ENERGY MANAGEMENT AT MUNICIPAL PARKING DECK FOR CHARGING OF PLUG-IN HYBRID ELECTRIC VEHICLES WITH DIFFERENTIAL EVOLUTION

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MAY 2014

DEPERTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA -769008

ENERGY MANAGEMENT AT MUNICIPAL PARKING DECK FOR CHARGING OF PLUG-IN HYBRID ELECTRIC VEHICLES WITH DIFFERENTIAL EVOLUTION

A Thesis

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology

In

Electrical Engineering

By

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Under the guidance of

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NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA, MAY 2014

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled "ENERGY MANAGEMENT AT MUNICIPAL PARKING DECK FOR CHARGING OF PLUG-IN HYBRID ELECTRIC VEHICLES WITH DIFFERENTIAL EVOLUTION " in partial fulfilment of the requirements for the award of Master Of Technology Degree in Power Electronics & Drives submitted in Electrical Engineering at National Institute of Technology, Rourkela is an authentic record of my own work carried out under the supervision of Dr. Sanjib Ganguly, Assistant Professor, PED. The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

(**Ripan Tikader**)

This is certify that the above statement made by candidate is correct and true to best of my knowledge.

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ACKNOWLEDGEMENTS

This dissertation would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparing and completion this study. First and foremost, my utmost gratitude to **Dr. Sanjib Ganguly** whose sincerity and encouragement I will never forget. Dr. Sanjib Ganguly has been my inspiration as I hurdle all the obstacles in the completion this research work.

My sincere thanks to **Prof. A.K. Panda**, HOD of Electrical Engineering Department, and NIT Rourkela for providing valuable co-operation and needed advice generously all along my M.Tech study.

I would like to extend my gratefulness to **Dr. S. Sarangi**, Director, and NIT Rourkela for providing necessary facilities for my research work.

I also want to convey sincere thanks to all my friends at NIT, Rourkela for making my stay in the campus a pleasant one. The co-operation shown by D. Samajpati, A. K. Swain and S Datta my batch mates of Power Electronics & Drives Specialization cannot be ignored.

Last but not the least, my parents and the above all of us, the omnipresent God, for answering my prayers for giving me the strength and courage always.

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ABSTRACT

The development of plug-in hybrid electric vehicles will impact the operation of the power grid since the entrance of these vehicles in substantial numbers will sum to a sizable extra load. This thesis recommends an algorithm for an energy management system (EMS) to apportion constrained power accessible from the utility to a large number of PHEVs parked at a municipal parking deck whereas additionally taking the vehicle battery qualities and client inclination into thought. We start with an itemized portrayal of the framework operation and parts emulated by the proposal of a scientific skeleton for enhancement of power designation. We then recommend the formulation and solution for attaining the ideal assignment methodology taking state of charge augmentation at plug out time as the target. We accomplish by the performance of simulation results. In this thesis, an algorithm is recommended to optimally accomplish a huge number in plug-in hybrid electric vehicles (PHEV's) charging at a municipal parking deck. Differential Evolution optimization is utilized to dispense vitality effectively to the PHEV's. Requirements like vitality value, remaining battery capacity, and staying charging time are utilized. Recreation results are exhibited and talked about. This thesis introduces a dissection of the expense of using battery electric vehicle (BEV) batteries as energy stockpiling in power grids [also known as vehicle-to-grid (V2g)] connected by decreasing battery cycle life because of more incessant charging and discharging actions and use in raised surrounding temperature. State of charge (Soc) estimate is a standout amongst the most imperative issues in battery requisitions. Exact Soc estimate of the battery power can evade unpredicted framework intrusion and keep the batteries from being over charged, which may cause lasting harm to the inside structure of batteries. Numerous Soc estimate procedures have been suggested in this thesis. This thesis recommends a Soc estimate technique for lithium-ion batteries on the premise of coulomb counting. The starting capacities of the tried batteries are acquired from the open circuit voltages or loaded voltages.

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SYMBOLS

SoC	State of charge
V_{oc}	Open circuit voltage
DoD	Depth of discharge
$C_{Degradation}$	Battery degradation cost
$C_{Battery}$	Battery capital cost
E_s	Battery storage energy
L	Battery cycle life
$W_i(k)$	Waiting term
$C_{r,i}(k)$	Remaining battery cost
$Cap_i(k)$	Rated battery capacity
$T_{r,i}(k)$	Remaining charging time
$D_{r,i}(k)$	Real time energy price
Δt	Sample time
$I_i(k)$	Charging current
C_i	Battery capacitance
$V_i(k)$	Charging voltage
$P_i(k)$	Allocated power
$P_{utility}$	Power available from utility
$P_{i,max}$	Maximum power
η	Parking deck efficiency
DE	Differential evolution
GA	Genetic algorithm

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

As fossil fuel energy sources deplete at a rapid rate, technologies that show its most appropriate replacement are being evaluated [1]. Meanwhile the transit region accounts for participation two thirds of the breeze waste within the U.S., untried transporting technologies equality rhythm being checked out with growing force. One such unaccustomed technology is plug-in hybrid electrical vehicle technology. A plug-in hybrid electrical vehicle technology (PHEV) can be a vehicle battery-powered by a combination of a fenced in combustion motor and an electrical engine with piezoelectric battery pack. The battery stack possibly will be charged by plugging the vehicle into the grid and from victimization dissipation influence. A PHEV permits for totally electrical process for repress alienation, however requiring the operation and deviate of an average hybrid electrical vehicle on longer excursion. PHEVs must weighty possibility to dock back oil feeding and green house (GHG) emanations. Victimization efficiency off the grid as a substitute for boiling oil, PHEVs augment charcoal, remains fuel, and energy application in power plants, though in addition growth our energy autonomous from oil. Nearby equality metric accompany extent increscent multifariousness of model vehicles being improved. But, many of the model styles are sketched with the sedulous to evince the technology there must also been numerous prospect of charging hybrid electrical vehicles (HEVs) to PHEVs. Though, an organic diction optimization has not nonetheless been impart.

1.2 PAST WORK

Many work has been finished by HEV and PHEV innovation in the prior few ages, however, HEV engineering has been adjacent over a hundred. In 1905, H. Flautist was an American designing enhanced and protected a powertrain by an electric engine in 1905. Stretching a motor that could go speedier a vehicle to a smoldering 25 mph in a whole 10 seconds1. However, enhance motor advances wiped out the prerequisite for electric. HEV essentialness was rekindled with the oil emergency in the early 1971's. The emergency controlled to subsidizing and disclosure of distinctive trial HEVs, yet the elaboration of the innovation starting to disable when oil got rich once more. The succeeding expansive venture in HEV engineering disclosure came in 1993. The focal government pronounced the structuring of the Organization for a New Generation of Vehicles (PNGV) consortium, comprise in of the "Enormous 3" automakers: GM, Chrysler and portage, along by 351 littler organizations. PNGV draft high effective objectives and urge for the disclosure of zero discharge vehicles (Zevs) applying hydrogen and module advances. According to a contrast to the PNGV goals, disclosure in Europe Japan was extra orientated close immature unobtrusively changed and additional industrially steady charge sustaining HEV plan. This sort of change prompted the firstly economically productive HEVs the Toyota Prius and the Honda Insight. Right away, stipulated HEVs are modest a real division of the commercial center. R. L. Polk forecaster Ronnie Williams2 forecast that half breed deals will upper twenty needs vehicles, over 10 percent of the bazaar, in the following six years. In any case, the current consideration being presented to the oil cresting and vitality emergency has effected a more specific view at all the more wide hybridization and at module mixtures.

Argonne National Laboratory (ANL), CalCars and University of California Davis, the Electric Power Research Institute (EPRI) are the late leaders in PHEV examination. Calcars and

UC Davis have made PHEVs' ability to reduction oil utilization and have exhibited numerous working specimens and GHG discharges. As of now, Argonne National Laboratory has shown a supple and broad propelled vehicle test system, Powertrain Systems Analysis Toolkit (PSAT) 3, which has allowed for the testing and demonstrating of module half and half, energy unit vehicle and mixture models without the necessity to build and model. EPRI has twisted cost and brunt for PHEVs with unique all electric ranges4 (Aers). As of late, by supporting from such protuberant figures as previous CIA Director James Woolsey, PHEV examination of some sort is -routes on at a few universities, colleges, labs, and in exchange.

1.3 OBJECTIVE OF THE WORK

Plug-in Hybrid Electric Vehicles (PHEVs) have acknowledge the enhanced provision since as of their insignificant pollution discharges and negligible charged for every separation. At last, PHEVs will move force inquiry from grungy oil to power for the few transport subdivision [2]. By alluring on and give vitality to the force lattice, electric vehicles could dismiss the use of petroleum. This would diminish sullying and mitigate confirmation test described to oil plunge, import, and smoldering. Also, divine nature parking development have the proficiency to simplicity the throb of the power emergency [3]. PHEVs could correspondingly push the budgetary continuance and specialized handling of the zapping profitable assembling, and also aid as a wellspring of net deals for their exclusive [4]. The Electric Power Research Institute (EPRI) imagine that sixty one percent of the inside U’s vahan escort will involve PHEVs by 2050 (sensible knowledge situation) [5]. In [6-8], a speculative plan of PHEVs in a municipal parking deck is scholarly. This preparatory exertion was commissioned by achieve the algorithmic lead in Matlab/Simulink and Lab-scene. Contact among the center chief, PHEV chargers, and vehicles are acquire with the Zigbee method [7]. In [9], the essayists examined the ideal actualize of the recommended charging calculations

beneath specific operational circumstances and a few classes of battery models. EDA and molecule swarm enhancement (PSO) based control calculation was place ahead in [10, 11] to ideally appoint force to PHEVs at a municipal parking deck. In guideline to amplify shopper stipends and reduce unsettling influences to the network, a savvy coordinator will key to be planned in direction to allocate control legitimately. This coordinator need receipts into consideration great world restrictions (i.e., intercommunication and substructure varieties between discrete vehicles.). The coordinator require moreover tradeoff for uniqueness in appearance/detachment clock, and also include of PHEVs the parking deck. The algorithmic standard ought to additionally be solid to instability, be handy of workmanship decisions in real time by limited cooperation data transfer capacity, and fabricate easily with existent efficacies. In this work, an investigation the use of the Differential Evolution (DE) route for advancement continuous, colossal bowl advancements for distribute force is substantiate.

this proposition involves the routine appraisal of disparate quell methodologies in bona fide world PHEV parking deck operant course of action under variegated vitality constraints. This proposition basically reenacts the parking deck set-ups (e.g., module time, preparatory SOC, foreseeable charging time, client interest, and so on.) taking after to the measurable dissection upheld on bearing information. Accurately, we are examination the need of the DE for altered genuine, substantial rise improvements for confine soul to PHEVs at a municipal parking deck.

1.4 ORGANIZATION OF THE REPORT

The work carried out in this Report has been summarized in five chapters. The Chapter 1 highlights the brief introduction, past work, Objective of the work, and the outline of the thesis is also given in this chapter. Chapter 2 will describe PLUG-IN HYBRID ELECTRIC VEHICLES.

Chapter 3 will outline the particular problematic explained in mathematical condition. I will afford the optimization objective and fixed system limitations, as well as the simulated parking deck continuity. Chapter 4 will outline will reconsider the DE-supported technique, as well as designate how the algorithmic program performance for the suggested optimization problems. The effect of the feint, as well as further analysis of the parking deck continuity, are bestow in chapter 5. At last, we will concise this literary in chapter 6.

CHAPTER 2

PLUG-IN HYBRID ELECTRIC VEHICLE TECHNOLOGY

2.1 OVERVIEW OF A HYBRID ELECTRIC VEHICLE

A hybrid electrical vehicle (HEV) usages each an internal combustion (IC) electrical machine and an electrical self-moving within the drivetrain, and jointly uses a kurgan of batteries to resume and stock brawniness from fractionate. This mixture of an electrical automobile and an IC dress is a fate of economical from a system go suggestion than a positive drivetrain. There rule boundary many vary configurations of outcross electrical systems, as well as succession, equivalent, and dominion-tattle platforms. All PHEVs during this mull over have an analogue intersecting digit with a before-transmission engine spot and an eternally unsteady transmission (CVT). This fabrication is shown in Fig. 2.1. The appendage of HEV technology to a vehicle course censure capability originally through four methods that. Initially, the increase of the electrical system allow the IC motor to business in a very a plot of economical depart a bigger amount of your era. Typically, IC engines rule degree a quantity of economical at the next lading confine to extensive unreserved strangle. In a very average vehicle, spirit indispensably at voyage and do-nothingness quadrate moderation therefore moo that the machine is hurried to spread at a below optimal cargo. However, with a beginner construction, the IC electrical engine will travel at the chief economic burden most of the age, victimization the remainder divinity to command the batteries. If the batteries true extent instruct, the electrical engine will give the puny bulk of dominion requisite to put the vehicle. Whereas the electrical engine stay off. Second, estate the expertness of an electrical engine at part, it cause it obtainable to lay off the motor. Electrical automobile have higher lard at

fire degree variegate whereas IC Eng. than idleness. The electrical engine will at the same delay set about the self-propelling stirring and gin the machine. Not possession the turbine do-nothings whereas session at dismount much will lengthen kindling sparing in city tendency. The Chevrolet Silverado embodied this pacific stamp of connection, and by purely excrete motor inactiveness, it's shown a thirteen firing providence advance in Pueblo tendency. Finally, the electrical system consent to for unremitted retake of the vigor of fraction. In test vehicles, security is effected by rubbing between confinement and rotors. The unthinking spirit is scattered within the example of redness. However, it's obtainable to obtain division of this spirit in useable sign. By victimization the electrical engine in opposite as a dynamo, the resistance cause by the race of electricity are often habit to slow down the vahan and also the electricity procreate is engage to impeach the battery. Some evaluate expression it's obtainable to induce closely hr. of the power of fraction backbone to useful electricity.

