans for utilization with an immaculate sine wave inverter. The battery charger is such that identifies the condition of charge of the battery and changes from distinctive modes till the battery achieves its full charge state. Artificial canny frameworks however learn rapidly when contrasted with a customized framework. Basically, the charger and the controller are generally joined together. The battery is subject to the charger as whatever the condition of the battery seems to be, the charger can know it and subsequently course the status to the controller that serves as the processor. The inverter is a stand-alone unit all alone and it simply needs nourishes just when AC force is off (when it changes to upsetting mode) or when it is to demonstrate that the battery is in its charging mode. Since the outline takes the control framework calculation, we would have a square chart which has a criticism as demonstrated in the fig 1 beneath.

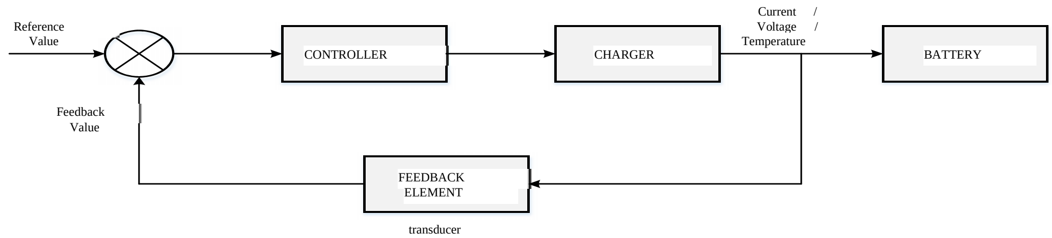

Figure 4: Block Diagram of an Intelligent based battery charge Controller

Cheating in lead corrosive battery which is broadly utilized as a part of galaxies is a consequence of disgraceful charging control. Cheating can be averted by planning a suitable control framework for charging of batteries. A decent charging control framework will diminish the capacity limit and administration time for force supply. R. Swathika *et al*. [52] have made an endeavor to outline a PI calculation based charging control framework for a first-request element model of the lead corrosive battery framework. To track the set point reaction and to reject the unsettling influences because of outer calculates, for example, change power of the sun based radiation; a criticism control framework has been composed. As the issue ways to a very nonlinear procedure, ordinary control hypothesis is not a proper decision. A fluffy rationale controller with a uniquely picked triangular participation capacity has been proposed as a compelling option approach. It is demonstrated that by utilizing fluffy rationale system, the voltage of the battery can be controlled adequately than with a routine controller.

Precise condition of-charge estimation in leadcorrosive batteries is a perpetually expanding need in an industry that requests low-upkeep costs and exceptionally accessible frameworks. Miguel A. Cristín Valdez *et al*. [53] has exhibited a strategy to gauge SOC by method for a fake neural system. Yanqing Shen *et al*. [54] has portrayed a novel versatile online approach to determinate SOC for lead-corrosive batteries by consolidating changed PID controller with Radial Basis Function Neural Network based terminal voltage assessment model, which is utilized to mimic battery's conduct while it is under load. An astute lead-corrosive battery charger in light of SCM twofold shut circle control is presented by Wei Luo *et al*. [55]. In view of the controlling of Single Chip Microcomputer, the recurrence and wave width tweak charger has four charging procedure, they are consistent current charging, heartbeat current charging, steady voltage charging and float charging.

Fluffy control of a Lead-Acid Battery Charger is being explored by G.E.M.D.C. Bandara *et al*. [56]. Compelling control of the charging methodology is perplexing because of the exponential relationship between the charging current and the charging time. Te-Wei Wang *et al*. [57] have proposed a fluffy SOC estimation for Reflex TM battery charging, which permits fast and productive charging for fixed leadcorrosive batteries utilized as a part of electric vehicles. The proposed SOC estimation was abstained from undercharging or cheating. Cheat specifically can abbreviate a battery's lifetime. The charging control and the SOC estimation are taking into account fluffy hypothesis and they are actualized by a computerized sign controller

2.6. Review on Desulfation by Other Techniques

The PLC (programmable logic controller) assumes a vital part in the field of modern mechanization due to its fantastic execution. Its different capacities incorporate rationale number juggling, count, correspondence, clamor safe and soundness. What's more (PC) has extraordinary capacity in fast computation adapted to the capacity to store gigantic data. In the most recent 20 years, PC has promoted everywhere throughout the world as a result of its less expensive and less expensive cost.

