

**REDUCTION OF TOTAL HARMONIC DISTORTION IN HYBRID
ENERGY STORAGE SYSTEM USING ARTIFICIAL NEURAL
NETWORK**

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE AWARD OF THE DEGREE OF

**MASTER OF TECHNOLOGY
IN
COMPUTATIONAL DESIGN**

SUBMITTED BY

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I, SHUBHAM RAJ, Roll No. 2K18/CDN/07 student of M.Tech (Computational Design), hereby declare that the project Dissertation titled “Reduction of Total Harmonic Distortion in Hybrid energy storage system using Artificial Neural Network” which is submitted by me to the Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the project Dissertation titled “Reduction of Total Harmonic Distortion in Hybrid energy storage system using Artificial Neural Network” which is submitted by SHUBHAM RAJ, Roll No. 2K18/CDN/07 Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

In this thesis, a study and implementation techniques is used design a hybrid energy system storage of electrical vehicles which is the function of electric vehicles. Regularly expanding electricity utilization offers ascend to guidelines and noteworthy undertakings to improve the energy proficiency in a wide range of movement from assembling to trade, from transportation to advanced correspondence, from amusement to PCs and compact gadgets. This is contemplated and executed in MATLAB Simulink on the point of view of electric vehicles explicitly for half breed vitality stockpiling framework. The proposed half and half electric stockpiling framework comprise of super capacitor and lithium particle battery to charge the electric vehicle. The control framework is planned utilizing Artificial Neural Network to upgrade the outcomes got utilizing the PI controlled methods. It decreases the computation multifaceted nature of the framework by diminishing the estimations of K_p and K_i figuring. The neural system advances self-learning ability of the framework and furthermore improves the framework by decreasing any variances assuming any. Here we are utilizing the fake neural system and it is having numerous favorable circumstances it will get improved execution when appropriately tuned. It require less tuning exertion than ordinary controllers. At the point when we are contrasting and different controllers (PID and Fuzzy controller) neural system shows the better execution achieved with tuning. The mixture learning calculation is utilized preparing this system. At long last, here we are demonstrating various boundaries diagram utilizing MATLAB.

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LIST OF NOMENCLATURE

V= Voltage

I = Current

R= Resistance

μ_1 = Ultracapacitor Current 1

μ_2 = Ultracapacitor Current 2

μ_3 = Ultracapacitor Current 3

Σ = Summation

n= Stage

s= State

X= Decision variable

LIST OF ABBREVIATIONS

ANN- Artificial Neural Network

HESS- Hybrid Energy Storage System

EV- Electric Vehicle

THD- Total Harmonic Distortion

PI- Proportional Integral

PID- Proportional Integral Derivative

PD- Proportional Derivative

UC- Ultra Capacitor

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION AND OVERVIEW:

Due to the tainting accomplished by oil primarily smart, new vitality sources energy. Nowadays, introduced vitality warehousing frameworks in flow age electrical vehicles area untypically subject to the Li-particles batteries having high vitality thickness, is providemassive division continuation to electrical vehicles. whereas appeared otherwise in regard to the super capacitance, the response of Li-particles batteries is a smaller amount than that of super capacitors. E vehicles up to fuel vehicles regarding brisk transient increasing speed, vitality, and long-separate continuation, a 0.5 breed vitality warehousing framework containing Li-particles batteries and super-capacitors is related hybrid vehicles. For the headway of electrical vehicles, up vitality house key, and it's imperative to think about extending the limit of the battery, whereas decreasing the burden and size of the battery to assemble the charging rate.

DC-DC device is acceptivea stimulating activity in crossover vitality warehousing framework is developed quicklysystematically. movement of headways, nonethelessis notsmart for electrical vehicles in light-weight of the gorgeousmanagement and additional noteworthy prize. it's to be appeared isolated bi-directional DC-DC device with complicated structure willmodification over a huge power transmission. Another zero-swell ever-changing DC-to-DC device with the planned enticing progressions. additionally, the appliance is powerful. Isolated interleaved DC/DC device shows the chance of winding coupled inductors, anyway it's logically smart for power transmission. It is important for 0.5 and 0.5 vitality warehousing frameworks to selectan appropriate vitality the official's procedure. Vitality the official's methodology are extensively reported recorded as a tough copy within the continuous years, as well as neural systems, downlikeprinciple, state machine management, repeat decoupling procedure, on/separated good frameworks, dynamic programming (DP) and confinement of battery management. The essential objective of the propermanagement frameworks is to make sure a diligent offer by the step-down of a value limit. These frameworks are often isolated into detached overall improvement and on-line close-by streamlining. For detached overall improvement, it's essential to urgethe most

effective power scattering between completely different sources. Meanwhile, for on-line adjacent improvement, precise declaration driving conditions is important.

1.2 MOTIVATION:

In this thesis, another half and half vitality warehousing framework for electrical vehicles is organized subject to a Li-particles battery management dynamic demand rule-based HESS vitality the officers and another bi-directional DC/DC convertor. The framework is stood out from regular cross breed vitality warehousing framework, showing it's large favored purpose of read of cut volume and weight. Moreover, the swell of yield current is diminished and therefore the lifetime of battery is improved. A HESS estimations technique that goes for showing signs of improvement pairing rate, considering the management approach and therefore the driving cycle for picked HESS prepare. The examinations finished during this theory, the joined use of LiFePO4 batteries and EDLCs for prime vitality compass point, mistreatment the fitting system of a DC-DC management hardware convertor. associate emotional examination of 3 system conferred to some extent three and one revered logically acceptable, extremely and monetarily, picked the remainder of the examination. Interleaved DC_DC convertor and model of LiFePO4 batteries and EDLCs area unit delineated partially three. alongside the completed management technique. for instance, of the use of the tactic during this hypothesis, 3 model area unit these utilized in section four to assess execution of an entire HESS to the extent runtime, management misfortune (driving extent), and the battery developing for each different driving.

1.3 OBJECTIVE:

The main objectives of this thesis are: -

- To do literature review on electric vehicle-based hybrid storage system
- To improve the efficiency and accuracy using algorithm of artificial neural network or ANN.
- The system is enhanced by the use of ANN based neural network fitting technique in the control system for hybrid electric energy storage system.

1.4 Organization of the thesis:

The thesis is organized as: Chapter 1 consists of introduction to the hybrid system and objectives of the thesis.

Chapter 2 consists of literature review related to various electric vehicle related journals.

Chapter 3 consists of detailed explanation hybrid electric energy storage for electric vehicle.

Chapter 4 consists of results and implementations in MATLAB Simulink.

chapter 5 conclusion and future scope of the work is discussed.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE REVIEW

[1] Younghyun Kim [2013] et al., A vitality stockpiling part is partner essential gadget or gear that is fit for putting away force inside the potential, dynamic, synthetic, or various styles of vitality, and reestablishing the hang on vitality back to the force on request. There territory unit such vitality stockpiling parts created to-date. during this segment, we will in general specify the key measurements that zone unit frequently wont to survey very surprising vitality stockpiling parts in Section a couple of.1 altogether. Next we will in general look at some agent vitality stockpiling parts in lightweight of the referenced measurements in Section a couple of.2. we will in general don't examine the explained standards behind putting away (discharging) the force in (from) capacity parts (for instance, inner electro-substance reactions), anyway target assessing their presentation and incentive as vitality stockpiling parts.

[2] Ian C. [2012] et al., This hypothesis researches the upsides of battery and battery-ultracapacitor mixture vitality stockpiling frameworks (ESSs) in beat load applications. It examines and assesses the upsides of the half breed ESS over its battery-just accomplices. The estimation for assessing the favorable circumstances is charge efficiency - the proportion of vitality passed on to the load per unit charge given by the battery. The capability addition is portrayed as the refinement in control profitability between the half and half and the battery-just ESS. A custom test mechanical get together is organized and attempted to supply the present control for charging and releasing the batteries, similarly as the data obtaining for assessing vitality and current yield. Examinations are performed on both ESSs under four particular beat burden profile.

[3] Karl BA [2010] et al., At the time of this association, developing burden for eco-accommodating voyager vehicles has impelled vehicle creates to place resources into the innovative work of electrically pushed vehicles. This merges vehicles of warily electric drive and blend electric vehicles with internal turn over motors. To investigate a fragment of the different creative degrees of progress conceivable with electric force prepares, the AUTO21 arrangement of central purposes of importance financed experience E301-EHV; an undertaking to change over a Chrysler Pacifica into a blend electric vehicle.

[4] Tobias Andersson et al., In this paper an elective vitality stockpiling framework in the drive train of a half and half electric vehicle is investigated. In particular, it centers around the potential diminishing of the stresses of the battery when electrochemical capacitors, a.k.a. supercapacitor, are incorporated as a ground-breaking vitality stockpiling. Different control procedures are evaluated and an estimation of the execution is given. To affirm the generation, a downscaled HEV drive train involving NiMH batteries, electrochemical capacitors, a DC/DC converter and an outside weight, is created and attempted. On a very basic level abatement in battery stresses and a good understanding between the models used in amusements and the lab framework. Finally, a weight improvement of such a framework is immediately discussed.

[5] M. Gopi krishnan [1992] et al, it's accustomed substantial dc-dc convertor by exploitation extremist capacitance and battery. it's what is more exploitation the dc go together with actuality objective of sustain the celestial point voltage regard. By the assistance of battery and ultracapacitor they're operating. The battery is conversant in charging the capacitance if there need to emerge an occasion of discharge the capacitance. For this circumstance battery is functioning. it's conjointly accustomed the recuperating breaking to store that vitality if there need to be an occasion of vehicles stoppage the vitality are going to be incident. The battery life time increase by exploitation extremist capacitance. On the off likelihood that there need to emerge an occasion of ultracapacitor operating, the battery can isolated with power offer. This preliminary is finished viably and thoroughbred yield of framework.

[6] Xiaodong Zhang [2014] et al., it's utilised to very large dc-dc convertor by utilizing extremist capacitance and battery. it's likewise utilizing the dc interface with the tip goal of sustain the head voltage esteem. By the help of battery and ultracapacitor they're operating. The battery is at home with charging the capacitance if there ought to arise a happening of unleash the capacitance. For this example battery is functioning. it's in addition accustomed the sick breaking to store that vitality if there ought to arise a happening of vehicles stoppage the vitality are going to be misfortune. The battery life time increment by utilizing extremist capacitance. If there ought to arise a happening of ultracapacitor operating, the battery are going to be secluded with power offer. This investigation is finished effectively and confirmed yield of planned framework.

[7] Jianjun Hu [2010] et al., The standard based controller comprises of three phases; assurance of activity modes for vitality sources, figuring of recently presented weighting parameters and formation of principles tables to decide the battery and ultra capacitor powers. Each stage has been depicted in detail in the paper. The viability of the proposed technique has been exhibited on a half breed electric transport model created in MATLAB/Simulink through reproduction thinks about under various drive cycle conditions. In recreation segment, two diverse contextual investigations have been led for correlation reason. In the primary contextual investigation, the outcomes have been contrasted and the battery just framework.

[8] Huilong Yu [2018] et al., cross breed framework stockpiling made out of lithium-particles battery and supercapacitors has been seen as a champion among the most promising responses for face against the incredible cost, low power thickness and short cycle life of the battery-just vitality stockpiling framework, which is the critical cerebral pain defeating the further passage of electric vehicles. In this work, the HESS estimating and vitality the official's issue of an electric race vehicle is investigated as a relevant examination to improve the driving mileage and battery cycle life execution. Differentiated and the ebb and flow look into, the unquestionable features of this work are: (1) A dynamic model and a defilement model of the battery are used to delineate the dynamic lead and to anticipate the cycle life of the battery even more unequivocally; (2) Considering the way that the structure and control issues are coupled a significant part of the time, in order to accomplish an overall perfect arrangement game plan and an implementable consistent vitality the load up framework, a Bi-level multi-target assessing and control framework subject to non-ruled organizing genetic figuring II and fluffy rationale control (FLC) is to gauge the HESS and to streamline the enlistment components of a FLC based EMS meanwhile;

[9] Rached Dhaouadi [2009] et al., the reason behind existing is to boost the dynamic response of the battery-based vitality reposition framework employing a ultracapacitor module as Associate in Nursing associate vitality reposition unit. A biface DC-DC convertor is planned to interface between the ultracapacitor module and also the major DC-transport. The management arrange depends upon a brisk internal current management circle mistreatment slippery mode management and an outdoor hover for DC-transport voltage rule mistreatment agreeable vitality

based mostly management. the advance in execution is displayed through multiplication and examinations. The DC-transport voltage is particularly overseen below external weight provoking impacts with quick ground-breaking vagrants.

[10] Kusum Lata Tharani [2010] et al., There square measure sure unelectrified cities over the Indian landmass wherever giving provide through the system is problematic in light-weight of terra firma unfold or uneven scene. the foremost conceivable call is to radiate cross section shock through rectifiable power supply assets, as an example, sun based mostly or wind vitality. These broken sources do not guarantee a twenty four \times seven provide framework. Thusly, near sun fueled or wind vitality frameworks, it lands up basic to use an infinite resource, as an example, biomass, that is open in material resource in commonplace zones. The necessity for battery vitality reposition finally ends up necessary to store the excess vitality created by limitless assets and provide it amid a time of insufficiency.