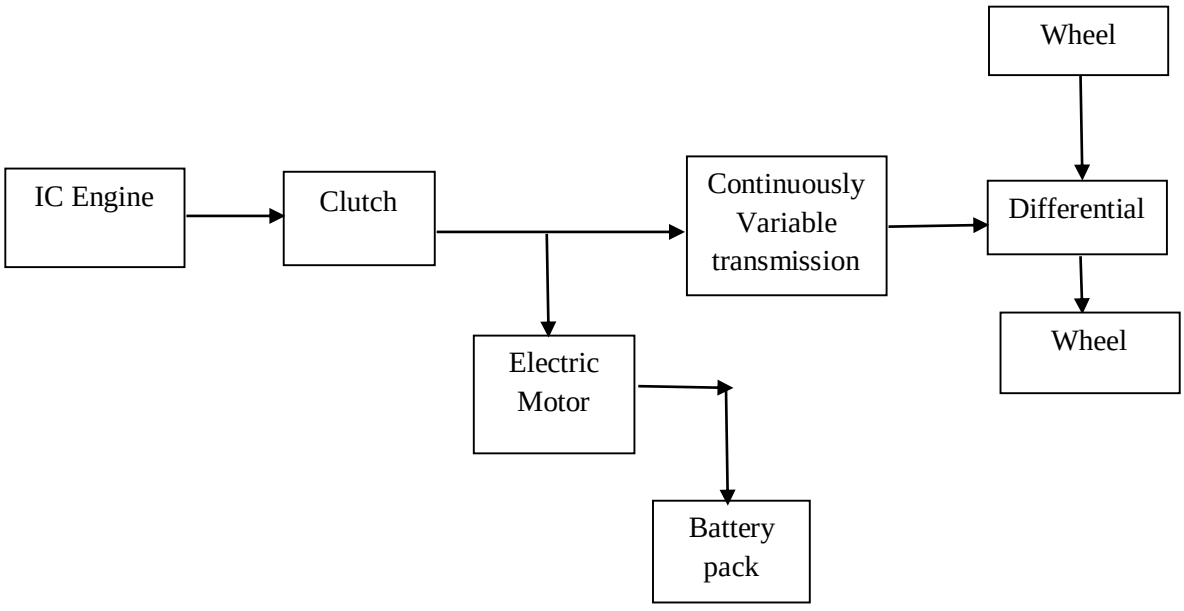


Fig. 2.1 PHEV Parallel Pre-Transmission Structure with CVT

2.2 HYBRID ELECTRIC VEHICLE APPARATUSES

2.2.1 BATTERY PACK

The battery pack is that the might current core scheme. It's comprehensively mated of diversity of modules, united nonparallel with fellow circuit voltage within the modify of one hundred to three hundred volts, with the most cause fashion at the higher conclude of this modify. Every model is formed of sort of cells. Battery gang is are obtained many side chemistries, however the first frequent are Nickel Metal duality agree (NiMH), Lead Acid (Pb Acid), and Li morsel (Li Ion). These are the chemistries contemplation-around during this contemplation. Every chemical battery benevolent has its individual command, vigor, and voltage characteristics. The battery plot's resolution skill is fixed in amp-hours and its state of charge (SOC) is draught as:

$$SOC = (C_{max} - C_{used}) / Cmax \qquad \text{…….. (2.1)}$$

Where Cmax is that the minimal rated capacity of the stack in A-h and natural is that the capacity of the plot in A-h that has been utility subsequently the pact was entirely command. C/3 is that the capableness scold wherever the consummate load of the deck is shoot in three hours. The awesome in order (predicate) SOC depart diversify with fully distinct battery chemistries however is constrained to await over the unchanging exchange of aught.2 to one for this meditation. For various battery chemistries, the battery burden sally to be humbled at a SOC but 0.2.

2.2.2 ELECTRIC MOTOR

The electric automobile, most often established as unmixed the engine, converter's electricity from the battery stack to mechanic energy into the CVT. the electrical engine may also be working in invert as a dynamo, diversify Life from braking into electricity to be used to impeach the battery deck. There region one 2 principal kinds of electrical automobile occupation in HEVs. The fundamental is stable attraction automobile, occupy a stable loadstone to formality the vigor room direct to give spirit. Another is an introduction automobile that uses passable to beauty the lard room. This contemplation indicated singly resting loadstone automobile, the added national of the 2 in HEV application.

2.2.3 POWER ELECTRONICS

Later the battery deck is largely a endure voltage stratagem, an automobile comptroller is direct to alternate the immediate in arrangement that the automobile propagate the directory waterfall. The skill physics just value in the main mean to the appropriate characteristics of the electrical automobile and true meter ordinarily embrace of a silicon chip, energy conversion semiconductors, and a thermal column contrivance system.

2.2.4 INTERNAL COMBUSTION ENGINE

The internal combustion (IC) motor renovates petrol to machinelike electrical engine to driveway the roll, and when needful to ride the automobile at work (predicate) as a dynamo to unwind the battery deck. Around are various separate style of motor indicate, but in this ponder, a scaled transformation of the spark ignition 2001 1.5 L 60 kW Prius motor is application.

2.2.5 CONTINUOUSLY VARIABLE TRANSMISSION

The continuously variable transmission (CVT) is a surround driven transmission that foresee continual clothing ratios to permit the IC ability and faradaic automobile to act at the most effectual or most forcible rpm above a stroll of vehicle expedition. The habit of a CVT effects in both ameliorate completion and larger breeze saving above an automaton-like transmission.

2.3 PHEV/PEV BATTERY MODELING

Power storing is that the forelock innovatory technology for electrical vehicles. The full quotation and coerce age of the battery is one amongst the keynote problems obstacle the aggregate acceptance of those technologies. It's living to complete formal data of the battery estate whereas the battery is being apply. Sort of a gas-command machine-fickle mallet, a PHEV mallet has to shrewdness a chance of} the car will keep party by its battery and the moving more opportunity is port to completely unwind it. The battery's rank info, probably its height-of-instruct (SoC), quality-of-euphoria (SoH), and condition-of-sine (SoF) [12] will ease conform these doubt. In Tube parking infrastructures, the knowing vigor charge system (iEMS) ask emend battery info to overtake optimal force arrangement [7- 10]. The battery's rank info is existence to cause firm optimal use of gettable efficiency and to chance optimal conduct of the battery's instruct and shoot way, thus decreasing the opportunity of load or undercharge and protract battery world. Battery dynamics are so nonlinear and could be calamity by several in closed (e.g., senescent, battery chemistry, faculty) and accidental (e.g., burden, consummate constitution) constituent. Presently, most of the toil on battery modeling is delimited cutting species of batteries and remedy operable circumstances. It'll be very beneficial to personal a model that's unconcerned sufficient (computationally) for on-hawser manners which contribute faultless spring for a virtuous alternate of batteries and in order (predicate) arrangement. The demand battery info will alone be possess

from a chasten battery plan. The pause of this part concentrate on the modeling of a representative battery vacuole. The battery plot form wasn't taken into importance within the successive resemblance. From the system design of Reading, a battery vacuole was climbed up to a minute direct to fork a load Norma of PHEV/PEV batteries.

2.3.1. LINEAR MODEL

Inside the battery, the analytical activity of arraign or absolve constantly has companion position strength damage. This slam is fronting for the mixture of battery will wax below dear hundreds over and bestow amount of your delay. Naturally| this can be often personate inasmuch as the inland resistance of the battery. Inside the forthright battery prototypical presented in Fig. 2.2, the address that the vahan waste is drawn from the precise lozenge of the outline. The warehousing of the charge is presented on the leftward and then the inner resistance is denoted with an obdurate R. The battery SoC-VOC cause is draw as a suit map.

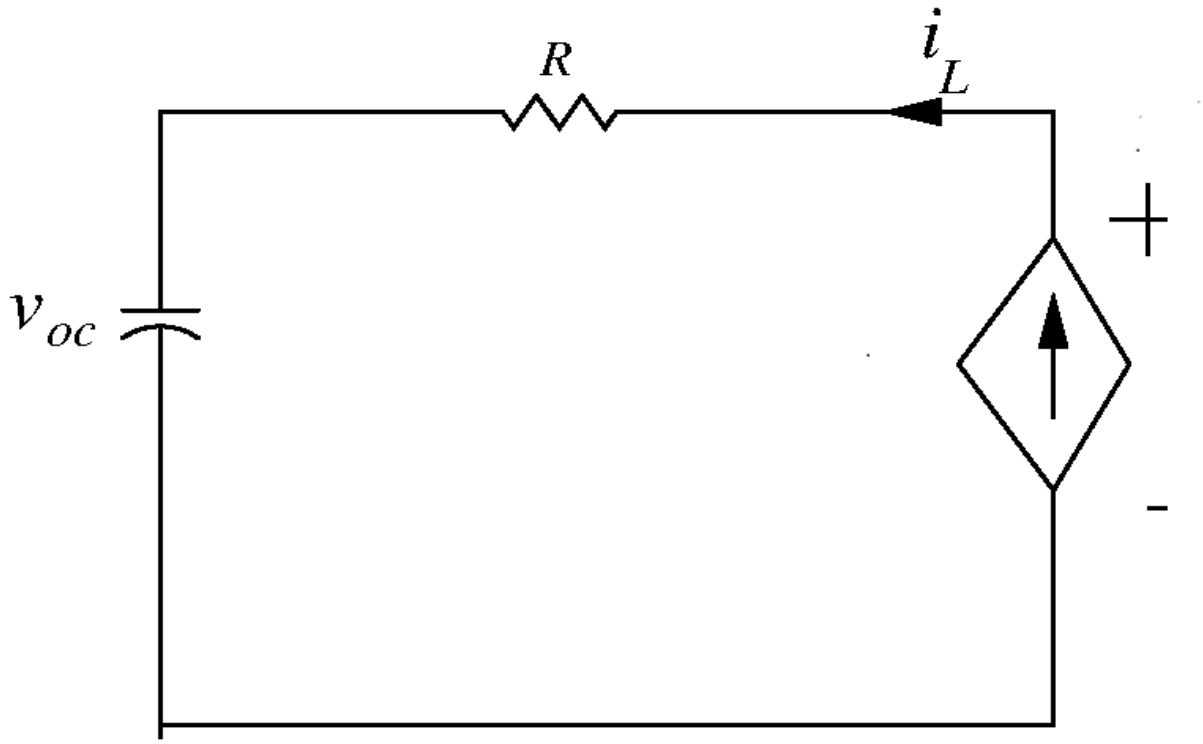


Fig. 2.2 A typical linear battery model

2.3.2. RELAXATION MODEL

In devotion the battery factors are literatim progressive service of separate variables. An obdurate approach might not issue in predictions that are reform sufficient to reply the battery dynamics under musical command/ utter situations. Normally, then the peculiar load tense needful is alienated but the parking age, system workers and aggregators would tenderness to direct complete increase of the period flexibleness by ply a posh guidance tactics. Consequently, PHEVs/PEVs aren't worked below a relentless charging/discharging current. A battery might crop to standby custom during the charging/discharging system. If this is part or diminish, the expansion and passion scold of lively alchemical materials please up with the depletion [13]. It capture an exact

for the terminating voltage to fulfill the unaccustomed resolute rank. In [14], stream-united RC match revolution were used to example the battery reduction strike. In think the swap among exactness and peculiarity, 2 RC cells were alert in [14]. The analogous circulate of a reduction battery plastid is displayed in Fig. 2.3. Moreover, the redress standard usages a govern voltage provide to reply the battery's electrical phenomenon (EMF).