Went with the advancement of PC and the advancement of the correspondence innovation, Internet has since developed and been produced, by which we can contact with anyone, whenever and anyplace. The use of lead-corrosive battery is expanding later on. Step by step instructions to enhance the charged proficiency of lead-corrosive battery and amplify the battery utilization life to diminish vitality utilization and battery harm is more imperative. Wen-Bin Lin *et al*. [58], have MITSUBISHI PLC FX2n-32MR to be controlled. The battery was by method for rater and FX-2AD in charging state. The simple and computerized information is gone to PLC to be ongoing observing and controlling. Charging is situated time and voltage steady to achieve optimization charging. Then again, utilizing AD590 is to be reference measuring and battery assurance in temperature control. InZhang Yi *et al*.[59]have proposed a switch-mode VRLA battery charger controller. The test results demonstrated that all normal capacities were actualized. What's more the framework transient reaction was quick and the precisions of both consistent present and steady voltage charge modes.

So far the survey for the desulfation for leadcorrosive batteries in light of five separate sorts is given. However the real motivation behind desulfation or charge controlling is just to improve life of battery. The hybridization of ultra-capacitor with the lead-corrosive battery likewise upgrade the life time of the battery. Hence, ultra-capacitor based battery framework can likewise think about as an online desulfation and it can turn into one of the suitable alternative for battery administration framework in HEV. A percentage of the late research identified with the ultra-capacitor based battery administration in HEV is checked on as takes after.

2.6. Review on Ultracapacitor Based Battery Management in HEV

Batteries in HEV work with prominent proficiency and have a more extended life time when discharged at a low, consistent rate. Notwithstanding, the discharge rate of the battery is controlled by the vitality needs of the outing and relies on upon the driving systems can't be controlled by producer [60] and an approach to handle this instability identified with quick changing burden is to optional vitality stockpiling framework that immediately react to the sudden changes in burden. Ultra-capacitors are guaranteeing to be used as such secondary energy storage framework because of high power thickness, long life cycle and great charge or discharge proficiency [61] and Ultra-capacitor immediately provide and consume large transient power help address the heap prerequisites amid sudden quickening and regenerative braking. A few strategies have been by and by to join Ultra-capacitor with the battery [62].

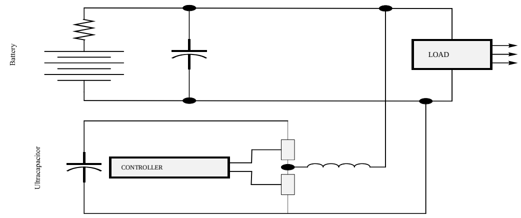

Figure 5: Block Diagram of Ultracapacitor based battery management in HEV

Fig. 2 demonstrates the schematic plan for that framework. The simulation result demonstrates that this model effectively occupy the surge current to the Ultra-capacitor amid the sudden changes in burden. N.P. Gyawali *et al*. [63] have proposed a way to interface the Ultra-capacitor with the battery using digital hysteresis current mode controlled bidirectional boost converter. This methodology has the advantage of simplicity and lower expense contrasted with different topologies.

3. Comparative Analysis

The desulfation or the charge controlling is extremely crucial for the lead-acid battery administration framework in all over the place particularly for the mixture electric vehicle. The desulfation totally counteract by the best possible charging or discharging in lead-acid battery framework. The desulfation attain by distinctive procedures PWM, Pressure feedback, resonant frequency, chemical reaction, artificial intelligence etc, In the past area the outstanding framework for the desulfation or charging control is investigated and in this segment those research works are looked at in view of the wide using different research work and controller sort procedure and control parameter is given in table 1.