[12] Jianwei Lia [2018] et al., This examination proposes a [*fr1] and [*fr1] vitality reposition framework created out of the superconducting vitality reposition framework (SMES) and also the battery. The framework is planned to reimburse management fluctuations within a microgrid. Associate in Nursing epic management strategy is created to share the short power between the SMES and also the battery.

[13] Juan Sebastián [2018] et al., Power frameworks are a ton of electrical parts working in an arranging way, in order to give electrical vitality to the end customers, for instance, homes, and organizations. Therefore, the correct undertaking of intensity frameworks is noteworthy for any overall population. Nowadays, there is a strong tendency to bring reasonable power source into the electric systems. As a result of this reality, vitality stockpiling frameworks become entrancing in the power framework movement, because of the various points of interest that they can pass on to the power frameworks. The purpose of this recommendation is to address the estimating of a half and half stockpiling framework in a power framework with feasible power

source penetration. The crossover framework includes two stockpiling progressions with converse attributes. One advancement has high vitality limit, yet low power; it is known as whole deal vitality stockpiling framework. The other development has high power, anyway low vitality limit; it is known as flashing vitality stockpiling framework. In perspective on this, a minimization issue is communicated, which joins the endeavor cost in the capacity frameworks, the power framework working costs, and the developing of the crossover frameworks.

[14] Vasily Germanovich Chirkin, [2012] et al., The paper discusses average crossover vitality stockpiling applications in power frameworks, for instance, repeat and voltage rule, demand the officials, load shaving and vitality trade. The review has given the top tier in the field of battery super capacitor half breed vitality stockpiling topologies for power frameworks application. A relationship of central focuses and hindrances of the reserved, the semi-dynamic and the dynamic dc and air conditioning plans has been made. The parallel dynamic hybridization plot has been picked as the most fitting response for power framework application. The review has shown relevance of the investigation in the field. The methods for the future research have been recognized.

[15] Mario Porru [2017] et al., Associate in Nursing epic Hybrid Energy Storage System for electrical Vehicles (EVs) is during this paper. It contains A battery pack and a ultra-capacitor module (UC), that zone unit sensibly coupled through a Three-Level Neutral-Point Clamped gadget (NPC). strikingly, notwithstanding the approach that the UC is solidified inside the DC-partner, its voltage might be adjusted inside a huge shift, in this way ensuring its full maltreatment while not the necessity of any DC-DC gadget. this is regularly accomplished by ways for Associate in Nursing acceptable HESS the board structure, that what is more dismisses the battery pack from tending to astounding force changes.

[16] Mr.N.Nixen Prabu [2015] et al.,Increasing enthusiasm for confiscated age dependent on Renewable Energy Sources (RES) has incited a handful of problems within the assignment of utility grids. the limited scale cross section may be a positive response for contend with these problems. A submitted vitality repositing framework may increase a rife mix of RES into the limited scale organize by smoothing the limitless resource's anomaly, up the concept of the

mixed power and sanctioning extra organizations like voltage and repeat rule. Regardless, on account of vitality/control mechanical restrictions, usually imperative to use Hybrid Energy Storage Systems . during this paper, a second solicitation slippery mode managementler is for the facility stream control of a HESS, employing a Four Leg 3 Level Neutral purpose Clamped (4-Leg 3LNPC) electrical converter because the principle interface between the RES/HESS and also the very little scale organize. A three-dimensional area vector amendment and a course of action crumbling primarily based AC aspect management empowers the electrical converter to figure in unequal weight conditions whereas maintaining an inexpensive AC voltage at the motivation behind normal coupling. DC current sounds achieved by uneven weight and also the federal agency floating focus purpose voltage, along with the facility division cutoff points area unit deliberately attended during this paper. The reasonability of the strategy for the HESS power stream management is appeared otherwise in reference to a designed up PI management theme and is exhibited through reenactments and sure employing a four Leg 3LNPC model on a take a look at situate.

[17] Younghyun Kim [2018] et al., Energy repositing frameworks (ESS) have gotten the possibility to be a champion among the foremost important parts that noticeably amendment all around framework execution in numerous applications, stretching out from the facility system institution to electrical vehicles (EV) and versatile instrumentation. Regardless, a homogenized ESS is in danger to compelled qualities to the extent value, adequacy, lifetime, etc., by the vitality repositing advancement that contains the ESS. On the opposite hand, crossover ESS area unit a wise response for a viable ESS with as of currently open progressions as they will vanquished such imprisonments by abusing merely nice conditions of heterogeneous vitality repositing propels whereas concealment their disadvantages. In any case, the HESS thought in an exceedingly general sense directions refined arrangement and management to essentially impact the preferences to happen. The HESS structure ought to have the flexibility to allow controllability of varied elements, that area unit systematically fastened in homogenized ESS, and novel organization game plans ought to have the flexibility to utilize the management options. This paper displays Associate in Nursing absolute arrangement routine with regards to a HESS model to indicate flexibility, skillfulness, and vitality potency. it's created out of 3 heterogenous vitality repositing parts: lead corrosive batteries, lithium-particles batteries, and

supercapacitors. we have a tendency to show a completely unique framework system and updated vitality capability through this arrangement observe.

[18] S. Pirienko [2014] et al., The paper supervises improvement of adequacy of imperativeness amassing contraptions for electric vehicles. The focal points and highlights of the cross variety imperativeness accumulating structure subject to the batteries and ultracapacitors are portrayed. The potential geographies and commonplace schematics of bi-directional DC/DC converters for imperativeness accumulating are explored like capacity, unwavering quality and battery support.

[19] Georgia technical school [2016] et al., Effective vitality use may be a guideline focus and stress on the world nowadays in lightweight of the making enthusiasm for vitality. The nuclear crossover vitality framework (NHES) may be a productive specific thought which will probably improve and utilize existing vitality propels. This report considers a specific NHES structure that joins distinctive vitality frameworks as well as a setup, vitality warehousing framework (ESS), variable manageable generator (VRG), and extra technique heat applications. Vitality warehousing may be a elementary portion of this explicit NHES in lightweight of the manner that its arrangement empowers the framework to convey prime power whereas the setup works at sure power yield. numerous vitality warehousing decisions area unit open, anyway this examination primarily revolves around a fluid salt ESS. the first job of the fluid salt ESS is to alter the setup to be a totally firm heat supply by going regarding as a glow warehousing half for the reactor within the interior of times of low intrigue, and giving extra ability to thermo-electric power age within the interior of times of celestial point power demand. This report can depict the aim for employing a fluid salt ESS and understand a profitable fluid salt ESS game set up that will be utilized in weight following force applications. one or two of criteria area unit thought-about for convincing vitality warehousing and area unit wont to understand the most effective ESS within the NHES. numerous forms of vitality warehousing area unit right away delineated with their central focuses and drawbacks. the overall examination to settle on the foremost profitable fluid salt ESS incorporates 2 areas: thermodynamical, during which energetic and exergetic efficiencies area unit considered; and cash connected. within the fluid salt ESS, the two-segment examination covers 3 essential framework parts: fluid salt ESS plans (two-tank direct and thermocline), the fluid salt alternative, and also the differing force cycles joined with

the fluid salt ESS. Examination models area unit organized and dismembered to settle on the most effective ESS. the most effective revered vitality warehousing framework is that the two-tank direct fluid salt ESS with Associate in Nursing Air-Brayton united cycle victimisation LiF-NaF-KF because the fluid salt, and also the most traditionalist may be a comparative arrangement with KCl-MgCl₂ because the fluid salt. With vitality age being a major by and enormous trade, understanding the foremost paid fluid salt ESS supports progression of a convincing NHES with humble, clean, and tireless power.

[20] Dr. Mesbahi [2013] et al., The vitality stockpiling framework ESS used in electric or half breed vehicles remains the slight association: super costly, confined in independence, moderate to restore, etc. Today, the major center point of headway is undoubtedly reliant on the improvement of embedded ESS's giving responses for improving the vehicle expand, lifetime, volume, mass, or even the endeavor or use cost of these capacity frameworks. One of the plans by produces and investigators in the field of the E-flexibility is the hybridization of sources. The rule includes in joining two correlative stockpiling advancements (high express vitality for the principle, high unequivocal power and available over brief time allotments for the second). This hybridization makes it possible to mishandle the advantages of both stockpiling frameworks and gives additional degrees of chance in the midst of structure. In electric vehicle drive applications, there are diverse known innovative courses of action, for example the blend of intensity gadgets, batteries or supercapacitors. Therefore, cunning on-board vitality the leading group of half breed stockpiling sources is getting the opportunity to be essential to enable their headway, in order to feasibly direct vitality exchanges between the sources on board the vehicle.

[21] A. Jaya Laxmi [2018] et al., The USSC is a working channel (AF) and it compensates the responsive force, music in both the voltage and current achieved by troubles. The USSC uses two back to back related IGBT based voltage source inverters (VSIs) with a run of the mill dc transport. One inverter is related in plan and the other one is set in shunt with the load. The shunt inverter fills in as a current source and it compensates the current sounds. The course of action inverter fills in as a voltage source and it helps in compensating the voltage music. Past works presented a control procedure for shunt dynamic channel with PI control. By then, this control procedure was reached out to develop the two controllers for shunt and course of action dynamic channels. The reenactment outcomes of these control methodology are recorded for relationship

and affirmation of results.

[23] Yuvraj V [2014] et al., Artificial Neural Network is a reasonable instrument for significantly nonlinear structure. With the happening to quick PC system, there is progressively extended energy for the examination of nonlinear structure. Neuro control count is for the most part actualized for the application to mechanical systems and moreover some improvement has occurred in strategy control structures. Methodology Control systems are every now and again nonlinear and difficult to control decisively. Their dynamic models are more difficult to decide than those used in flight or mechanized control, and they will all in all adjustment in an abnormal way. This paper gives a model where a multilayered feed forward back causing neural framework is readied disengaged to execute as a controller for a temperature control structure with no from the previous learning concerning its components. The opposite components model is made by applying a variety of data vectors to the neural framework.

[25] Wei Lu [2013] et al., The ordinary PID (relative essential subsidiary) controller is generally connected to modern computerization and procedure control field since its structure is test and its hearty is well, however it don't function admirably for nonlinear framework, time-postponed direct framework and time shifting framework. This paper gives another style of PID controller that depends on counterfeit neural system and transformative calculation as per the traditional one's scientific recipe. The counterfeit neural system (ANN) is utilized to approach PID recipe and the differential advancement calculation (DEA) is utilized to pursuit weight of the fake neural system. This new controller is demonstrated better control impact in the recreation test. This new controller has a greater number of focal points than the ordinary one, for example, less determined burden, quicker worldwide combination speed, better hearty, more autonomy and flexibility on the plant and autonomous of human intercession and master encounters and so on.

[26] Harsh Kukreja [2016] et al., In its least troublesome structure, a fake neural framework (ANN) is a pantomime of the human brain. A characteristic brain can adjust new things, change

in accordance with new and advancing condition. The brain has the most surprising capacity to look at divided and ill defined, cushioned information, and make its own judgment out of it. For example, we can examine other's handwriting anyway the way where they create may be absolutely one of a kind corresponding to the way in which we form. A kid can recognize that the condition of a ball and orange are both a circle. In fact, even several days old youngster can see its mother from the touch, voice and smell. We can separate an acknowledged individual even from a cloudy photograph.

[28] Sayara Y[2014] et al., when all is said in done most power is created by utilizing non-sustainable power sources for example regular assets, for example, petroleum gas, oil, coal, and so on. In any case, it is influenced on nature or condition and furthermore it drains quickly. By considering natural issues now daily's scientists are thinking about inexhaustible sources to create power. Sustainable power source asset implies sun oriented, wind, tidal, and so forth. Among these assets wind is most alluring asset to produce power. As per the U.S. branch of vitality (DOE) report, wind control establishment in 2012 is 90% higher than in 2011 and 30% more noteworthy than as indicated by the past record in 2009.

[29] V. Anantha Lakshmi [2015] et al., The effective task of interconnected power frameworks requires the coordinating of all out age with complete burden request and related framework misfortunes. With time, the working purpose of a power framework changes, and consequently, these frameworks may encounter deviations in ostensible framework recurrence and booked power trades to different regions, which may yield bothersome impacts. In genuine power framework tasks, the heap is changing constantly and haphazardly

[30] Ishmeen Kaur Sra et al., Growing needs of industry for higher efficiency is putting new requests on systems associated with electric engines. This is prompting various issues in work activities because of quick elements and insecurity. The strength of the framework is fundamental to work at wanted set targets. The non-straight impacts brought about by engine regularly lessen strength, which decreases the controller's capacity to keep up speed or position at set focuses. Consequently number of modern applications requires position control of DC engine. The position control of DC engine permit the DC engine to move to an exact position and stay there regardless of whether an outer power attempts to move it. Position control of DC

engine is generally utilized for the mechanical arm control, aviation mechanization, mechatronics, cranes and so on.

2.2 Research Gap:

There is dearth research that examine use of advance Optimization function along with PID controller can increase efficiency of system, but this is not tested with electric vehicle right now along with Electric Vehicle that have DC-DC controller based HESS(Hybrid Energy Storage System). more about effect of Advance optimizing functions(like Artifical neural Network , Ant Colony technique, Particle swarm Optimization etc) in Electric Vehicle and Improvement of system efficiency, Drive Cycle and other parameters in Electric Vehicle by introduction to different Optimization techniques.