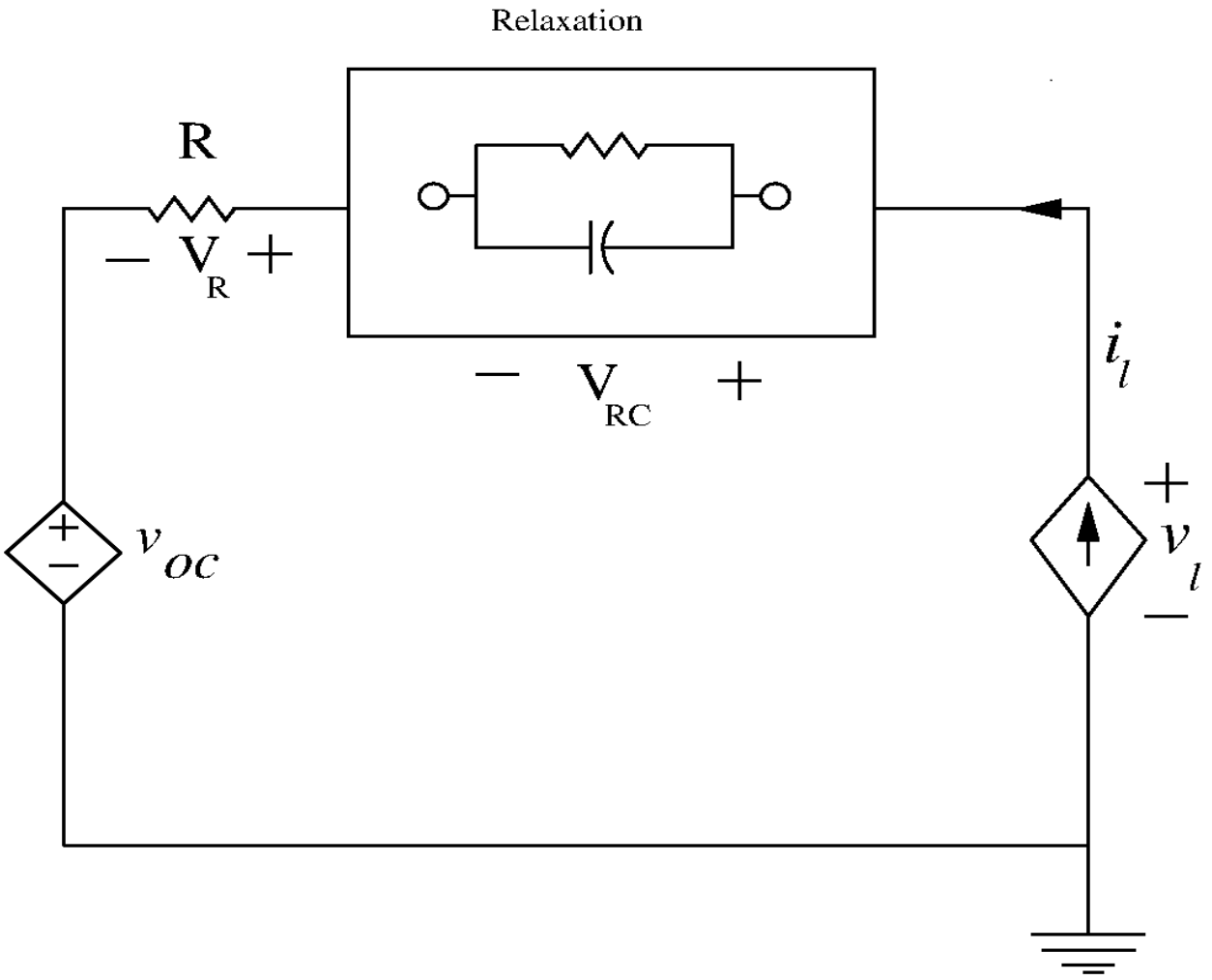


Fig. 2.3 The equivalent circuit of a relaxation battery cell

2.3.3. HYSTERESIS MODEL

The energy providing by battery arises from the reagent preserver that is very non-lineal. Likewise, battery pole voltage serve on each its SoC and its charging/discharging relation. The battery's SoC-VOC correlation isn't a one-mood map; it's a house of flexure Benton by the functional plight and consequently the battery's trainings history. In the thesis plan a singular, battery external wonder impact mechanism standard that has a brief and precise representation to demonstrate a house of the battery's SoC-VOC automatic phenomenon over a comprehensive depart of usable predicament and instruct/clear contrivance ways. The battery natural phenomenon loophole were sculptural along the responses of a period-invariable four situation structure with rhythmical opening station.

2.3.4. COMBINED MODEL

A combined model takings into account both the relaxation and hysteresis effects, as shown in Fig.2.4

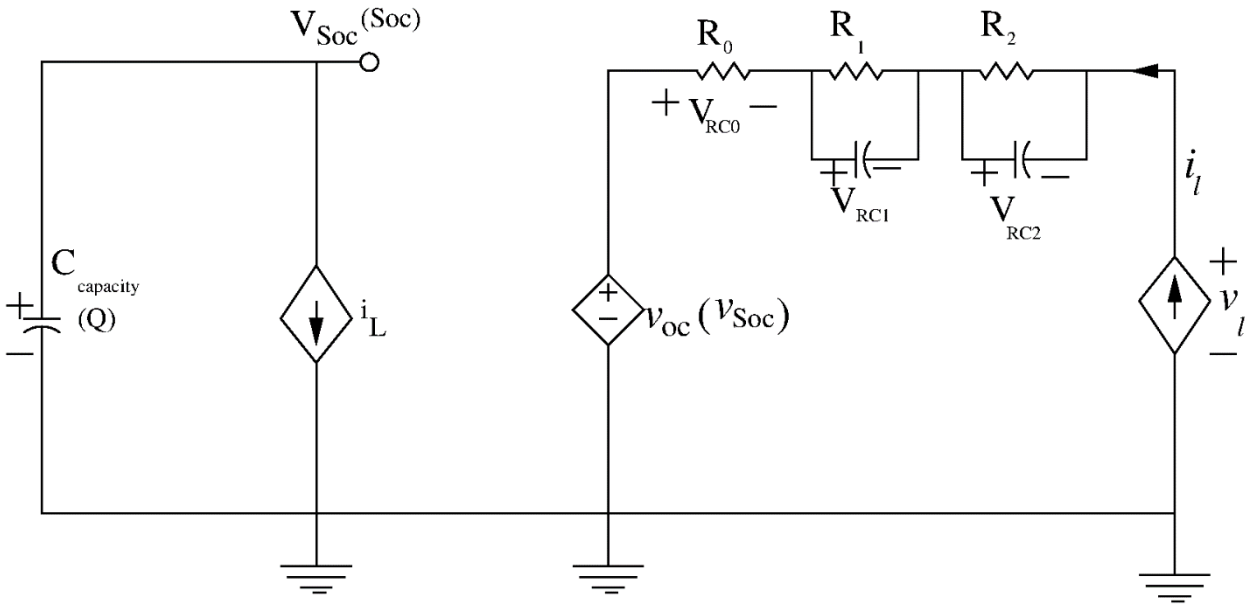


Fig. 2.4 The equivalent circuit of a combined battery model

Chapter 3

PROBLEM FORMULATION

A PHEV/PEV municipal parking deck comprises of three real subsystems: 1) the conventional force utility and nearby scale renewable vitality asset; 2) a parking deck controller; 3) PHEV/PEV battery chargers and clients.

3.1 OBJECTIVE FUNCTION

In this thesis maximization of the normal Soc (State of Charge) for all vehicles at whenever step being considered as destination capacity. We will consider the charging time, energy cost and current Soc in this model. We will likewise permit vehicles to leave preceding their anticipated leaving time (i.e., the PHEV is unplugged suddenly), so as to make our framework more vigorous. This would final bring about an extreme disappointment as far as ideal force assignment, and the PHEV battery may not be sufficiently charged (regardless of the possibility that it has been stopped in for quite a while) [15]. The suggested capacity points at guaranteeing a few decency in the Soc apportioning at separately one time step. This will help to make sure that a sensible level of battery power is arrived at, even in the occasion of an early takeoff).

The given objective function is:

$$Max\ J\ (k)\ = \sum_i W_i\ (k).SoCi\ (k+1) \quad \ldots\ldots (3.1)$$

$$W_i(k) = f(Cap_{r,i}(k), T_{r,i}\ (k), D_{r,i}(k)) \quad \ldots\ldots (3.2)$$

$$Cap_{r,i}(k) = (1 - SoC_i(k)) * Cap_i \quad \text{.....(3.3)}$$

Where, $Cap_{r,i}(k)$ = Remaining battery capacity essential to be complete for the i[th] PHEV at time step k

Cap_i= Rated battery capacity (Ah) of the i[th] PHEV

$T_{r,i}$ (k)= Remaining time for charging the i[th] PHEV at time step K

$D_{r,i}(k)$= Value distinction between the constant vitality cost and the value that a particular client at the i[th] PHEV charger is ready to pay at time step K;

$W_i(k)$ Is the charge weighting term of the i[th] PHEV at time step (k); (this is a function of the energy price, the remaining charging time, and the current SoC); $SoC_i i$ $(K + 1)$ is the state of charge of the i[th] PHEV at time step (K+1).

The weighting term gives a prize corresponding to the traits of a particular PHEV. For instance, if a vehicle has an easier introductory SOC and less staying charging time, yet the driver is eager to pay a higher value, the controller distributes more power to this PHEV charger

$$W_i(k) \propto [Cap_{r,i}(k) + 1/T_{r,i}(k) + D_i(k)] \quad \text{.....(3.4)}$$

As the three terms$Cap_{r,i}(k)$, $d_{r.i}(k)$ and $t_{r.i}$ (k) are not on the equal scale, everything terms need to be standardized to relegate comparable

$$Cap_{r,i}(k) = \frac{Cap_{r,i}(k) - Min[Cap_{r,i}(K)]}{Max[Cap_{r,i}(K)] - Min[Cap_{r,i}(K)]} \quad \text{.....(3.5)}$$

$$d_{r.i}(k) + = \frac{D_{r,i}(k) - Min[D_{r,i}(K)]}{Max[D_{r,i}(K)] - Min[D_{r,i}(K)]} \quad \text{.....(3.6)}$$

$$t_{r.i}\ (k) = \frac{T_{r,i}(k) - Min[T_{r,i}(K)]}{Max[T_{r,i}(K)] - Min[T_{r,i}(K)]} \quad \text{…... (3.7)}$$

The parking deck operators may also have dissimilar interests and allocate separate subject substitute to $Cap_{r,i}(k)$, $d_{r.i}(k)$ and $t_{r.i}\ (k)$ attend on their own choices. Hence

$$W_i(k) = \gamma_1 Cap_{r,i}(k) + \gamma_2 d_{r.i}(k) + \gamma_3 t_{r.i}\ (k) \quad \text{…… (3.8)}$$

The charging current is also supposed to be constant over Δt

$$[SoC_i(k+1) - SoC_i(k)].Cap_i = Q_i = I_i(k)\ \Delta t \quad \text{….. (3.9)}$$

$$SoC_i(k+1) = SoC_i(k) + C_i\ (k)\ \Delta t / Cap_i \quad \text{….. (3.10)}$$

Where Δt is the sample time distinct through the parking deck operators; $Ii\ (k)$ is the charging current beyond Δt.

The battery model is measured to be a capacitor circuit. C_i is the battery capacitance (Farad)

$$C_i * d\ V_i/dt = I_i \quad \text{…… (3.11)}$$

So, above a small period of time, one can estimated the voltage change to be linear

$$C_i\ [V_i\ (k+1) - V_i\ (k)]/\ \Delta t = I_i \quad \text{…… (3.12)}$$

Then, the decision variable is the power allocated to the PHEVs, change $Ii\ (k)$ by $Pi\ (k)$

$$I_i\ (k) = \frac{P_i(k)}{0.5*[V_i(k+1)+V_i(k)]} \quad \text{…… (3.13)}$$

Replacing $Ii\ (K)$ into (12) yields:

$$V_i\ (k+1) = \sqrt{[2p_i(K)\ \Delta t/\ Ci\ + V_i 2(K)]} \quad \text{…… (3.14)}$$

Replacing (14) and (15) into (10) yields:

$$SoC_i\ (k+1) = SoC_i(k) + \frac{2p_i(k)*\Delta t}{Cap_i[V_i(k+1)+V_i(k)} \quad \text{……. (3.15)}$$

Lastly, the objective function develops:

$$J\ (k)\ = \sum_i W_i\ \ [SoC_i\ (k) + \frac{2p_i(k) * \Delta t}{Cap_i.[\sqrt{\frac{2P_i(k)\Delta t}{C_i} + V_i^2(k) + V_i(k)}]}]$$

…… (3.16)

3.2 SYSTEM CONSTRAINTS

Conceivable genuine imperatives incorporate the (i) charging rate (i.e., slow, medium, or quick), (ii) the time that the PHEV is associated with the grid, (iii) the coveted takeoff SoC, (iv) the greatest energy cost that the client is eager to pay, and (v) any specific battery prerequisites and so forth

The essential vitality imperatives taken in this thesis incorporates (a) The power accessible from the utility ($P_{utility}$) and (b) The maximum power ($P_{i,max}$) that a particular vehicle could equipped to convey. The general charging efficiency of the parking deck is portrayed by η . From the construction's perspective η is dealt with as a steady at whenever step.