Table 1: Comparative analysis of various desulfation or charging control systems

Author	Controller type	Control Parameter (Current/ Voltage/ Temperature)	Technique
Mohamed Dakkaka*et al.* [31]	-	-	PWM
Michael J. Rolfes [32]	Microcontroller	Voltage	PWM
J. Marcos *et al.* [33]	PDI	Current	PWM
NitinBhiwapurkar*et al.* [34]	PI	Current/Voltage	PWM
A. Chih-Chiang Hua*et al.* [35]	Digital	Current	PWM
Jae-Hak Yoon *et al.* [36]	Digital	Voltage	PWM
SuchartJanjornmanit*et al.* [37]	Microprocessor	Current	PWM
Wujong Lee *et al.* [38]	-	Voltage	PWM
Nosh K. Medora *et al.* [39]	Full-bridge/ Bidirectional	Current/Voltage	PWM
T.L. Tiang*et al.* [40]	PI	Voltage	PWM
Adithya Rajeev *et al.* [41]	buck	Voltage	PWM
XiongXin FU *et al.* [42]	Fuzzy-PI	Voltage	PWM
Ying Shi *et al.* [43]	-	Voltage	Pressure Feedback
Jay L. Chamberlin [44]	-	Voltage	Pressure Feedback
Alastair Couper [45]	IC	Voltage	Resonant Frequency
Robert A. Gelbman [46]	microprocessors	Voltage	Resonant Frequency
HishamMahmood*et al.* [47]	Bidirectional	Voltage	Resonant Frequency
S. G. Tesfahunegn*et al.* [48]	-	Current/Voltage	Resonant Frequency
Chandrasekar V *et al.* [49]	Digital	Current/Voltage	Resonant Frequency
Luiz C Ferracina*et al.* [50]	-	-	Chemical Reaction
R.K.K. Mbaya*et al.* [51]	-	-	Chemical Reaction
R. Swathika*et al.* [52]	Fuzzy/PI	Voltage	Artificial Intelligent
Miguel A. C.V *et al.* [53]	ANN	Both	Artificial Intelligent
YanqingShen*et al.* [54]	PID-ANN	Current/Voltage	Artificial Intelligent
Wei Luo*et al.* [55]	SCM	Voltage	Artificial Intelligent
G.E.M.D.C. Bandara*et al.* [56]	Fuzzy	Current	Artificial Intelligent
Te-Wei Wang *et al.* [57]	Fuzzy	Current	Artificial Intelligent
Wen-Bin Lin *et al.* [58]	PLC	Voltage	-
Zhang Yi *et al.* [59]	IC	Current/Voltage	-

The list of research work and their parameter settings, Controller and procedure is given in table 1. From this investigation we demonstrate that the PWM procedure is the method for the desulfation or charge controlling of lead-acid battery and in the second stage counterfeit smart is used. The parameter favored in the past research work for the controlling are voltage, current and temperature, in that voltage is generally used and mix of voltage and current is used as a part of some work, yet Miguel A. C.V *et al*. [53] alone used in both parameter. At that point verities of controller circuit are used, in that Fuzzy is the popular one.

4. Future Direction on Desulfation Motivated for HEV

In order to reduce the liquid fuel consumption the hybrid electric vehicle are the most appreciated technology in the automotive world. Hence importance of desulfation or charge controller is high in case of lead-acid battery usage in hybrid electric vehicle. The sulfation of lead-acid battery can be avoided completely with the help of a charging controller. These controllers can manage the charging and discharging of lead-acid batteries. So far many research works have been proposed for the charge controlling or desulfation of lead acid battery, some of them are reviewed in previous sections. From these review we are suggesting that the desulfation circuit or charge controller is highly essential for the charge management of lead-acid battery in HEV. In particular the future charge control or desulfation circuits must adopts an artificial intelligence technique along with the fuzzy, ANN or hybrid controller scheme. In previous controlling the voltage, current, temperature is the parameters mostly used, so in future utilizing these three parameters or more is appreciated.

5. Conclusion

Desulfation or charge controlling of lead-acid batteries is essential in order to enhance the life time of battery. The lead-acid batteries are mostly used in the HEV for the optimal fuel consumption. In this paper we have broadly reviewed some of the past work related research work for the desulfation. The review is progressed based on the various techniques of desulfation in lead-acid battery. The most notable techniques consider in this review are Pulse Width Modulation, Pressure Feedback, Resonant Frequency, Chemical Reaction and Artificial Intelligent. Then the comparative analysis is made based on the wide usage with respect to the Controller type, Control Parameter and Techniques. Eventually, based on the comparative analysis and review a future direction is given, which motivated that the future desulfation system must adopts an artificial intelligent technique with more than three control parameter.

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