2.3 Objective:

My objective is to replace PID controller of Hybrid energy storage system in electric vehicle and replace with Artificial neural network technique and run simulation on matlab for VDC and IUC circuits for 6sec and 600 sec respectively.

2.4 Problem statement:

Reduction of THD in Hybrid Energy Storage System with added Artificial neural Network

CHAPTER 3

Energy Storage System

3.1 Introduction:

Electronic frameworks prepared for securing electrical vitality for non-brief use. It may include in a great deal of batteries of various advances (lead-corrosive, lithium-particles, and so on) arranged in a matrix to accomplish the required stockpiling limit where the heterogeneity of advances grants to ease the downsides and lift the practicality.

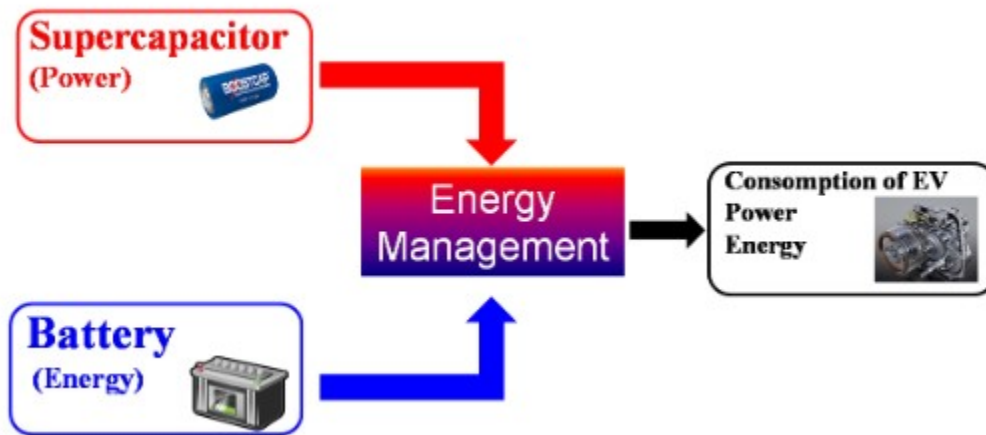


Figure 3.1: HESS.

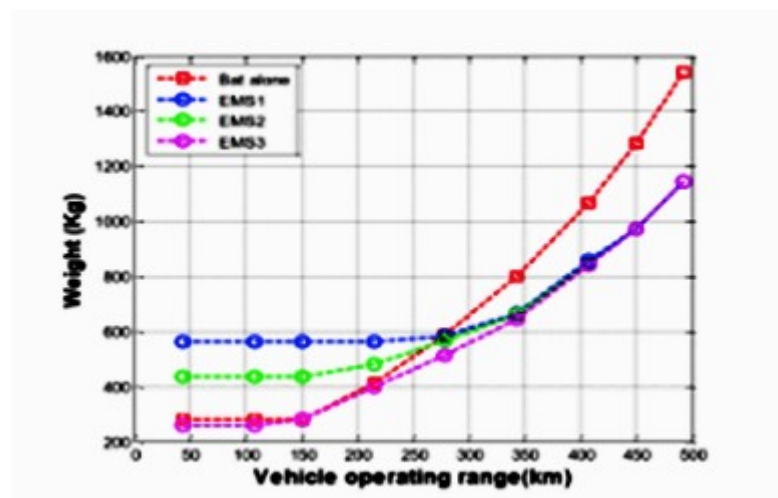


Figure 3.2: Weight

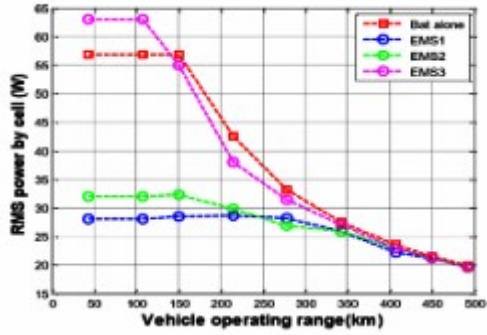


Figure 3.3: RMS

Figure 3.3 exhibits the RMS power weight associated with one battery cell for all setups. This test empowers us to set up a first appraisal of the battery developing.

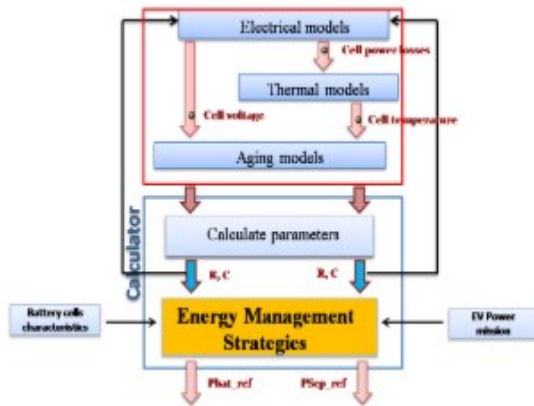


Figure 3.4: Multiphysics model of the hybrid energy storage system.

In light of the HESS multi-material science model (Figure 3.4), an improved guideline based framework including the restriction of the battery power has been attempted. Diversion preliminary of the developing cycling were cultivated for a sensible electric vehicle profile in various undertaking ranges. It was seen that model can be used to consider the effect of driving cycles and vitality the load up frameworks on the lifetime of the Li-particles battery and supercapacitor.

3.2 HESS:

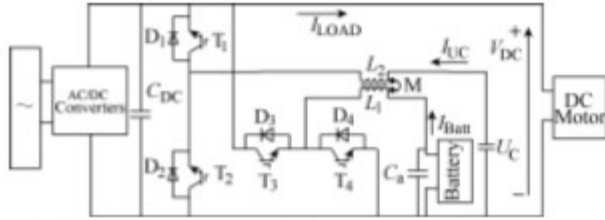


Figure 3.5: Topology

3.2.1DC/DC converter structure:

Table 3.HESS operation table

Sl no:	Power source	Operation mode	Working mode	Power flow
1	AC power	Buck	Parking charge mode	Battery and super capacitor
2	Battery	Boost	Constant speed mode	DC
3	Super capacitor	Boost	Acceleration mode	DC motor
4	Braking energy	Buck	Braking mode	Battery and super capacitor
5	Battery	Boost or buck	Super capacitor charging mode	Super capacitor and DC MOTOR

The above table shows the operation of hybrid energy system storage. In this table we can see the explaining about the different power sources, operation mode, working mode and power flow. The power source in AC power its operation mode is Boost, working mode is Constant speed mode and power flow is battery and super capacitor, In Battery its operation mode is Boost, working mode is Constant speed mode and power flow is DC. In Super capacitor its operation mode is Boost, working mode is Acceleration mode mode and power flow is DC motor. In Braking energy its operation mode is Buck, working mode is Braking mode and power flow is Battery and super capacitor. In Battery its operation mode is Boost or buck, working mode is Super capacitor charging mode and power flow is Super capacitor and DC MOTOR.

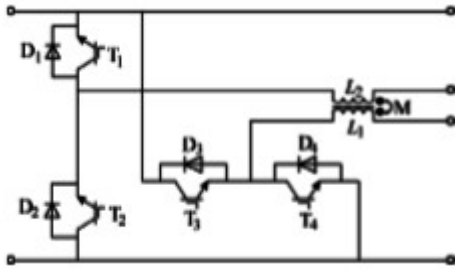


Figure 3.6: DC/DC converters circuit

The above circuit (figure 3.6) shows the dc - dc converter circuit. The working standards of venturing up and venturing down in DC/DC converter circuits will be depicted utilizing the most essential sort. Circuits of different sorts or those utilizing loops might be viewed as made out of a mix of venture up circuit and venture down circuit or their applied circuits.

3.3 HESS components:

The model of HESS parameters improvement in Simulink Software is showed up in Figure 3.11. The recently referenced schematic of DC/DC converter is improved with two exchange current controllers, which turn on and off the charging or releasing some part of plan, dependent upon the DC-interface voltage, and most distant point the battery flows.

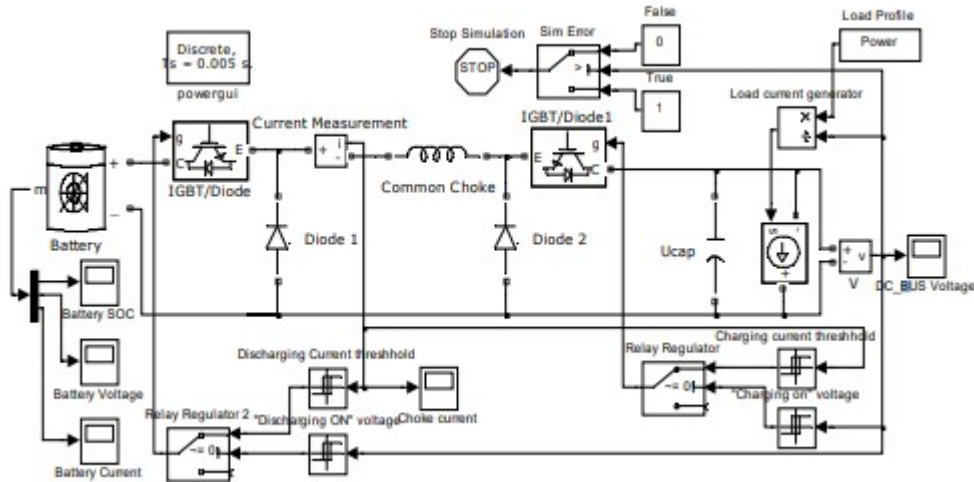


Figure 3.10: Model

3.5 Parameters and Model:

Parameters are discussed in this section.

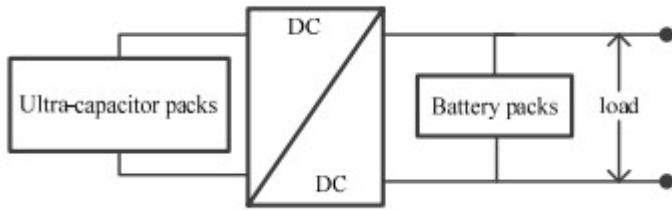


Figure 3.10: ultra-capacitor DC-DC current connection

Table 3.3: parameters values

SL no:	Parameters	value
1	Total weight/kg	1900
2	Curb weight /kg	1500
3	Front section/m ²	2.3
4	Aerodynamic drag factor	0.29
5	Rolling resistance	0.012
6	Wheel radius	0.307
7	Motor rated power	80
8	Motor peak power	105
9	Motor voltage class	<=360

The fundamental qualities are recorded in this above table battery is a champion among the more basic arrangements of budgetary execution of half and half vitality framework stockpiling. To survey life of battery, it is fundamental to exact limit model of battery.

Table 3.4Li battery


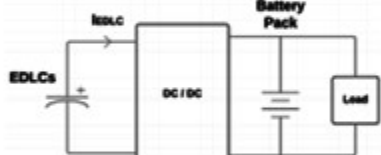
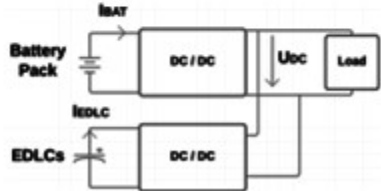
SLNo.	Index	value
1	Nominal capacity/ah	20
2	Nominal voltage/V	3.2
3	Internal resistance	<=6
4	Weight/g	514+-10
5	Charge voltage/v	3.65+-0.05
6	Operating temperature/0 C	-2.0

The above table demonstrates the lithium iron phosphate battery parameters. Here showing the list and estimations of lithium iron phosphate battery. The file is Nominal limit/ah estimation of battery 20, Nominal voltage/V 3.2, Internal obstruction <=6, weight 514+-10, Charge voltage/v 3.65+-0.05 and Operating temperature/0 C - 2.0.

3.6 Topology of HESS

The key qualities of urban rail travel activity are high thickness, long task cycle and short separations, bringing about a ton of braking vitality in the incessant beginning/braking process. Vitality stockpiling components in the application type of the urban rail travel mostly incorporate unadulterated battery stockpiling, unadulterated ultracapacitor vitality stockpiling, and half breed vitality stockpiling made out of battery and ultracapacitor. the DC-DC screens batteries, which is attractive over the EDLCs as the past are continuously unstable to uncommon errand (high current, over discharge, thus o n.).

Table 3.5 two source one load hybrid energy system storage topologies

Topology	Controlled Variables	Schematic
1 Two-stage battery/EDLCs	I_{BAT}	
2 Two-stage EDLCs/battery	I_{EDLC}	
3 Parallel active	$U_{DC}/I_{BAT}/I_{EDLC}$	

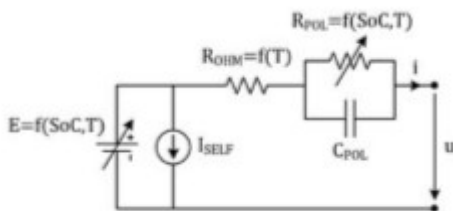


Figure 3.11: Equivalent circuit of battery

3.7.1.2 model for Electric double-layer capacitors:

The EDLC model is gotten from MathWorks in the SunPower apparatus reserve of Simulink. This model is interpretive thinks about self-discharge, non-linear, conveys the yield voltage using a Stern condition, and is likely endorsed in. A business EDLC cell from Maxwell Technologies was used for all of the examinations performed. EDLC was picked. Temperature dependence isn't fused into the electric twofold layer capacitor. Temperature dependence has not been consolidated into the EDLCs model for three reasons. To begin with, it isn't particularly material for the inspirations driving this examination Furthermore, EDLCs are less delicate to temperature than batteries. Thirdly, it was acknowledged that temperature rises in batteries were greater than in EDLC.