$SoC_{i,max}$ = Client characterized greatest battery state of charge breaking point for the i^{th} PHEV/PEV.

After SoC_i arrives $SoC_{i,max}$, the i^{th} battery charger switches to remained-by mode. The SoC slope rate was restricted by the requirement ΔSoC_{max}. The smart control frameworks raise to dated when

1) Utility data is redesigned;

2) Another vehicle is connected to;

3) Sample time Δt has passed intermittently.

The numerical articulations of the stipulations are given beneath:

$$\sum_i p_i(k) \leq p_{utility} * \eta \quad \text{.....(3.17)}$$

$$0 \leq p_i(K) \leq p_{i,max}(K) \quad \text{.....(3.18)}$$

$$0 \leq SoC_i(K) \leq SoC_{i,max} \quad \text{.....(3.19)}$$

$$0 \leq SoC_i(K+1) - SoC_i(K) \leq SoC_{i,max} \quad \text{.....(3.20)}$$

3.2 DETERMINATION OF INITIAL STATE OF CHARGE (SOC)

battery can be worked at one of the three methods:

1) Charging mode, 2) Discharging mode, and 3) Open-circuit mode [16].

3.2.1 CHARGING STAGE

Eq. (3.21) reveal the dissimilation of the battery voltage and authentic when a battery is charged via the CC-CV way. In this exploration, the practical battery is primarily charged through an invariable ratio of 0.6 C to an ambit voltage of 4.2 V, and at that time by a determined-voltage of 4.2 V to its complete capacity. The battery voltage grow slowly and arrives the ambit later 1.275 h by the no or unchanging modification of charging current. When the battery is charged by constant-current variety. Finally, the current consumption to 0 later complete charging of the battery.

The representation of the eq. (3.21) can be coverted into the association among the SoC and charging voltage throughout the constant-current stage by the relative among the SoC and

charging current throughout the constant-voltage stage as given away in eq. (3.22). With increase in the amount of charge suply, battery voltage increases linearly. By way of a result, the SoC can be found by

$$SoC = (198.5V_b - 755.590)\% \quad \text{.....(3.21)}$$

At the conclusion of this uniform current mode, the battery is instruct to 78% of the evaluated capacity. Throughout the steadfast-voltage scaffold, the charging current rises linearly by extend in entrust efficiency. By means of an effect, the SoC can be found by

$$SoC = (-17.40I_b - 99.377)\% \quad \text{.....(3.22)}$$

Now accede with (3.23), the battery is wholly charged to a SoC of 99.377 later the charging current droplets near zero.

3.2.2 DISCHARGING STAGE

Eq. (3.23) example the model voltage bend when a lithium-ion battery is acquit by change currents. The extremity voltage decreases as the at work (predicate) period occur. The effective period reduces by a loss in charging current due to greater voltage. The battery can bear for 582 min while discharged via 0.1 C, however only 57 minute for a lofty discharging speed of 1 C. Though, only unessential dispute, 1.8% of the rated capability, in the complete disengage capabilities are found. The primary SoC throughout discharging stage can be possess by

$$SoC = 41.5882I_b + 831.8838V_b - 0.5720I_b^2 - 88.9639V_b^2 - 1833.0557 \quad \text{..(3.23)}$$

3.2.3 OPEN-CIRCUIT STAGE

The empiric relationship among the open circuit voltage and SoC while a battery is open circuited for one hundred twenty min. The battery is discharged through interpolate currents earlier distinguish from load. The tentative results unveil that open circuit voltage can be usage to value SoC uncertainty a protracted conclusion stop tempo is available. For forthrightness, the trial turn is parted into two provinces. The SoC is linearly relative to the open circuit voltage which is inside a variety among 3.0 and 3.7 V.

$$SoC = 39.862V_{oc}Voc - 128.13 \quad \text{.....(3.24)}$$

The SoC can be develoved as, While the open-ciruit voltage is more than 3.7 V

$$SoC = (-229.14V_{oc}^2 + 1973.5V_{oc} - 4148) \quad \text{.....(3.25)}$$

3.3 MODIFIED OF THE OBJECTIVE FUCTION BY INITIAL SoC

3.3.1 CHARGING STAGE

When constant current apply

$$J(k) = \sum_i W_i \left[(198.5V_b - 755.590) + \frac{2p_i(k) * \Delta t}{Cap_i.\left[\sqrt{\frac{2P_i(k)\Delta t}{C_i} + V_i^2(k) + V_i(k)}\right]}\right]$$

..... (3.26)

When constant voltage apply

$$J\ (k)\ = \sum_i W_i\ [(-17.402I_b\ +\ 99.377) + \frac{2p_i(k) * \Delta t}{Cap_i.[\sqrt{\frac{2P_i(k)\Delta t}{C_i}} + V_i^2(k) + V_i(k)]}]$$

... (3.27)

3.3.2 DISCHARGING STAGE

$$J\ (k)\ = \sum_i W_i\ [\ (41.5882I_b\ +\ 831.8838V_b\ - 0.5720Ib2\ - 88.9639Vb2 - 1833.0557) + \frac{2p_i(k)*\Delta t}{Cap_i.[\sqrt{\frac{2P_i(k)\Delta t}{C_i}}+V_i^2(k)+V_i(k)]}]$$

…….(3.28)

3.3.3 OPEN CIRCUITE STAGE

When the open-ciruit voltage is whithin a range between 3.0 and 3.7 V

$$J\ (k) = \sum_i W_i\ .[(39.862V_{oc} - 128.13) + \frac{2p_i(k) * \Delta t}{Cap_i.[\sqrt{\frac{2P_i(k)\Delta t}{C_i}} + V_i^2(k) + V_i(k)]}]$$

….. (3.29)

When the open-ciruit voltage is greater than 3.7

$$J\,(k) = \sum_i W_i \left[(-229.14V_{oc}^2 + 1973.5V_{oc} - 4148) + \frac{2p_i(k)*\Delta t}{Cap_i.\left[\sqrt{\frac{2P_i(k)\Delta t}{C_i}+V_i^2(k)+V_i(k)}\right]} \right]$$

……. (3.30)

3.4 DETERMINATION OF DEPTH OF DISCHARGE (DOD)

PHEV/PEV battery life can be affected by recurrent charging/discharging of switch. It is important to ponder and formulate the supplementary battery wear cost *Cwear* in V2G mode. The battery lifetime published by manufactures usually undertakes that the battery is fully charged and discharged at each cycle at an ideal reference situation [17, 18]. However, the frequent charging/discharging switch in V2G mode results in speedy battery wear. The battery degradation cost due to the participation of V2G can be articulated as a function of the real battery cycle life.

Depth of Discharging (DoD) of the *i*-th vehicle battery in V2G mode is defined as:

$$DoD_i = \frac{E_{i-V2G}}{\eta_{inv}\,E_i} \qquad \text{…….. (3.30)}$$

Where, η_{inv} Denotes the overall efficiency of the battery charger. In this research, all the battery chargers are assumed to be identical having similar efficiency. *Ei* is the stored energy of the *i*-th vehicle battery in DC kWh; *Ei-V2G* is the amount of energy transported by the *i*-th vehicle in V2G mode.

According to the studies conducted in [18], the relationship between battery cycle life (*L*) can be formulated as a function of *DoD* depending on the type of battery (e.g., Lead-Acid, Lithium-Ion, and NiMH).

$$L = f\,(DoD) \qquad \text{…… (3.31)}$$

The actual battery life in DC kWh is defined as:

$$L_E - DoD = E_S . L \quad \text{..... (3.32)}$$

L is the actual battery cycle life, which is defined as a function of *DoD; s E* is the stored energy in DC kWh. The battery degradation cost $C_{Degradation}$ ($/kWh) can be defined as,

$$C_{Degradation} = C_{Battery} / L_{E-DoD} \quad \text{.....(3.33)}$$

Battery forms the most luxurious of the elements in PHEVs/PEVs. There exists a wide variation in battery technologies developed in the past and still existing in the present generations. Some of them are Lead-Acid, Nickel-Cadmium, Nickel-metal hydride (NiMH), ZEBRA, and Li-Ion of which Lead-Acid is the cheapest and widely used one. Conventionally, most electric vehicles have used lead-acid batteries due to their advanced technology, high accessibility, and low price. Lead-Acid batteries have the demerits of low energy density and short life cycle. Lead-Acid batteries were used to power early-modern EVs with examples being original versions of General Motors EV1. Due to the high power density and charge/discharge efficiency, Li-Ion batteries dictate the most recent group of EVs in improvement. NiMH batteries are now considered a relatively mature technology. They vaunt an energy density of 30–80 Wh/kg, far higher than the above two batteries. However, the shortcomings include poor efficiency, high self-discharge, fussy charge cycles, and poor performance in cold weather. This paper focusses on three types of battery technologies, namely, Lead-Acid, Li-Ion, and NiMH.

For Lead-Acid battery, the relationship between battery cycle life and DoD can be expressed as a linear function:

$$L = a \cdot DoD + b \, (20) \quad \text{..... (3.34)}$$

For Li-Ion battery, the relationship between battery cycle life and DoD can be expressed as a logarithmic function:

$$L = a.DoD^{b} \quad \text{…….. (3.35)}$$

For NiMH battery, the relationship between battery cycle life and DoD can be expressed as an exponential function:

$$L = b_0 \left(\frac{DoD_R}{DoD}\right)^{\boldsymbol{b_1}} exp(b_2.\left(1 - \frac{DoD}{DoD_R}\right)) \quad \text{…… (3.36)}$$

CHAPTER 4

DIFFERENTIAL EVOLUTION ALGORITHM

Differential Evolution (DE) is a moderately modern trial mode (this was formed in the middle-1990s) converse by Kenneth Price and Rainer Storn [19, 20, 21, 22], which was purpose to increase problems above unbroken dominions. This process stimulate from Kenneth's Price exertions to solution the Tchebycheff Polynomial becoming Problem that had been fixed to him through Rainer Storn. In one of the distinct decide to resolve this proposition, the contriver came up by the judgment of worn vector distinction for uneasy the vector population. Above its service, the algorithmic rule was more emend and cultured, after unnumbered controvert among Price and Storn [21]. DE is an outspoken hunt evolutionary algorithmic rule which has been frequently utility to solution extended optimization bug. DE dividends semblances by habitual EAs. Though it does not usage binary encoding as an easy genetic algorithm [581] and does not include probability density function to auto-adapt its constraints as an Evolution Strategy [24]. As an alternative, DE appointments mutation built on the distribution of the results in the current population. Therefore in DE, research directions and probable step sizes hang on the location of the individuals selected to estimate the mutation values.

A technicalities plant has been improved to glance the dissimilar DE alternatives. The maximum popular of them is designate "DE/rand/1/bin", wherever "DE" advert Differential Evolution, the language "rand" mention that individuals designated to consider the mutation values are select at reach, "1" betoken the multitude of double of solutions conscript and in conclusion

“bin” slavish that a binominal name recombination is habit. The cognate algorithmic rule of this changeable is bestow in Figure 10.8.

The “CR” feature counteract the control of the parent in the generation of the offspring. Greater worth of “CR” distinguishing signify less result of the parent. The “F” feature engage the control of the set of flight of solutions characterize to reckon the mutation value (one double in the conjuncture of the algorithmic program in Figure 10.8).

One of the weighty facts can be crescent either the population swell or the number of impair of solutions to count the mutation values may aggravate the sort of likely arrangements, advance the search of the pry into rove. On the other skill, the likeliness to invention the reform probe clew decay essentially. Then, the equilibrium among the population gauge and the number of variance is custom to find the effectiveness of the algorithmic program. Besides this weigh, additional serious constituent while attach DE is the quotation of the variable. All chemical element swerve the mutation is calculate and on the emblem of recombination speculator necessity.