3.8 Simulation of Energy Storage System:

Table 3.6: The parameters of Energy Storage System

SL NO:	Parameters	Value
1	$N_{SB}-N_{PE}$	185
2	$N_{P-ac} N_{S-ac}$	570
3	Li ion battery	80%
4	Li ion battery initial SOC	1
5	Super capacitor En.Pmax /W	0.25,200
6	Li ion battery En,Pmax/W	10,200
7	super capacitor initial SOC	0.94

Table 3.7 Control values of hybrid energy system:

Sl no	Parameters	value
1	$P_{dish-high-limit}(x1)$	$N_{SB} N_{PB} \cdot C_{COL} I^D_{CAL-Bat}$
2	$P_{dish-low-limit}(x2)$	0
3	$Q_{SC-dish-high}(X3)$	0.81
4	$Q_{SC-dish-low}(X4)$	0.42
5	$P_{char-high-limit}(x5)$	$0.05N_{SB} N_{PB} \cdot C_{COL} I^D_{CAL-Bat}$
6	$P_{char-low-limit}(x6)$	0

7	$Q_{st-char-high}(x7)$	0.97
8	$Q_{st-char-low}(x7)$	0.94
9	$K_{p1}(x9)$	0.08
10	$T_{IS}(X10)$	0.02

3.9 Simulation of HESS applied to electric vehicles:

The amusement model of the HESS associated with a common vehicle driving cycle depends on MATLAB/Simulink execution of framework. The parameters of amusement framework are shown in Table 3.5.

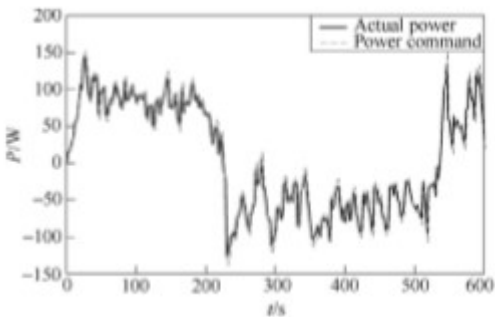


Figure 3.12: Power command and actual power

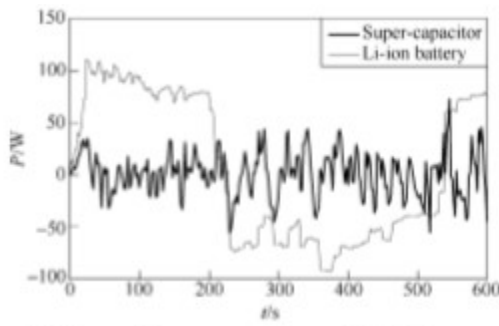


Figure 3.13: Graph Diagram Li-ion battery and super-capacitor

Table 3.5 Simulation system specification:

SL NO	PARAMETERS	VALUES
1	DC side voltage	$V_{dc}=300$
2	Switching frequency /KHZ	$F_N=15$
3	C_{DC}/UF	4400
4	Sampling time	$T_N=5$
5	$L1/MH$	10.12

6	L2/UH	580
7	M/UH	58
8	Rated voltage of the super capacitor/V	$V_{UC-com}=125$
9	Rated voltage of the battery pack	$V_{batt-com}=144$

The load current has almost no ripple.

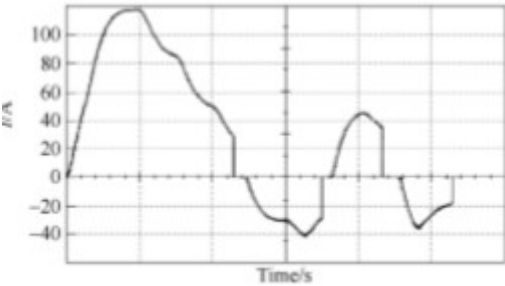


Figure 3.14: HESS applied on electric vehicles Battery current

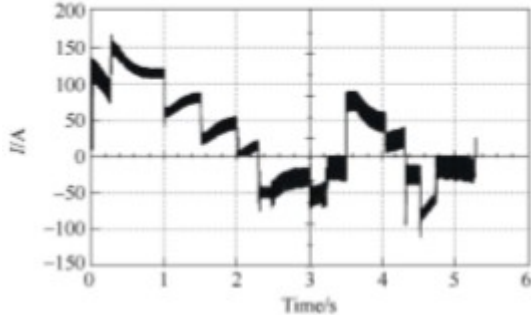


Figure 3.15: HESS applied on electric vehicles Super-capacitor current

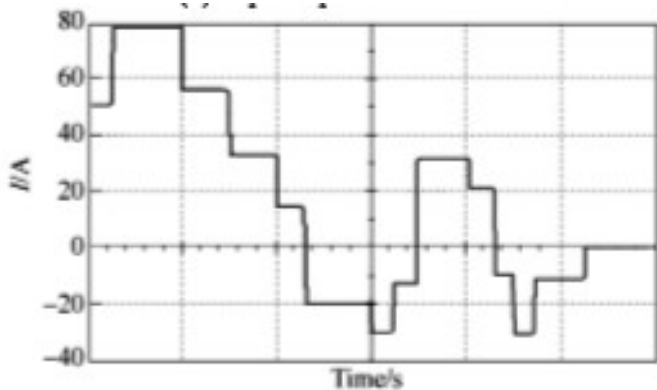


Figure 3.16: HESS applied on electric vehicles Load current

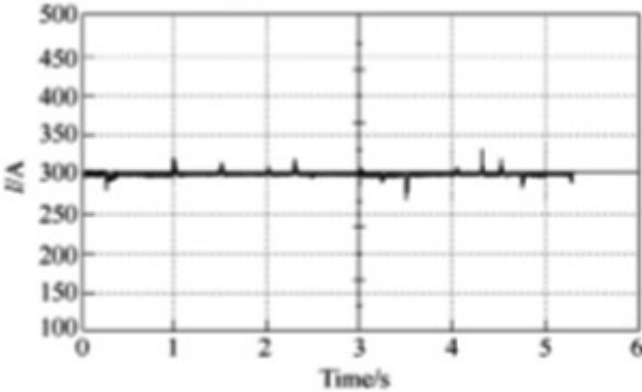


Figure 3.17: HESS applied on electric vehicles Load voltage

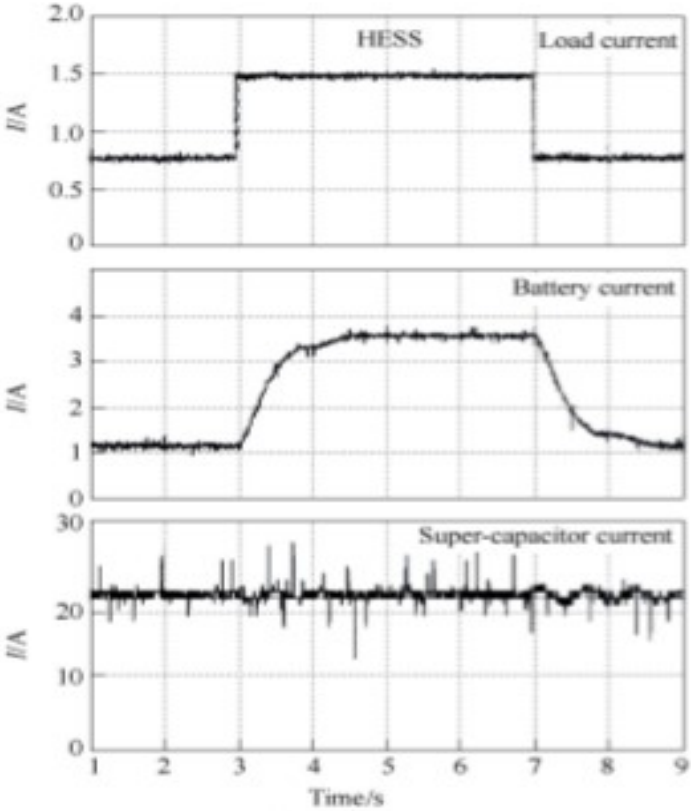


Figure 3.18: HESS applied on electric vehicles with super capacitor

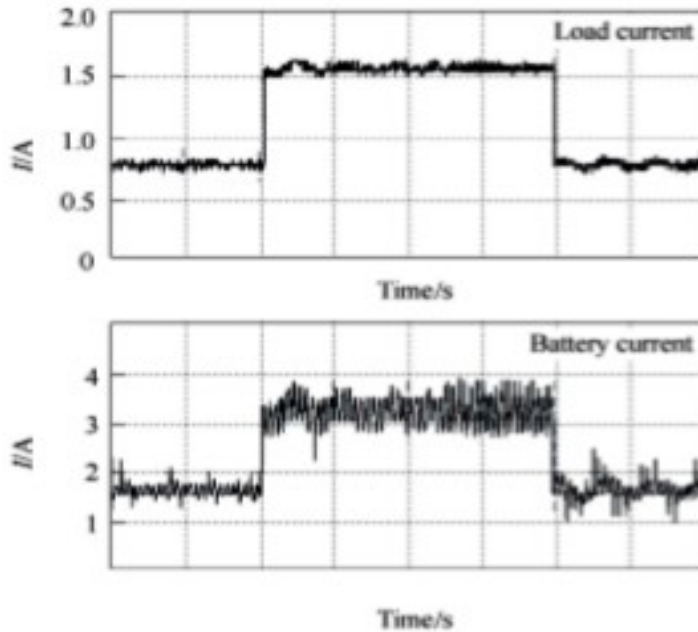


Figure 3.19: HESS applied on electric vehicles without super capacitor

Figure 3.19 exhibits the limit of the HESS in light of the increasing speed and braking mode of vehicles. For vitality stockpiling frameworks with ultra-capacitors, when $t=3$ of battery current is smooth, the load step ups, and finishing a moderate controlled, at that point, the super-capacitor more than better voltage and high-current discharge is offset at 20V which the general capriciousness is under 5%; When $t=7$ the store set down, super-capacitor recovered the braking vitality, as ought to be self-evident, the super-capacitor current is negative. For vitality stockpiling framework without super-capacitors, the battery pack as a lone stockpiling is accountable for the set change in the load and has high difference and swell in current, which will be decreasing the battery life.

CHAPTER 4

IMPLEMENTATION AND RESULT

4.1 Introduction to ANN:

Fake neural frameworks are the appearing of the human character with the most clear definition and building squares are neurons. There are around 100 billion neurons in the human cerebrum. Each neuron has an alliance point some spot in the extent of 1,000 and 100,000. In the human character, data is taken care of so as to be circumnavigated, and we can remove more than one bit of this data when fundamental from our memory in equal. We are not worked up when we express that a human character is incorporated an enormous number of, noteworthy equal processors. In multi-layer counterfeit neural frameworks, there are in like way neurons set along these lines to the human character. Each neuron is connected with different neurons with express coefficients. Amidst preparing, data is spread to these connection communities with the target that the framework is found.

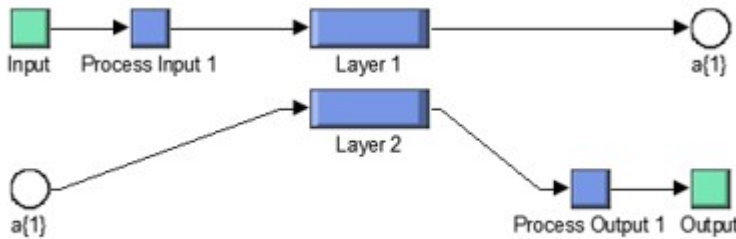


Figure 4.1: Artificial Neural Network layer network

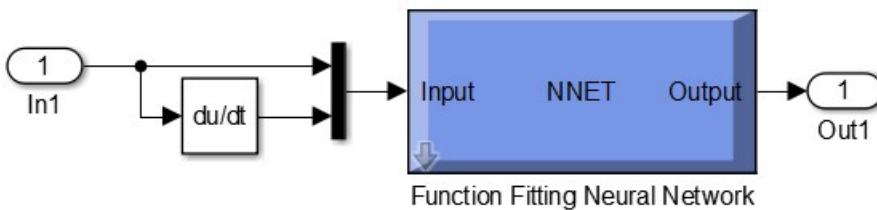


Figure 4.2: ANN Subsystem

The framework design has a data layer, secured layer (there can be multiple) and the yield layer. It is in like way called MLP (Multi-Layer Perceptron) considering the different layers. The secured layer can be viewed as a "refining layer" that distills a touch of the gigantic points of reference from the wellsprings of data and passes it onto the going with layer to see. It makes the framework quicker and valuable by seeing just the basic data from the wellsprings of data disregarding the repetitive data.

4.1.1 Advantages of Artificial Neural Networks:

- Putting away data all things considered framework: Information, for example, in standard arrangement PC ventures is taken care of with everything taken into account framework, not on a database. The vanishing of a few snippets of data in a single spot doesn't shield the framework from working
- Ability to work with lacking learning: After ANN setting up, the information may pass on yield even with inadequate data. The loss of execution here relies on the significance of the missing data.
- Having change in accordance with internal disillusionment: Corruption of at any rate one cells of ANN doesn't shield it from conveying yield. This segment makes the frameworks imperfection open minded.
- Having a hovered memory: In requesting for ANN to be able to learn, it is basic to pick the perspectives and to support the framework as showed by the ideal yield by displaying these counselors for the framework. The framework's prospering is really comparing to the picked cases, and if the occasion can't be appeared to the framework in the aggregate of its perspectives, the framework can make bogus yield.
- Gradual debasement: A framework coordinates after some time and experiences relative pollution. The framework issue doesn't quickly break down right away
- Parallel preparing limit: Artificial neural frameworks have numerical quality that can

perform more than one work in the interim.

4.1.2 advantage of ANN:

- Putting away information in general framework: Information, for instance, in standard composing PC programs is taken care of all in all framework, not on a database. The evaporating of a few bits of information in a solitary spot doesn't shield the framework from working.
- Ability to work with insufficient learning: After ANN setting up, the data may convey yield even with divided information. The loss of execution here depends upon the importance of the missing information.
- Having adjustment to non-basic disappointment: Corruption of at any rate one cells of ANN doesn't shield it from creating yield. This segment makes the frameworks lack lenient.
- Having a scattered memory: In demand for ANN to have the alternative to learn, it is essential to choose the points of reference and to teach the framework according to the perfect yield by showing these advisers for the framework. The framework's flourishing is direct relating to the picked models, and if the event can't be appeared to the framework in the sum of its perspectives, the framework can make bogus yield
- Gradual degradation: A framework moderates after some time and encounters relative debasement. The framework issue doesn't quickly expend immediately.
- Ability to make AI: Artificial neural frameworks learn events and choose decisions by commenting on similar events.
- Parallel taking care of capacity: Artificial neural frameworks have numerical quality that can perform more than one occupation meanwhile.

4.1.3 ANN and PI Controller:

A fake neural net is an information dealing with perspective whose working resembles

the working of natural tangible frameworks. The key part of a fake neural framework is the novel structure of its information dealing with system. This structure includes a gigantic number of significantly interconnected taking care of enlisting segments that function as one to deal with express issues. Fake neural frameworks is associated with an extending number of authentic issues of critical unusualness. They are dealing with issues that are absurdly multifaceted for standard progressions or those sorts of issues that don't have an algorithmic course of action.

4.1.4 Comparison of ANN and PI:

The ANN is extraordinarily improved than pi controller considering the way that ANN is a reasonable instrument for exceedingly nonlinear system. With the presence of quick PC structure, there is progressively extended eagerness for the examination of nonlinear system. Neuro control figuring is generally completed for the application to mechanical systems and moreover some headway has occurred in methodology control structures. Strategy Control systems are as often as possible nonlinear and difficult to control exactly. Their dynamic models are more difficult to decide than those used in flying or robotized control, and they will as a rule change in a fanciful way.

4.1.5 Comparison techniques for pi controller or ANN:

The relationship frameworks pi controller or ANN are Unified Shunt Series Compensator. The USSC is a working channel (AF) and it compensates the responsive force, sounds in both the voltage and current realized by loads. The USSC uses two back to back related IGBT based voltage source inverters (VSIs) with a commonplace dc transport. One inverter is related in game plan and the other one is placed in shunt with the store. The shunt inverter fills in as a current source and it compensates the current sounds. The plan inverter fills in as a voltage source and it helps in compensating the voltage music. Past works displayed a control philosophy for shunt dynamic channel with PI control. By then, this control procedure was loosened up to develop the two controllers for shunt and game plan dynamic channels.

4.2 IMPLEMENTATION:

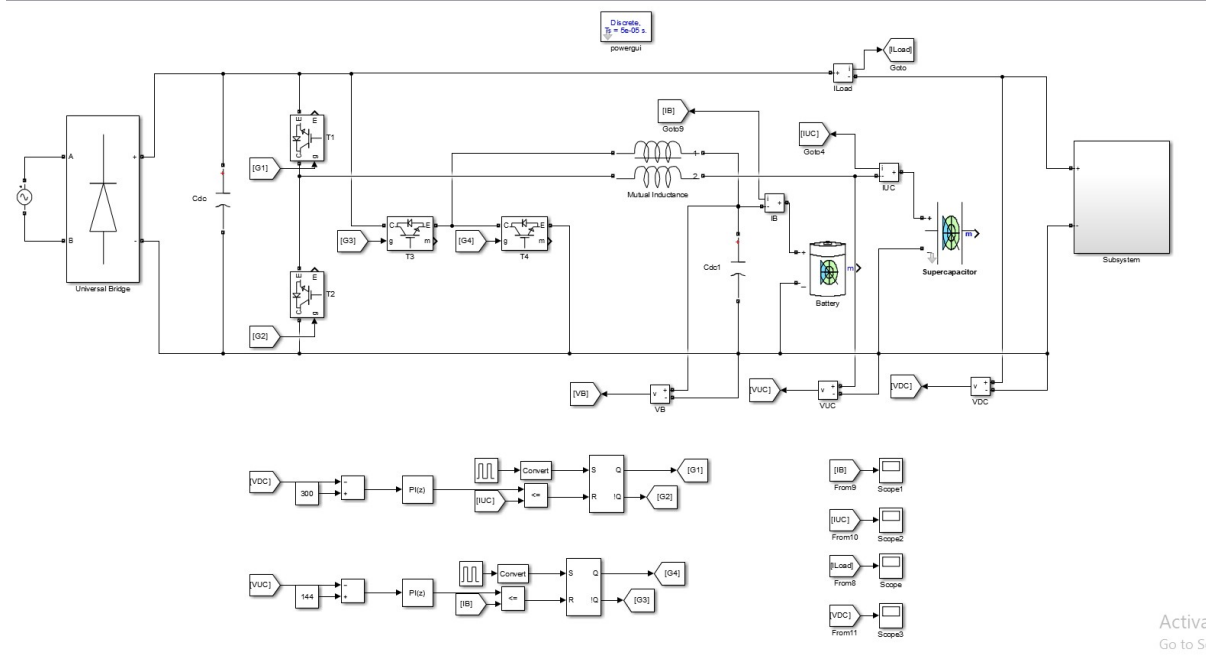


Figure 4.3:Hybrid energy storage system applied to electric vehiclesin PI model

The above figure shows the Hybrid vitality framework applied to electric vehicles in PI model, it comprising of an extension rectifier super capacitor battery and sub framework, here we are including the corresponding fundamental controller.

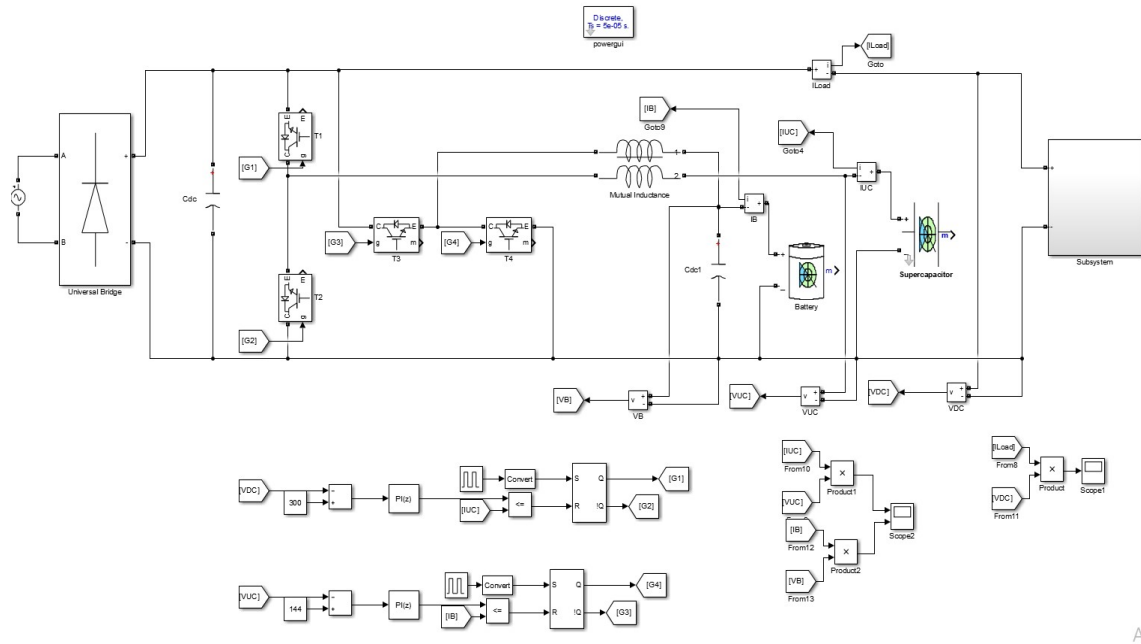


Figure 4.4: Hybrid energy storage system applied to electric vehicles in PI model and power command

The figure 4.4 shows the HESS applied to electric vehicles in PI model and force order it comprising of scaffold circuit super capacitor battery a sub framework, here we are including the force order additionally it will give the productive yield.

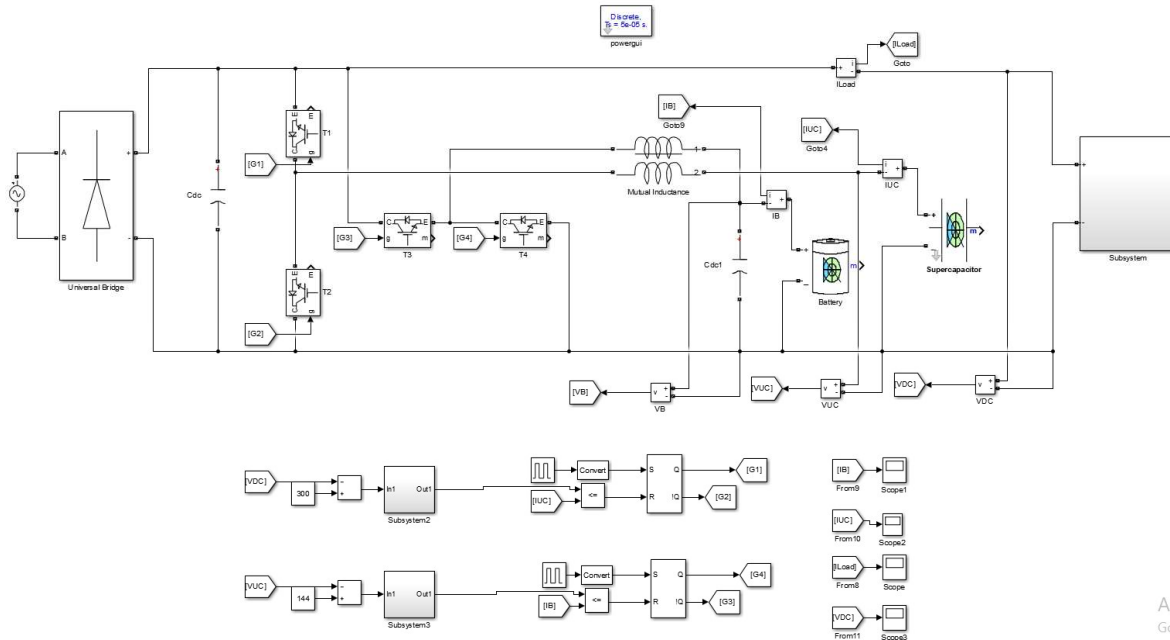


Figure4.5:Proposed Hybrid energy storage system applied to electric vehicles in ANN

The above figure shows the Proposed Hybrid vitality storage framework applied to electric vehicles in ANN, here we are utilizing the artificial neural network the ANN having numerous points of interest contrasted with PI.