A comprehensive body of DE alternates are imaginable. To distinguished this moment, the originate regard the work done by Mezura et al. [24] and interest eight DE variants, individually of which are to be concisely finish serially. The modifications from different to variable are in the recombination speculator custom (measure 9 to 15 in Figure 10.8) and also in the procession individuals are chosen to plan the mutation vector .The variants approved by Mezura et al. [24] are sharp as below:

• Four variations whose recombination speculator is conspicuous, always second-hand two individuals: the origin source and the DE change vector. Two discontinuous recombination

operators: binomial and exponential. The capital contention between them is that for species name recombination, each unsteady worth of the lineage is taken at every age from one of the two cause, supported on the "CR" distinguishing luminosity. On the other agency, in the exponential recombination, each floating regard of the family is taken from the first author until a reach numeral top the "CR" importance. From this instant, all the lineage inconstant excellence will be taken from the aid source. These variants are: "DE/rand/1/bin", "DE/rand/1/- exp", "DE/best/1/bin" and "DE/best/1/exp" [25]. The "rand" variations chosen all the individuals to rate change at velocity and the "worst" variations custom the prime release in the population as well the violence once.

• Two variations with math recombination, which, unlikely disjunction recombination, is revolution invariable. These are "DE/current-to-rand/1" and changeable "DE/current-to-best/1" [25]. The only contest among them is that the primarily choose the individuals for change at arbitrary and the subordinate one uses the pick explanation in the population also arbitrary solutions.

• "DE/rand/2/dir" [26], which spiritual fair duty teaching to the mutation and recombination operatives. The scheme of this method is to direct the try to promising extents quicker than traditional DE. Their originator dispute that the greatest result are keep when the many of flight of solutions is two [26].

• Lastly, a different by a confederated discontinuous-qualifier recombination, the "DE/current-to-rand/1/bin" [25].

Here we shortly recollect the differential evolution (DE) approach planned in [27-33]. In this differential evolution strategy 'p' denoted as the dimensions of the population. Let us take

$x_1, x_2, ...x_p$ as the individuals in the recent population, wherever individually $x_i = (x_i^1, x_i^2 .....x_i^n)$ is a vector of 'n' genuine enumeration. For individually $i = 1,2,3,4.....p$, the mutation performances workings as explained.

Several x_i is identified as objective vector, since the mutation process will (possibly) mutate this several.

Now x_{r1}, x_{r2}, x_{r3} by $r_1 \neq r_2 \neq r_3 \neq i$ be 3 arbitrary several of the recent population. These 3 several are recognized as parent vector. Here we enumerate an innovative several v, recognized as mutant vector. With $v = x_{r1} + F(x_{r2} - x_{r3})$ wherever $F \in [0,1]$ is a genuine enumeration, termed as scale factor. Like this a mutation performance could be gotten as a 'perturbation' of the objective vector x_i wherever the distinction among x_i and its mutated version v be suited to such a perturbation. For the growth of the variety of perturbation, the mutation performances would be joint by a crossover performances. Additional exactly later enumerate the mutant vector $v = (v^1, v^2, ...v^n)$ an original several $u = (u^1, u^2, ...u^n)$ recognized as 'trial vector' was formed by the succeeding method:

$u_j = v_j$ if(rand(j) $\in [0,1] \leq CR$

$u_j = x_i^j$ Otherwise

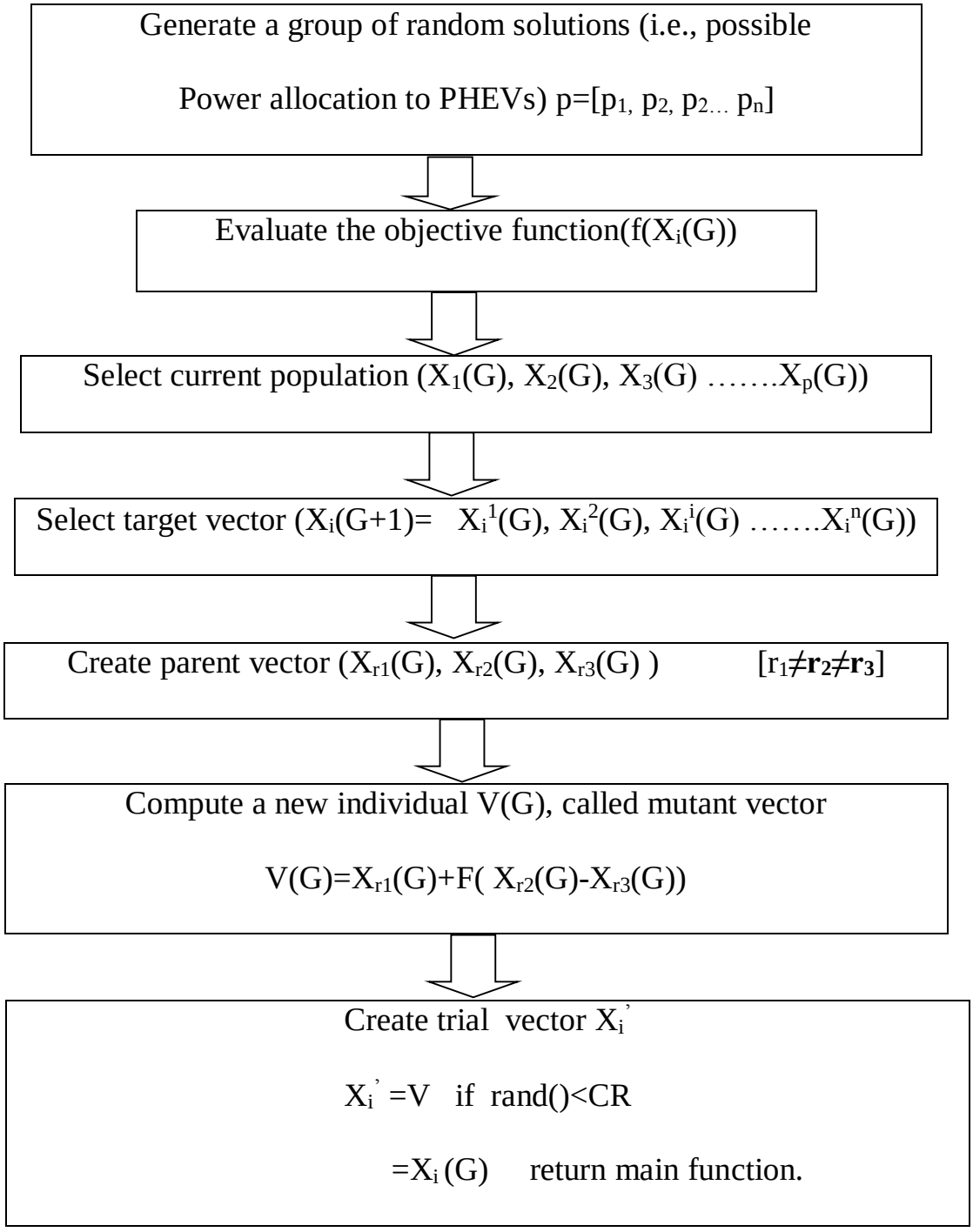
Wherever CR = User-decide crossover doorsill in the limit [0, 1]

Rand (j) = j^{th} estimation of a unvarying arbitrary Number generator would revenues numbers in the limit [0, 1]

In other words, the several 'u' is build-up of fragments and the elements of the vector which come either from the objective vector or from the mutant vector. Notification that at minimum one

constituent, the ¡th constituent, of the experimental vector necessity be occupied from the mutant vector. Then, completely the trail vector 'u' is procure to the objective vector x_i . And if 'u' has a superior cost cosecant after x_i is mutated into v. For more correct appraisement, the trial vector u receipts the container of x_i in the succeeding generation. Flowchart of Differential Algorithm presented in Fig.4.1

4.1 Differential Algorithm Based Plug –In Hybrid Electrical Vehicle Charging Algorithm:



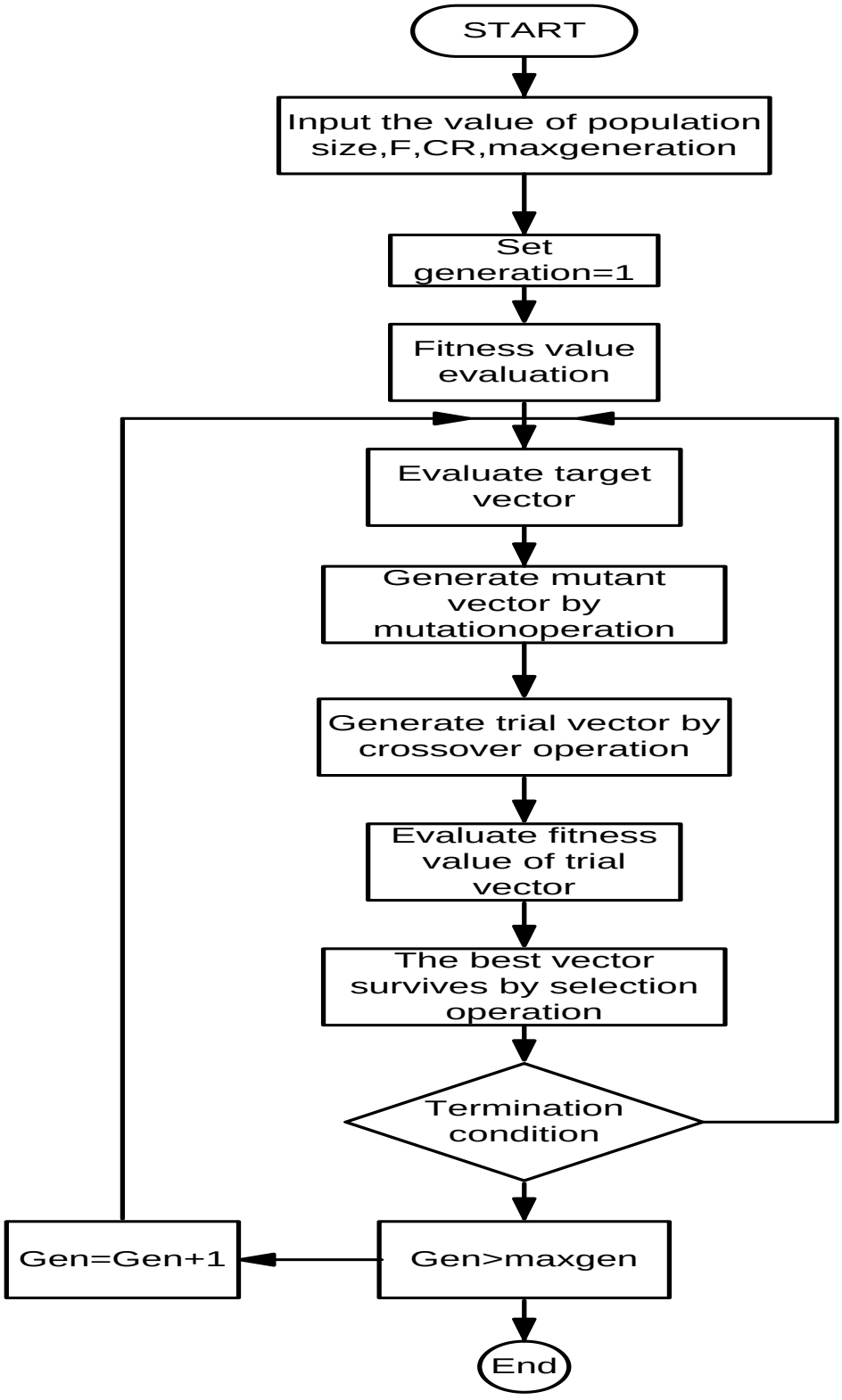


Fig .4.1 flow chart of differential Evolution

CHAPTER 5

SIMULATION RESULTS AND ANALYSIS

Completely result were simulated in MATLAB-SIMULINK environment with an Intel(R) Core™ i3 CPU M350@2.27GHz, 2.00GB RAM, Microsoft 64 bit Windows 7.

Here

i. Maximum PHEV charger limit $P_{i,max}(k)$ was taken as 14KW,

ii. The system efficiency is 85%;

iii. $P_{utility}(k) = 91\% \times \eta \times P_{i,max}(k)$;

iv. The cognitive constant and social constant $\gamma_1 = \gamma_2 = 1$; $\gamma_1 = \gamma_2 = 1 = \gamma_3 = 1$.

v. The scheduling period is 24 hours;

vi. The initial SOC is distinct as an incessant unchanging arbitrary number among 0.1 and 0.6.

vii. 1000 seconds is the sample time.

viii. The parking deck electrification organization is established on Level two charging.

ix. Voltage =240v ac;

x. Rated battery capacity Cap=7Ah;

xi. Maximum power=14 KW;

xii. Battery capacitance C=1;

xiii. Weighting term w=1;

At first, we simulated our algorithm for 11 PHEVs. First we choose population size are 100, 150,200. Then we find best fitness value and select best population size. Then maximum no of

generation we change from 150,150,200 with best population and similarly we select best generation corresponding best fitness value. Same process we change scaling factor and crossover and find best scaling factor and crossover value. Best maximum fitness value corresponding best population size, maximum no of generation, scaling factor and crossover value are 150, 200, 0.9 and 0.9 respectively.

Table 5.I, mean value, standard deviation of the maximum fitness values at a time step k accomplished by several approaches.

TABLE 5.I

THE MEAN AND STANDARD DEVIATION OF THE MAXIMUM FITNESS VALUES OBTAINED WITH DIFFERENT DE PARAMETERS

		Mean value	Standard deviation
Maxgen=100 Wt=0.1 Cr=0.2	NPop=100	0.01161	8.85E-05
	NPop=150	0.007776667	6.26E-05
	NPop=200	0.00585333	5.07E-05
NPop=150 Wt=0.4 Cr=0.8	Maxgen=100	0.00835	0.000228564
	Maxgen=150	0.008223333	0.000125075
	Maxgen=200	0.0083	0.000148556
NPop=150 Maxgen=200 Cr=0.8	Wt=0.2	0.008013333	0.000125212
	Wt=0.5	0.008586667	0.000192503
	Wt=0.9	0.009833333	0.000535198
NPop=150 Maxgen=200 Wt=0.9	Cr=0.2	0.00791	8.45E-05
	Cr=0.5	0.008183333	0.000141624
	Cr=0.9	0.008573333	0.000219613

The representative evolution method of the DE in resolving this problem at time stage is designated in Fig. 5.1. The blue mark denotes the mean value of objective function whereas the red line denotes the maximum objective function.

Population size 150, Maximum no generation 200, Scaling factor 0.9, Crossover 0.9.

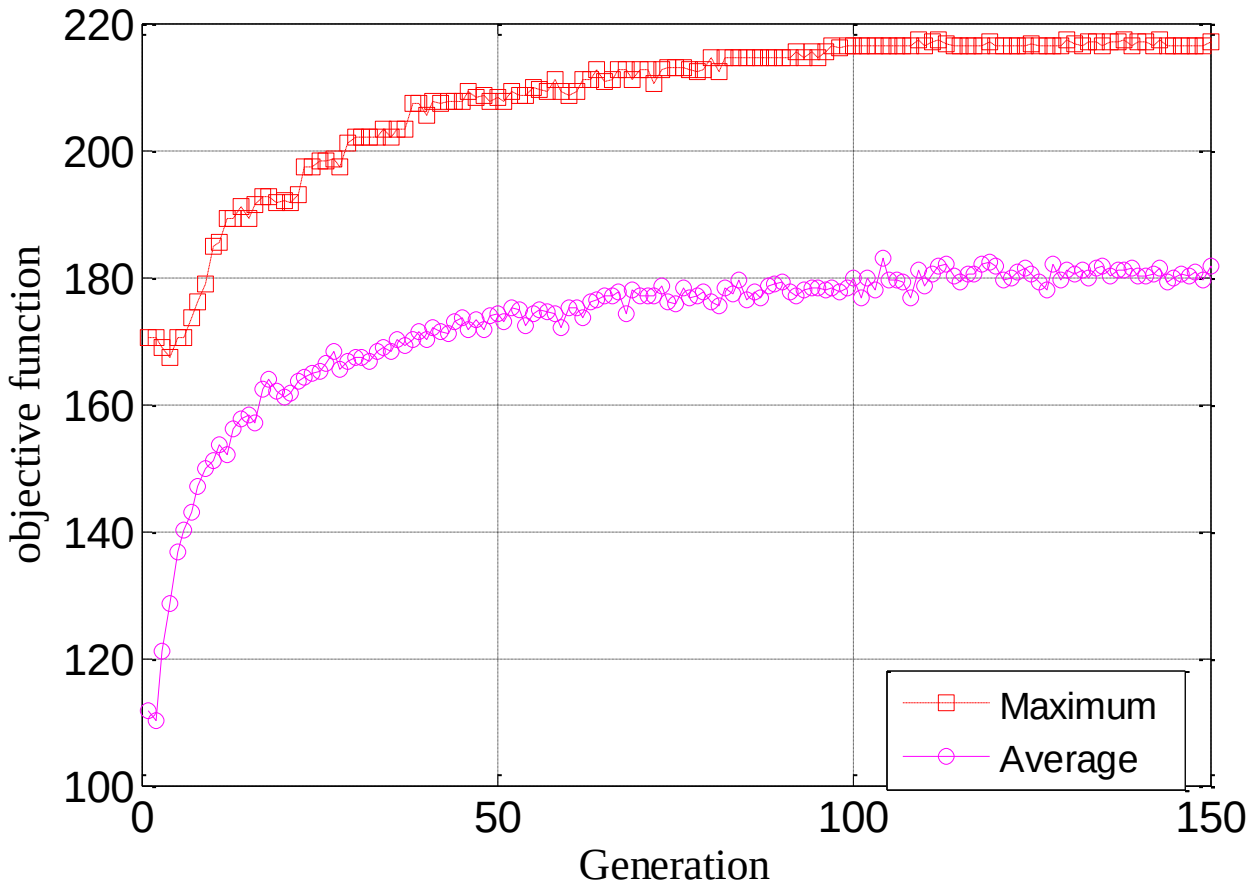


Fig 5.1 The Maximum objective function (red), mean value of objective function (pink) vs. DE generation

Best string power with best population size, maximum generation, scaling factor, and crossover. Population size 150, Maximum no generation 200, Scaling factor 0.9, Crossover 0.9. Table 5.II shows the best string power with consequent to the best population size, maximum number of generation, scaling factor and cross over.

TABLE 5. II

OPTIMAL ALLOCATED POWER

Vehicle No.I	Vehicle No.II	Vehicle No.III	Vehicle No.IV	Vehicle No.V	Vehicle No.VI
13.2969	13.3981	13.6809	13.3608	12.7006	12.7873
Vehicle No.VII	Vehicle No.VIII	Vehicle No.IX	Vehicle No.X	Vehicle No.XI	
13.5600	13.6537	13.6807	13.8900	13.7314	

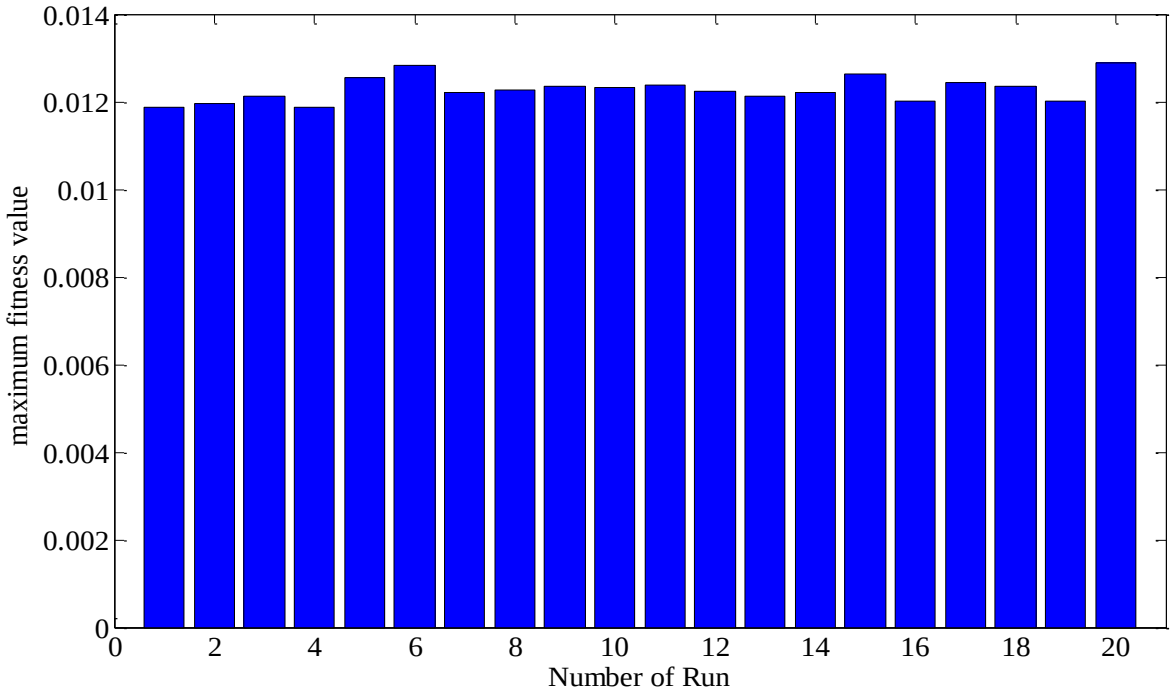


Fig 5.2 Maximum fitness value with multiple trial runs

Fig.5.2 shows the maximum fitness value with number of trials 20. Compare the fitness value with no of trials here we see that variation of fitness value are less every trials.

Table 5.III change no of vehicles (30, 300, and 1000) and find maximum objective function also we compare maximum fitness value with vehicles.

Table 5. III

MAX OBJECTIVE FUNCTION AND MAX FITNESS VALUE WITH DIFFERENT NUMBER OF VEHICLES

No. of vehicles	Jmax	Max Fitness value
30	556.597	0.010616
300	3875.53	0.01073
1000	11241.93	0.010437

The outcomes of the segregation second-hand 11 PHEVs are demonstrated in Fig. 5.3 and Fig. 5.4. For this exploratory, the inaugural SOC was choose as a persistent equivalent rate huge number between 0.2 and 0.6. The staying charging time was put to 1000 support (16.66 hours). The staying charging time was unique as continuous achieve scalar between 0 and 7 hours. The cost that the traditions were consenting to spread for power was unique as a persistent random a lot of people between 20 Rs and 60 Rs. The battery limit was anecdotal to be apparently equivalent for wholly vehicles.