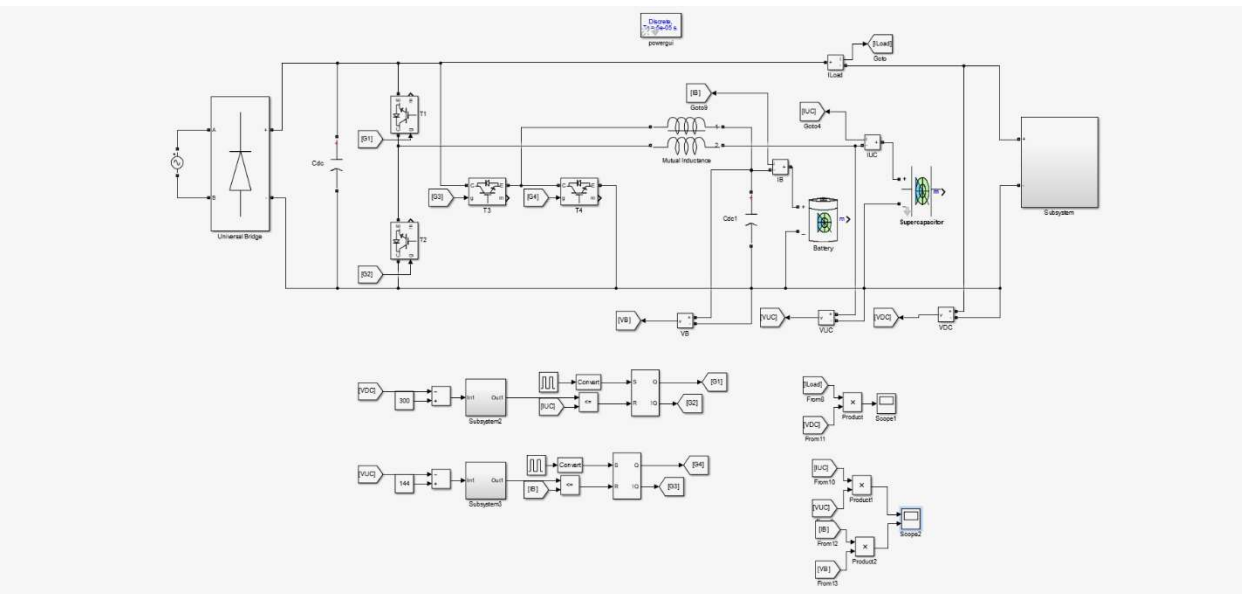


Figure 4.6: proposed hybrid energy storage system applied to electric vehicles in ANN

4.3 RESULT:

Table 4: Comparison table of THD of PI controller and ProposedANN

SL NO:	SIGNAL NAME	THD in PI techniques	THD in proposed ANN techniques
1	IB	109.85	80.59
2	IUC	76.48	66.00
3	Power Load VDC	1290.27	1290.27
4	Power Battery	80.31	77.13
5	Power UC	80.31	77.05

The table 1 shows the Comparison table of THD of PI controller and ANN. here we can see the distinctive boundary esteem in THD in PI methods and THD in ANN procedures. What's more, the boundaries are battery current, ultra-capacitive current, power load in PI, power battery and force UC values are shown in table. The low worth we have get in v contrast with THD in PI strategies.

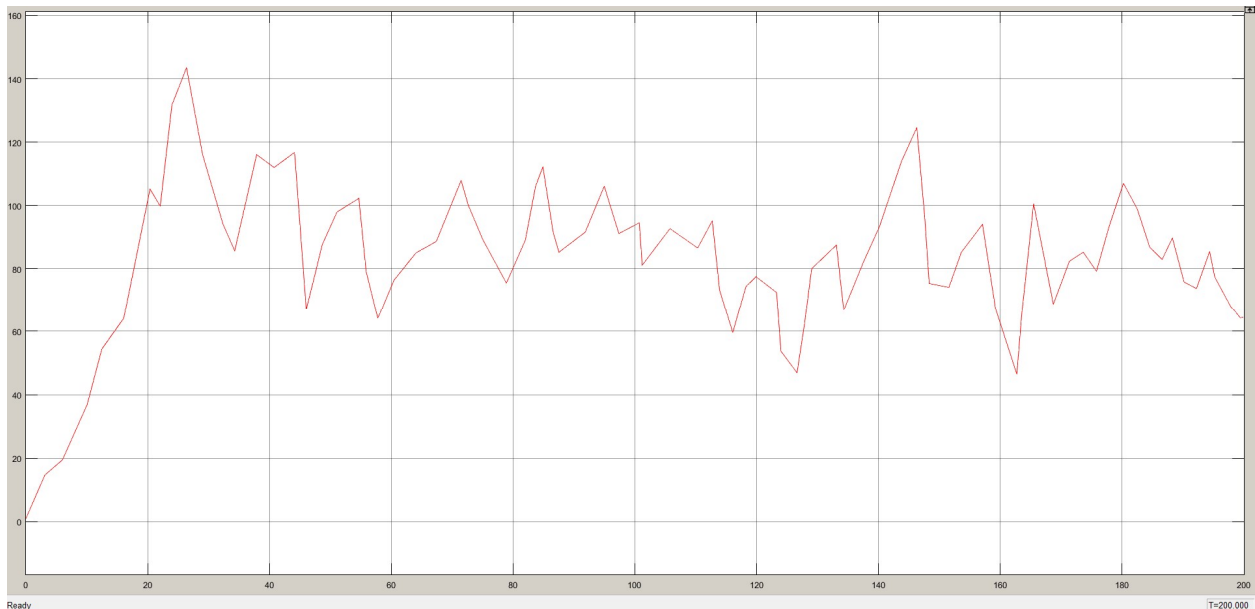


Figure 4.7: Power command and actual power of HESS applied on electric vehicles

The above figure 4.7 shows the force order and real force proposed hybrid vitality storage framework. Here the chart shows the force order and real intensity of the framework, the force variety is begun to zero and the high worth 150 w the 0 to 100 t/s it become elevated level.

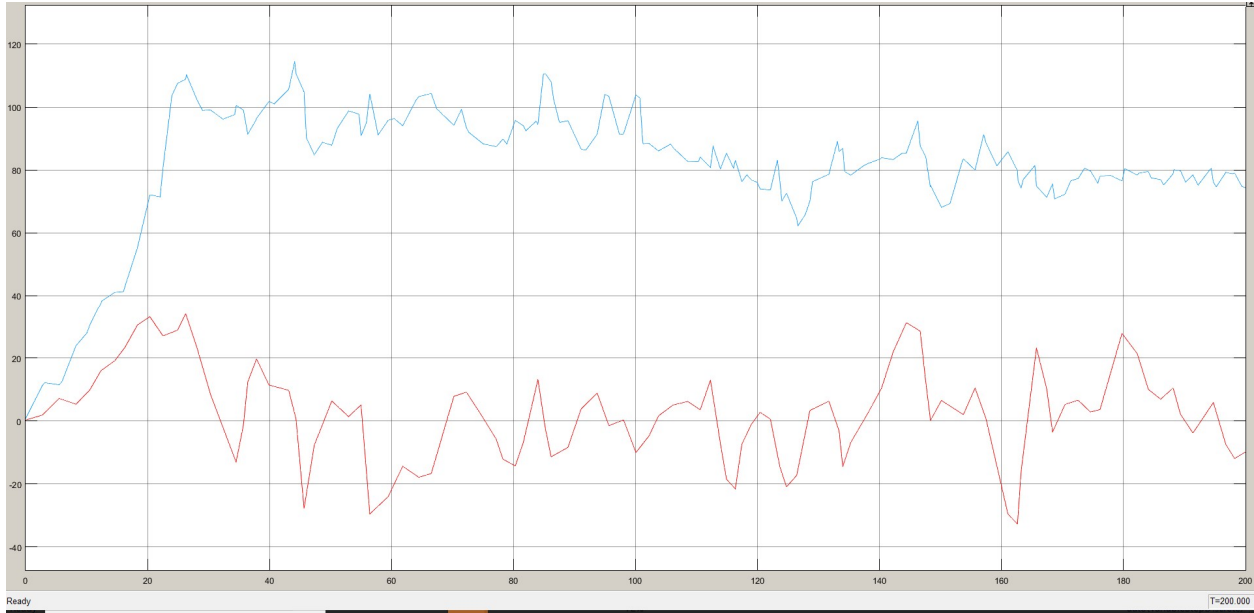


Figure 4.8: super-capacitor and Li-ion battery Power

The above figure is the waveform of Power of the super-capacitor and Li-particle battery HESS applied on electric vehicles here contrasting the intensity of li-particle battery and super capacitor, the li-particle battery having high force variety in power contrasted with super capacitor.

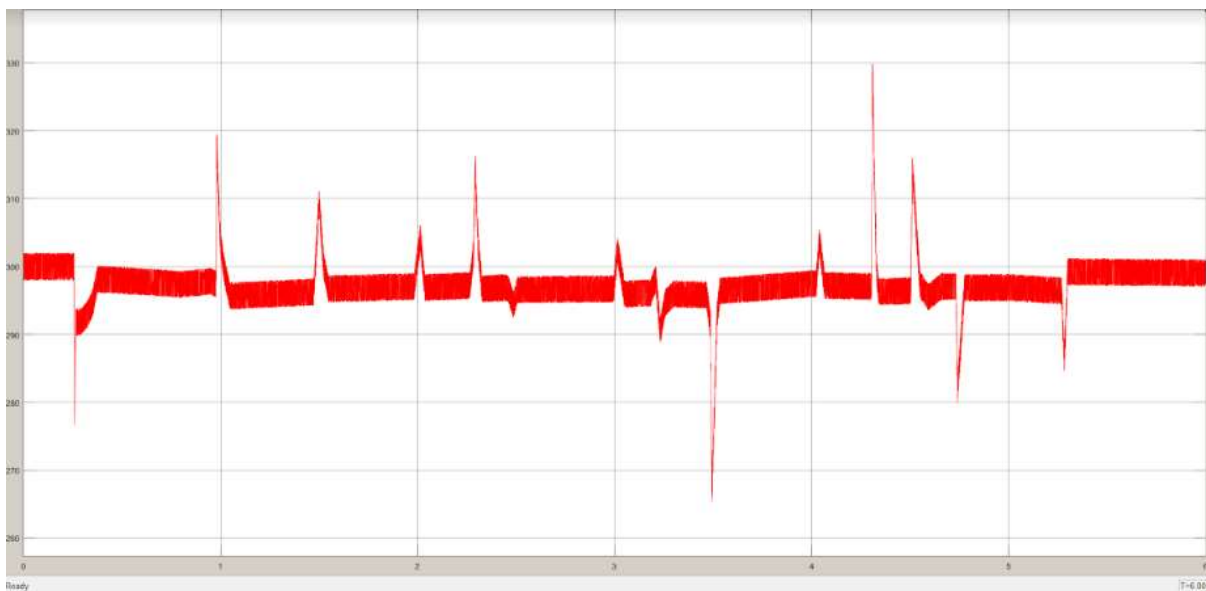


Figure 4.9: Graph diagram of PI VDC

The above figure 4.9 shows the graph diagram of DC voltage in PI controller circuit.

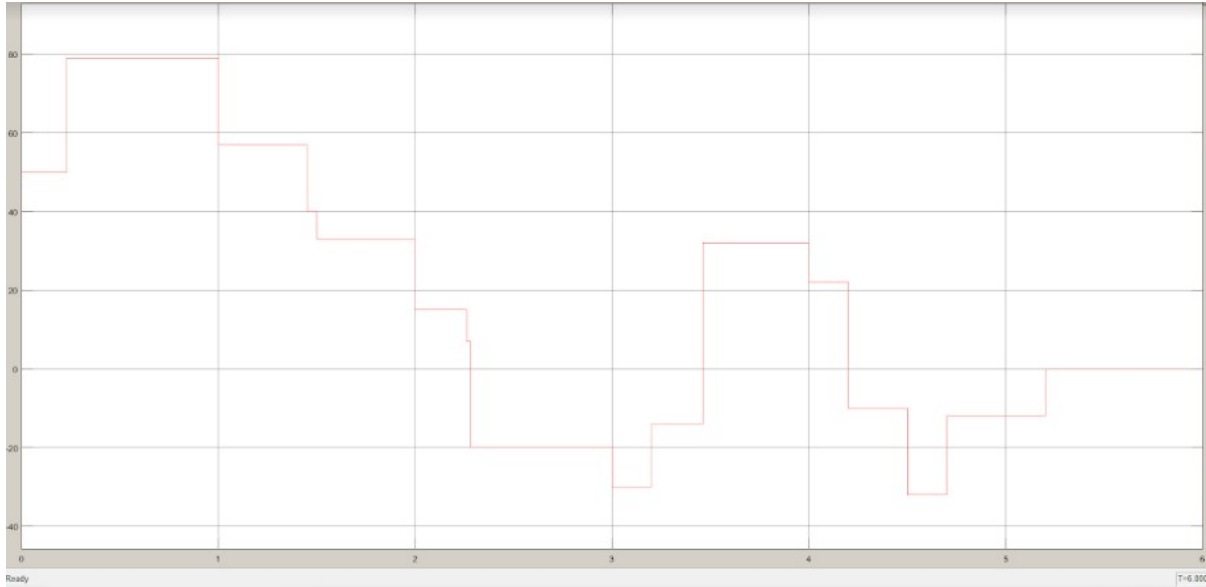


Figure 4.10:Graph diagram of PI Loads

The above figure 4.10 shows the graph diagram of loads in PI controller.