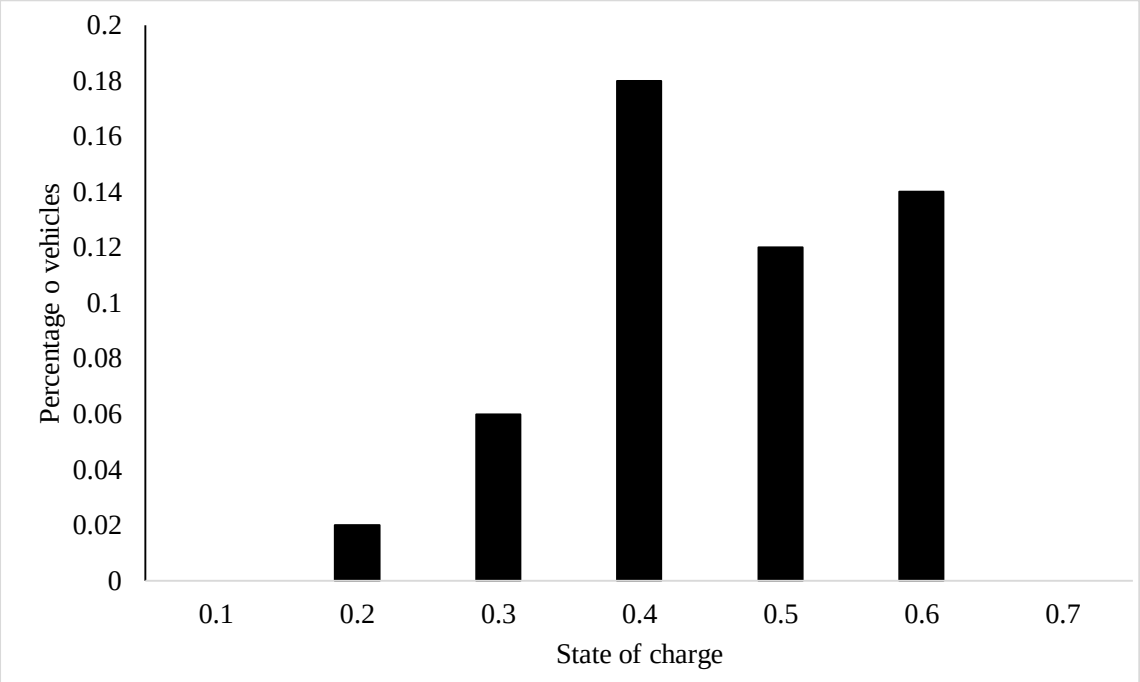


Fig. 5.3 inaugural SOC for 11 PHEV case

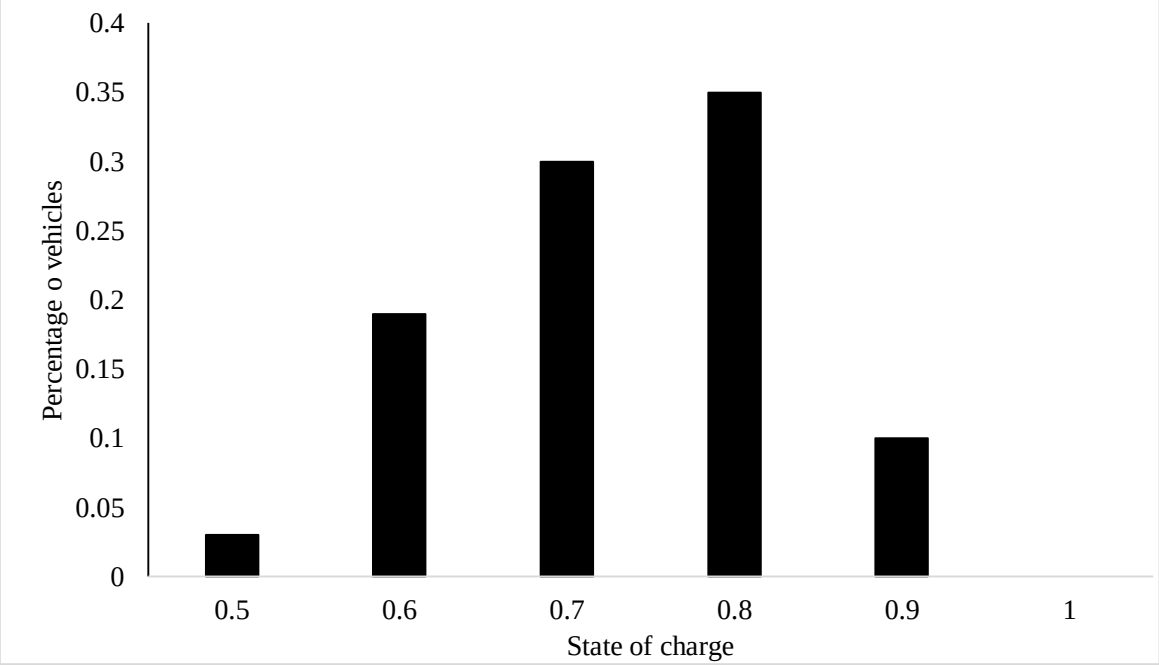


Fig. 5.4 Leaving SOC for 11 PHEV case

The outcomes of the segregation second-hand 100 PHEVs are demonstrated in Fig. 5.5 and Fig. 5.6. For this exploratory, the inaugural SOC was choose as a persistent equivalent rate huge number between 0.2 and 0.6. The staying charging time was put to 1000 support (16.66 hours). The staying charging time was unique as continuous achieve scalar between 0 and 7 hours. The cost that the traditions were consenting to spread for power was unique as a persistent random a lot of people between 20 Rs and 60 Rs. The battery limit was anecdotal to be apparently equivalent for wholly vehicles.

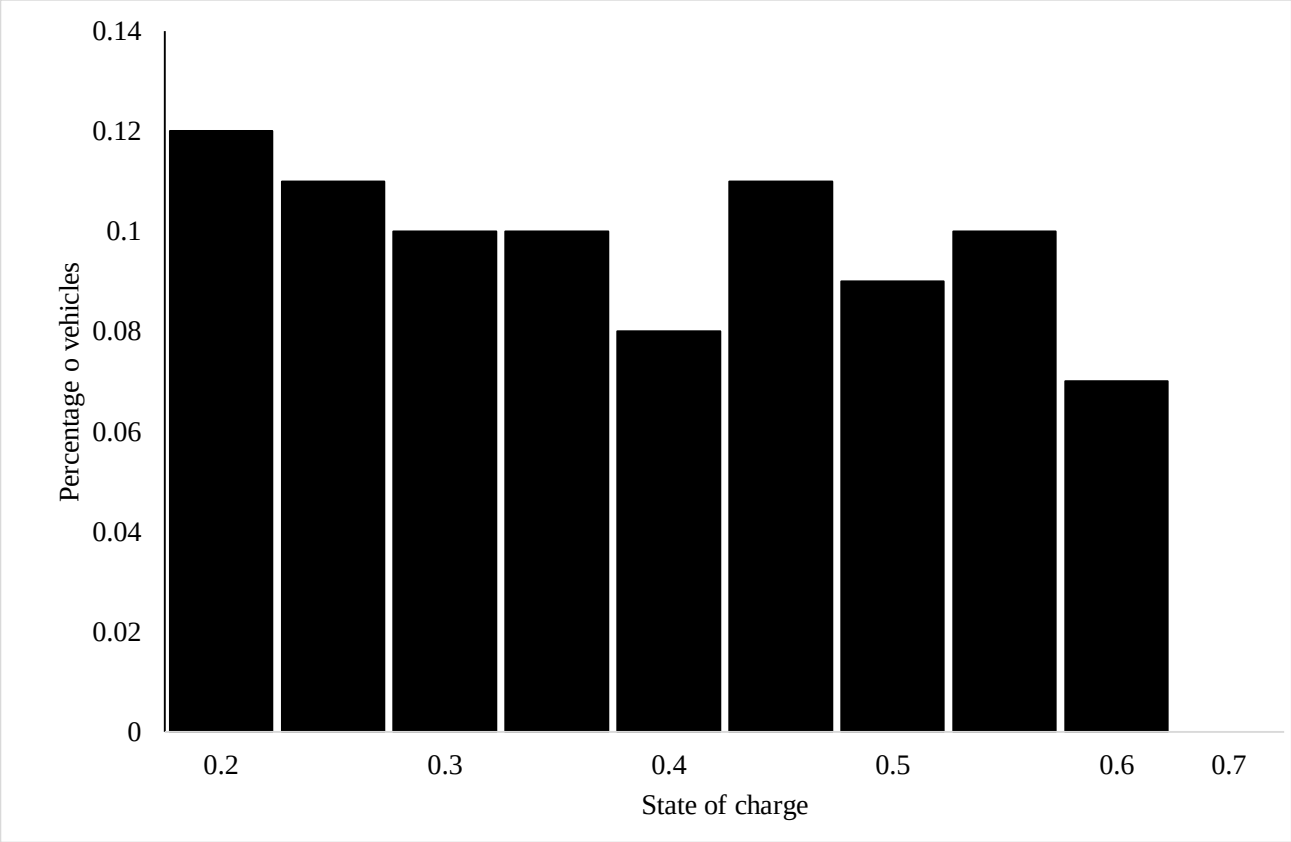


Fig. 5.5 inaugural SOC for 100 PHEV case

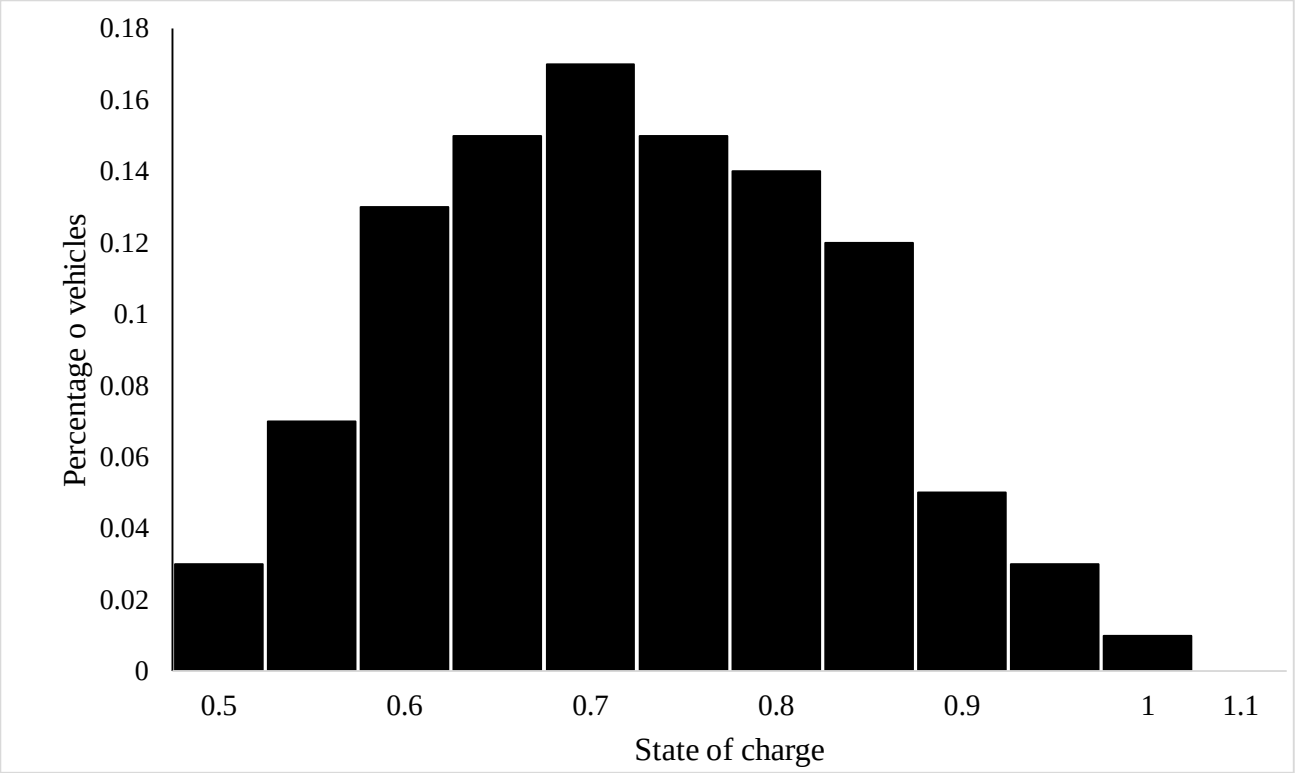


Fig. 5.6 Leaving SOC for 100 PHEV case

Initially, the creators reproduced the calculation with 30 PHEVs. At that point, the creators expanded the amount of PHEVs to 300 and 1000. Contrasted and the inspecting time, 5 s is a sensible choice setting aside a few minutes on 1000 vehicles. As seen in Table 5.iv, the execution time does not exponentially develop regarding the amount of PHEVs/PEVs, showing that the DE based strategy is suitable for vitality administration at an extensive scale city parking deck.

TABLE 5.IV

AVERAGE CPU TIME WITH 30,300 AND 1000 PHEVs

# of PHEVs	Average CPU Time at time step k
30	8.056 sec
300	10.74 sec
1000	15.34 sec

We look at the streamlining execution of the DE with the Genetic Algorithm system. The best result accomplished by all the techniques is analyzed in Table 5.v in excess of 20 trials. Fig.5.7 shows wellness values at time step k accomplished by distinctive techniques in excess of 20 trials. DE has high wellness esteem as contrasted with GA.

TABLE 5.V

RELATIONSHIP ON DE AND GA WITH 11 VEHICLES

	No of trials	Mean value (Fitness value)	Standard deviation (fitness value)
DE	20	0.0122800	0.00028210
GA	20	0.0120500	0.00035762

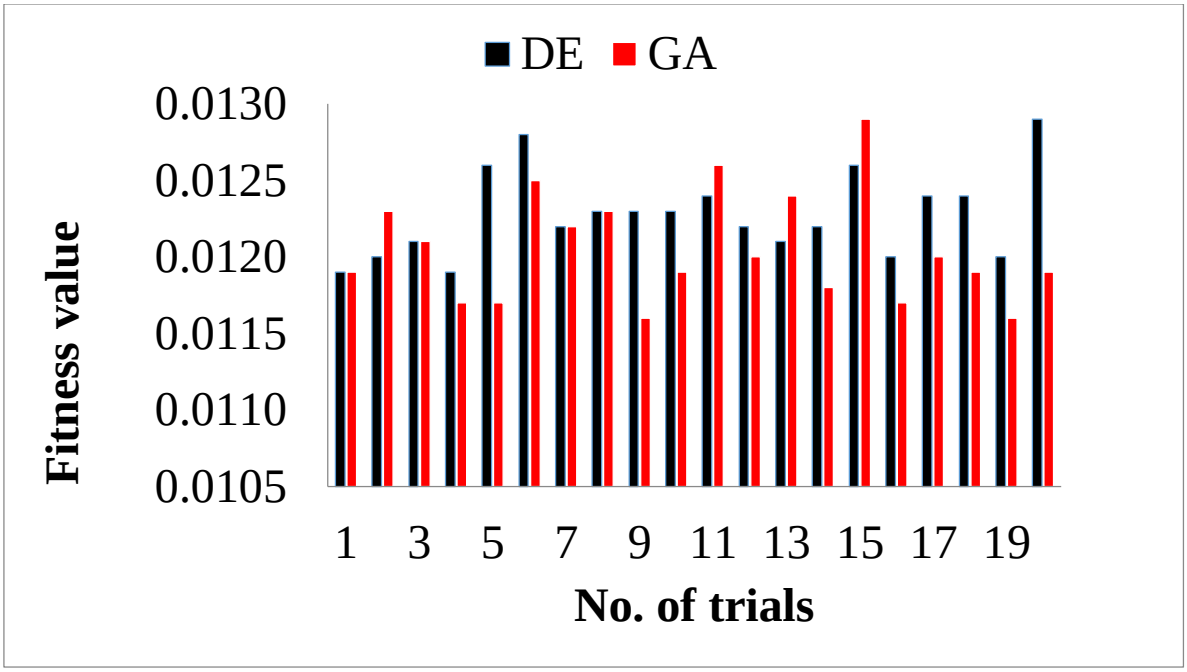


Fig. 5.7 Relationships on fitness values over 20 Runs

The computational speed of EDA and GA is compared in Table 5.VI. EDA is less time-consuming than GA.

TABLE 5.VI

RELATIONSHIP ON DE AND GA WITH 50 PHEVs

	CPU Time at time step k
DE	9.56 sec
GA	30.80 sec

5.1 MODIFIED OBJECTIVE FUNCTION RESULT BY INITIAL STATE-Of CHARGE

Here we evaluate maximum fitness value using difference mode of initial STATE-OF CHARGE. Table 5.VIII shows that charging stage has high fitness value as compare at other method.

TABLE 5.VII

RELATIONSHIP OF DIFFERENT MODE OF INITIAL STATE-OF CHARGE

		Fitness value	Standard deviation of fitness value	Cpu time
Charging stage	**Constant current**	**0.010616**	**0.00028210**	**9.78 sec**
	Constant voltage	0.0177	0.0002987	11.89 sec
Discharging stage		0.01022	0.0003451	20.21 sec
Open-circuit stage	$3.0<V_{oc}<3.7$	0.00912	0.0003678	12.45 sec
	$V_{oc}>3.7$	0.00895	0.0003917	12.89 sec

5.2 RELATIONSHIP ON DIFFERENT TYPE OF BATTERY

Fig. 5.8 shows the deep discharge effect on the battery cycle life in V2G mode. Fig. 5.9 shows the battery degradation cost ($/kWh) of different types of batteries with respect to *DoD*. Fig. 5.10 compares the overall cost/profit with 3 types of PHEV/PEV batteries in V2G mode.

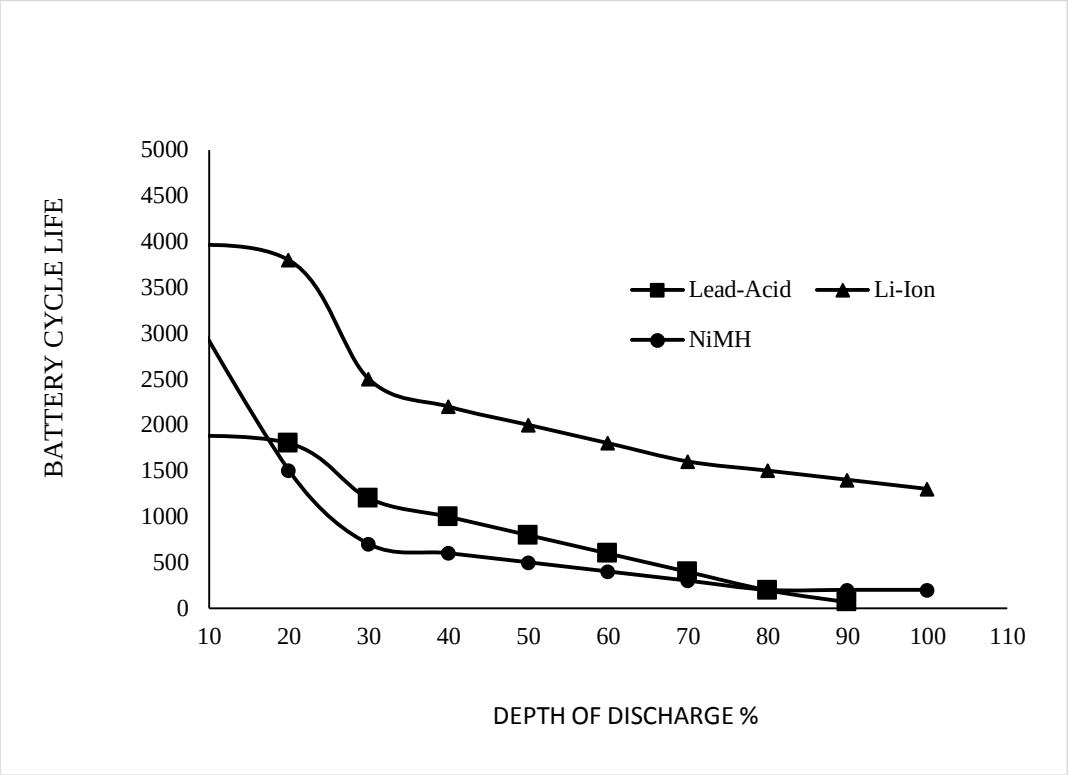


Fig. 5.8 battery cycle life

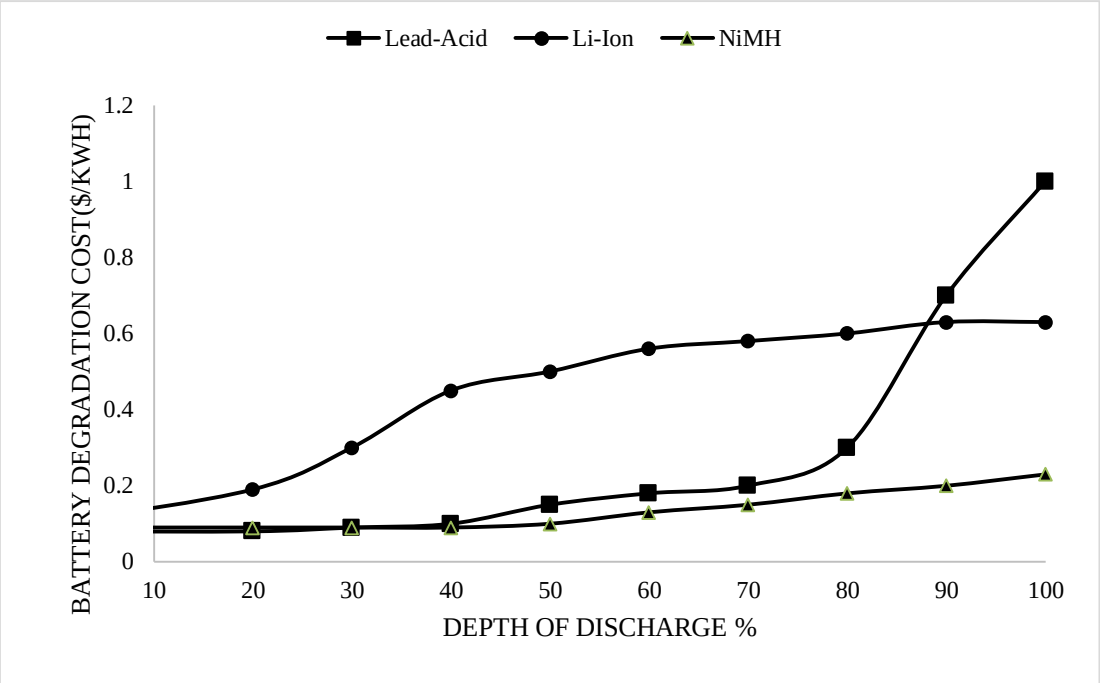


Fig. 5.9 Battery Degradation cost

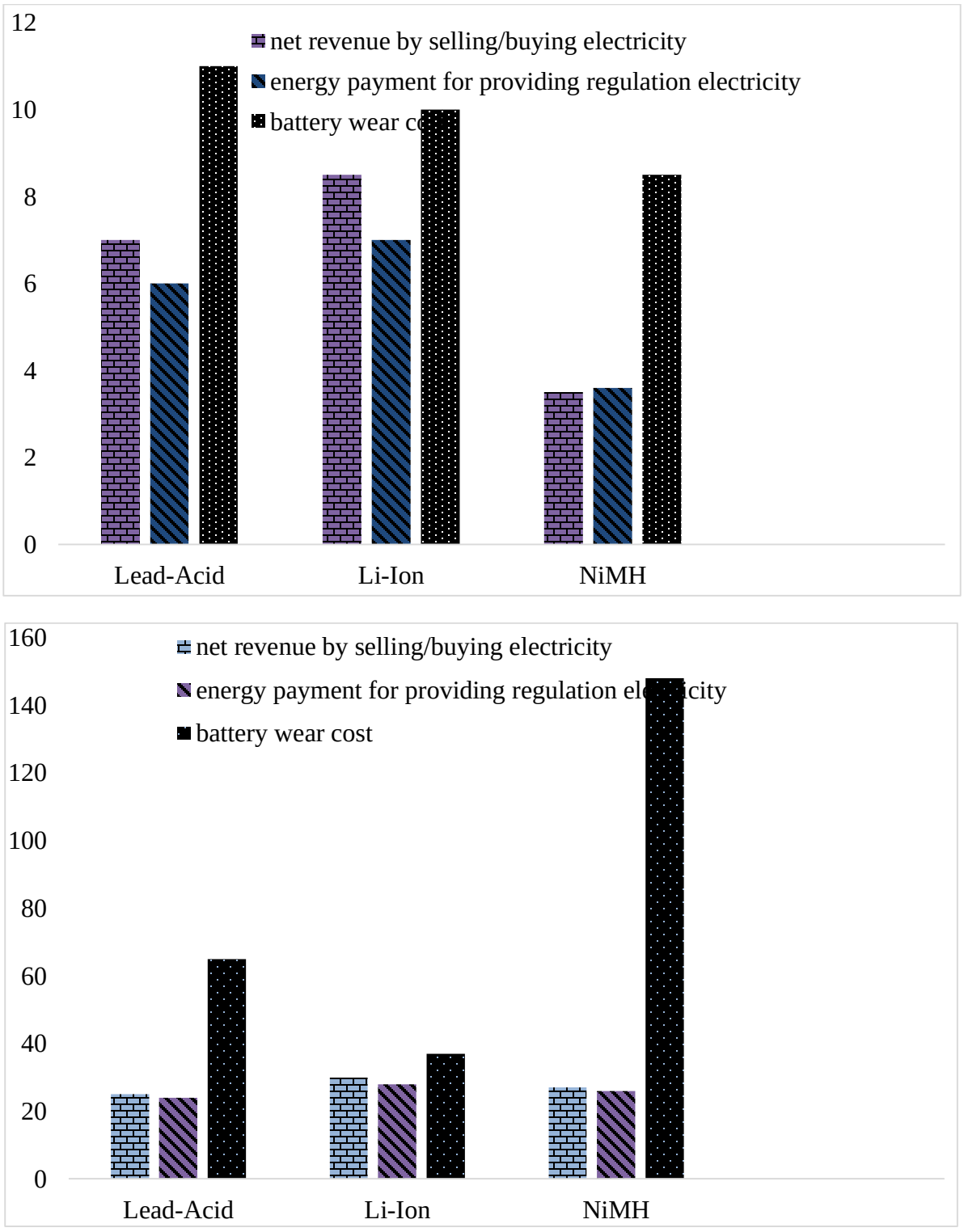


Fig. 5.10 Variation of cost/profit with different types of batteries

Mode (case 1 and case 2)

The profit-to-cost ratio is defined as

$$\gamma = \frac{c_{wear}}{r_e + r_{reg}} \qquad \text{……..(5.1)}$$

The comparison listed in Table 5.IX is also in favor of Li- Ion battery in V2G application. According to the simulation results, Li-Ion battery technology is the best candidate among three major battery technologies for V2G application.

TABLE 5.VIII

PROFIT-COST RATIO WITH DIFFERENT TYPES OF BATTERIES

	Lead-acid	Li-ion	Nimh
Case 1	1.3091	1.6432	0.8673
Case 2	0.7515	1.6705	0.4109

CHAPTER 6

CONCLUSION

In this thesis, an algorithm for the energy optimization of a PHEV municipal parking deck has been presented. To optimize the energy allocated to the PHEVs in real-time, we have used DE. The optimization is carried with the constraints of remaining battery capacity, the maximum electricity price that the user is willing to pay, and remaining charging time. The results show the algorithm can work on a problem with large number of vehicles. In our model, we considered the limitations imposed through energy cost, remaining battery capacity, and remaining charging time in our model. An upgraded coulomb counting strategy for evaluating Soc is proposed for lithium-particle batteries. The charging and discharging aspects of lithium-particle batteries were studies deliberately. This proposition creates a strategy for deciding the expense of utilizing the BEV battery in a V2g provision the U.k. In this proposal, on the grounds that it is perceived that Dod and ambient temperature are noteworthy impacts on battery cycle life, the current center of the study is to disengage and quantify these impacts while perceiving that future work ought to take a gander at different components, for example, discharge rate and charge administration. Three regular sorts of BEV batteries—lead-Acid, lithium-ion, and NiMH—were considered in this study.

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