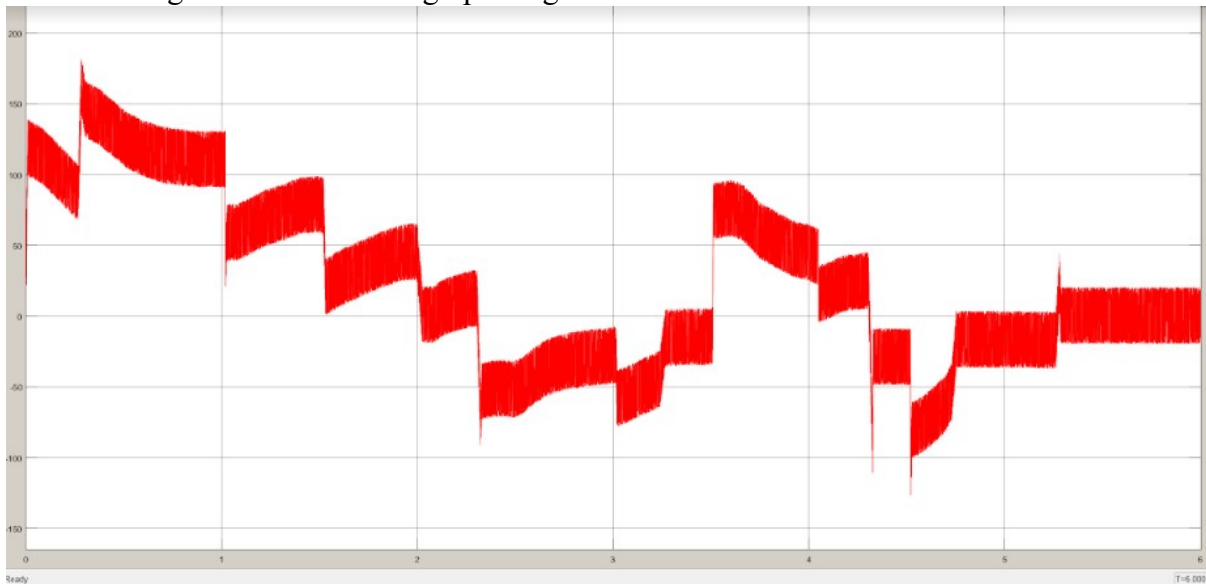


Figure 4.11:Graph diagram of PI IUC

The above figure 4.11 shows the graph diagram of ultra-capacitor current (IUC) in PI controller. it has hundreds of times more electrical [charge quantity](#) than a normal capacitor current.

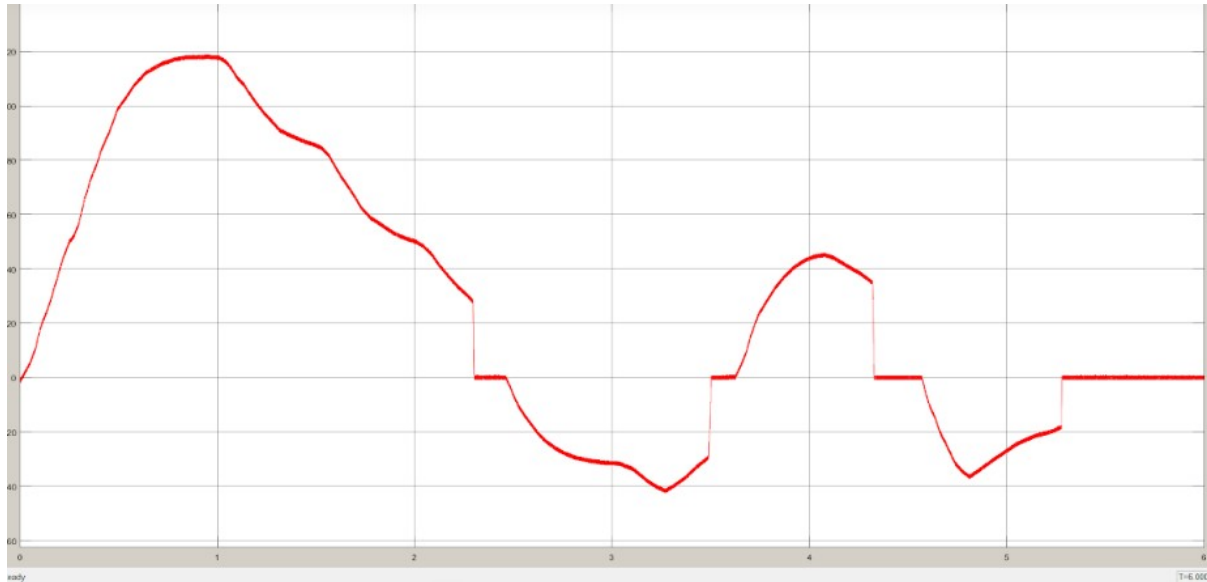


Figure 4.12:Graph diagram of PI IB

The above figure 4.12 graph diagram shows the battery current (IB) in PI controller.



Figure 4.13:Graph diagram of THD ANN VDC

The above figure 4.13 shows the graph diagram of THD ANN VDC. Here we have the DC voltage in artificial neural network-based circuit. Here we can see the total harmonic distortion (THD).

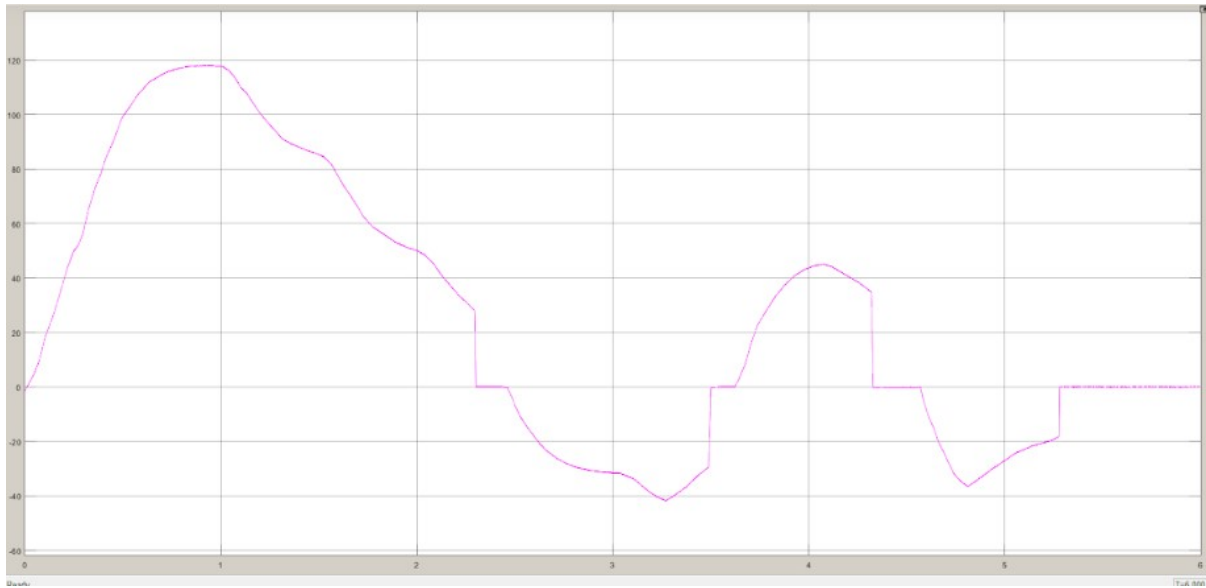


Figure 4.14:Graph diagram of THD ANN IB

The above figure 4.14IS graph diagram of THD ANN IB. here we can see the battery current in ANN based circuits.



Figure 4.15:Graph diagram of THD ANN LOAD

The above figure 4.15 graph diagram of THD ANN LOAD. Here graph shows the load current in ANN based circuit.



Figure 4.16: Graph diagram of THD ANN IUC

The above figure 4.16 is the graph diagram of THD ANN IUC. In this graph diagram, it shows the ultra-capacitor current in an ANN-based circuit.

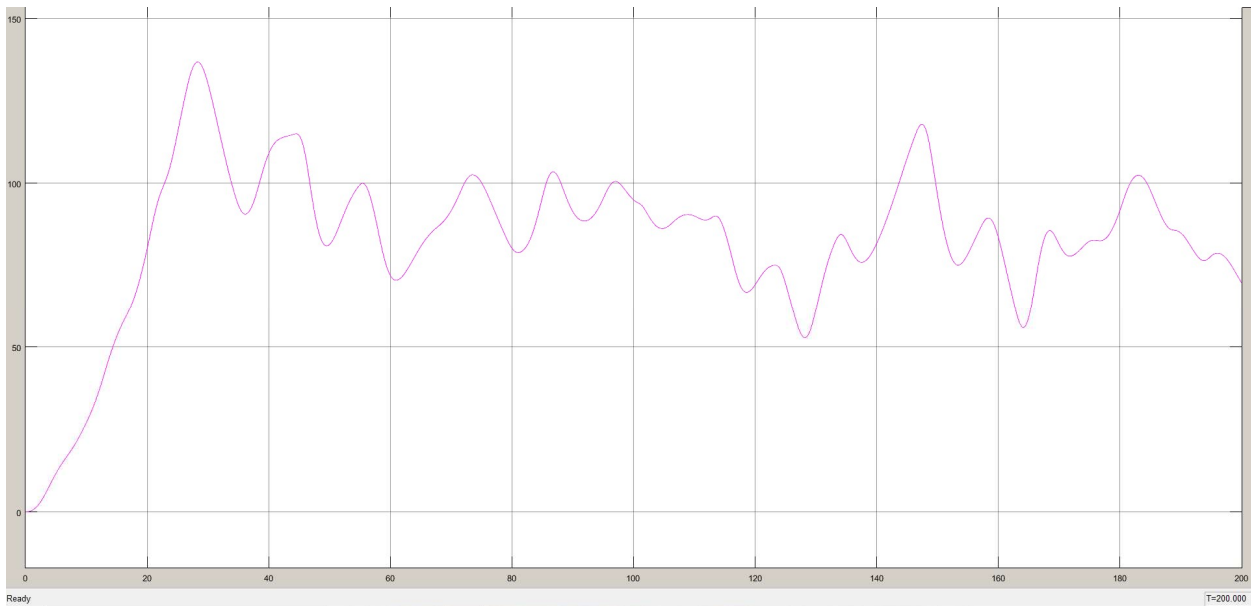


Figure 4.17 Graph diagram of THD ANN power command and actual power

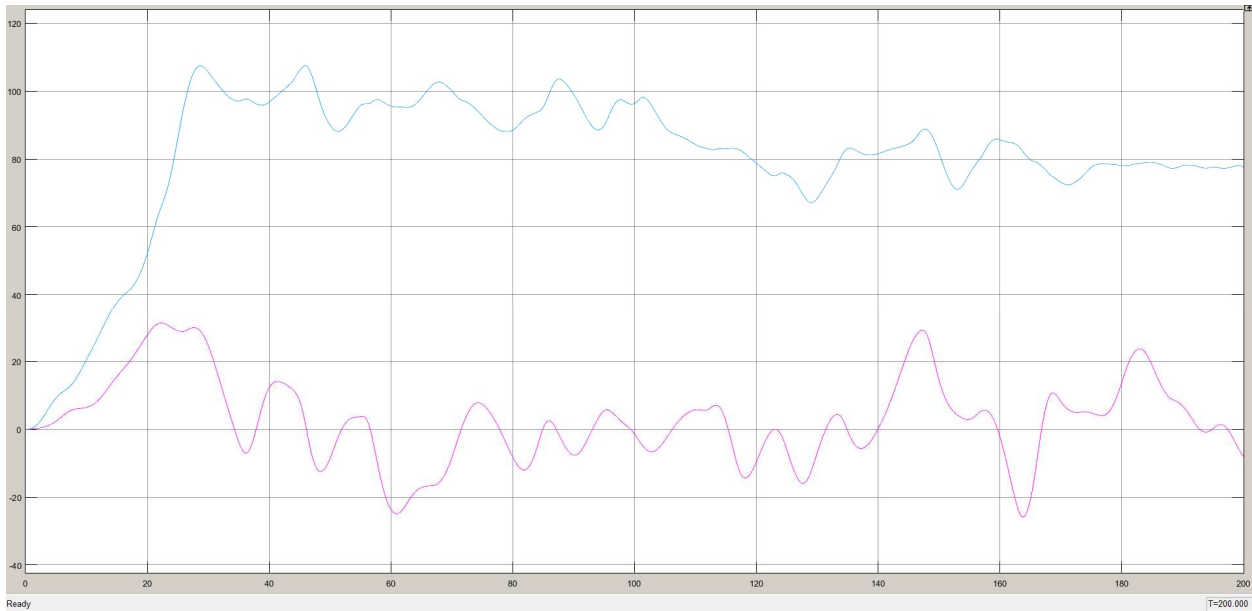


Figure 4.18 Graph diagram of THD ANN power of the supercapacitor and li-ion battery
 The above graph diagram shows the THD ANN power of the supercapacitor and li-ion battery.

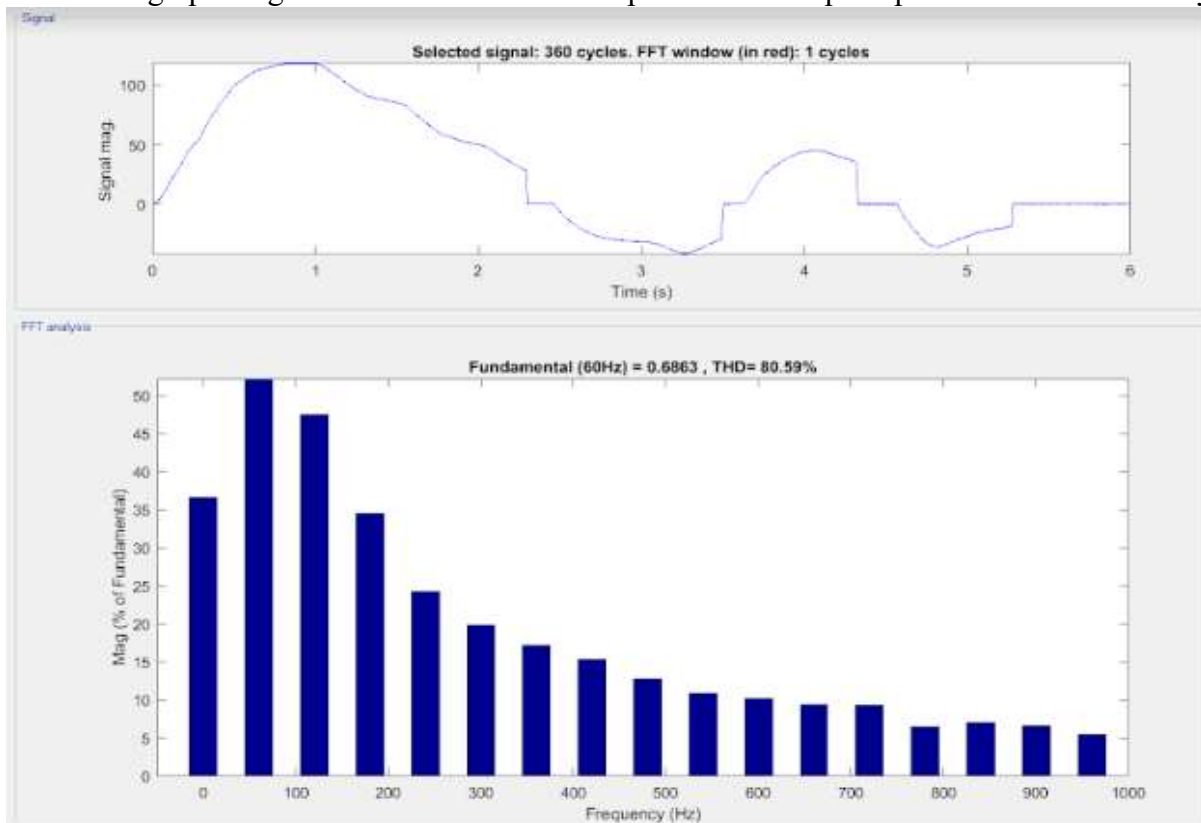


Figure 4.19: Graph diagram of IB in ANN
 The above figure 4.16 shows the graph diagram of IB in ANN. here we can see the total harmonic distortion of ANN circuits. Here we can see the 80.59% of THD that means total harmonic distortion.

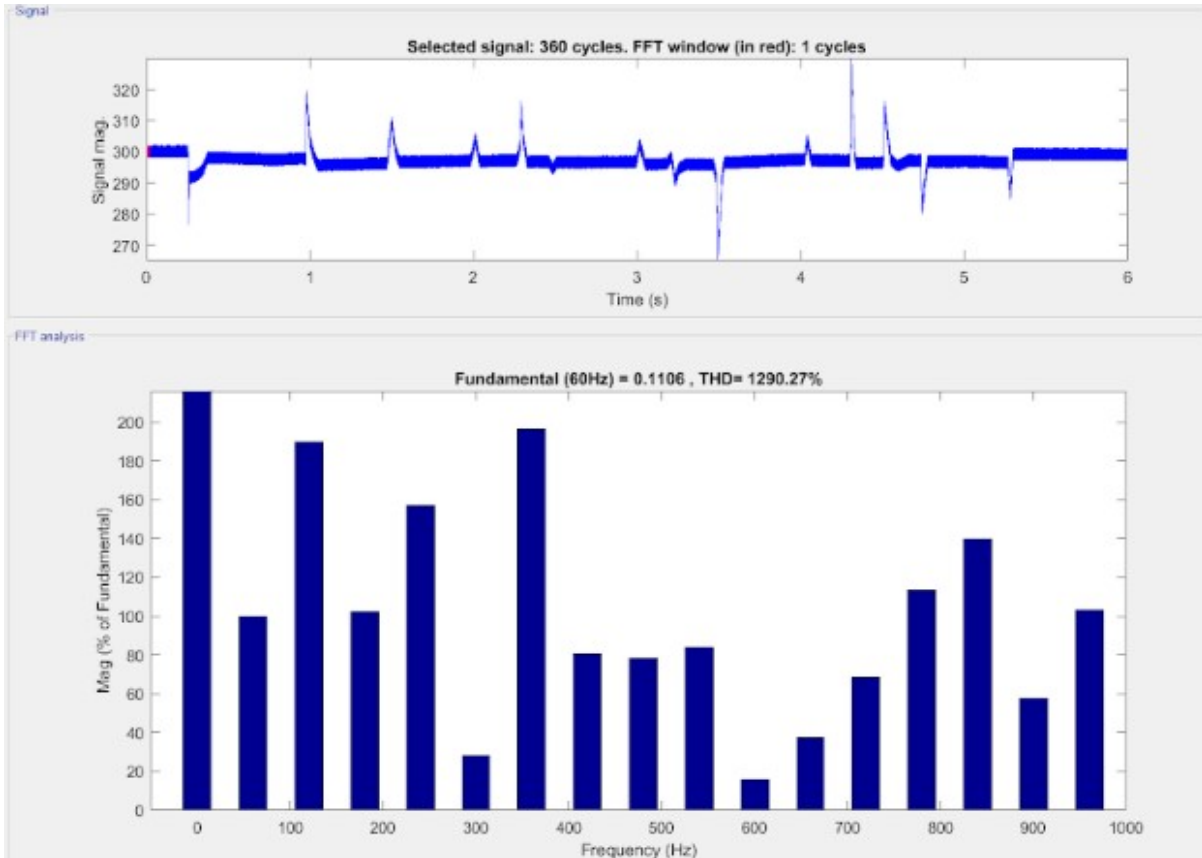


Figure 4.20:Graph diagram of ANN VDC

The above figure 4.20 shows the graph diagram of VDC. The diagram shows the total harmonic distortion in ANN circuit (display from MATLAB). here we can see the total harmonic distortion 1290% is in this graph.

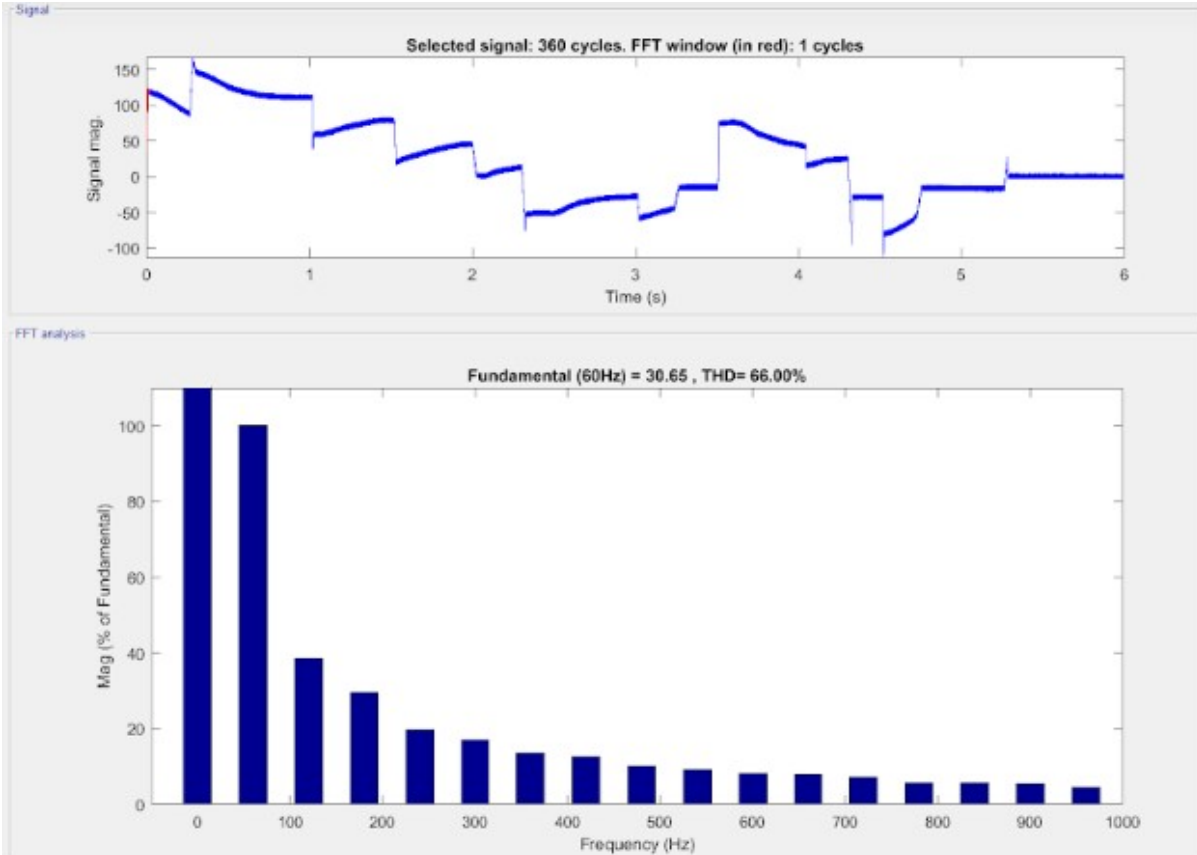


Figure 4.21:Graph diagram of IUC in ANN.

The figure 4.21 shows the graph diagram of ultra-capacitor current in proposed system. Here we can see the total harmonic distortion of ANN based proposed system. In the graph shows the total harmonic distortion 66%.

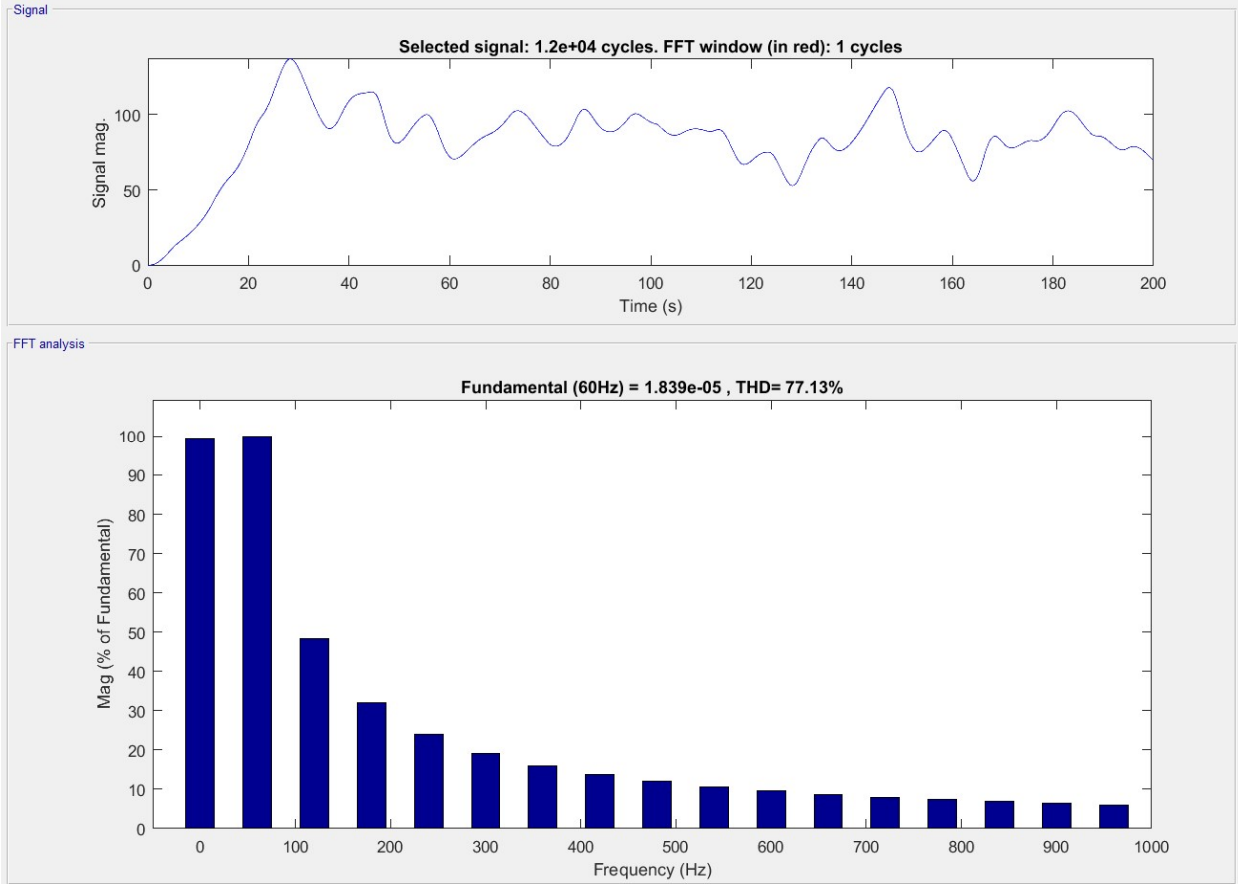


Figure 4.22: Graph diagram of ANN power command and actual power

In figure 4.22 shows the Graph diagram of battery power ANN. here we can see the ANN of THD (Display From MATLAB). The total harmonic distortion is 77.05%.

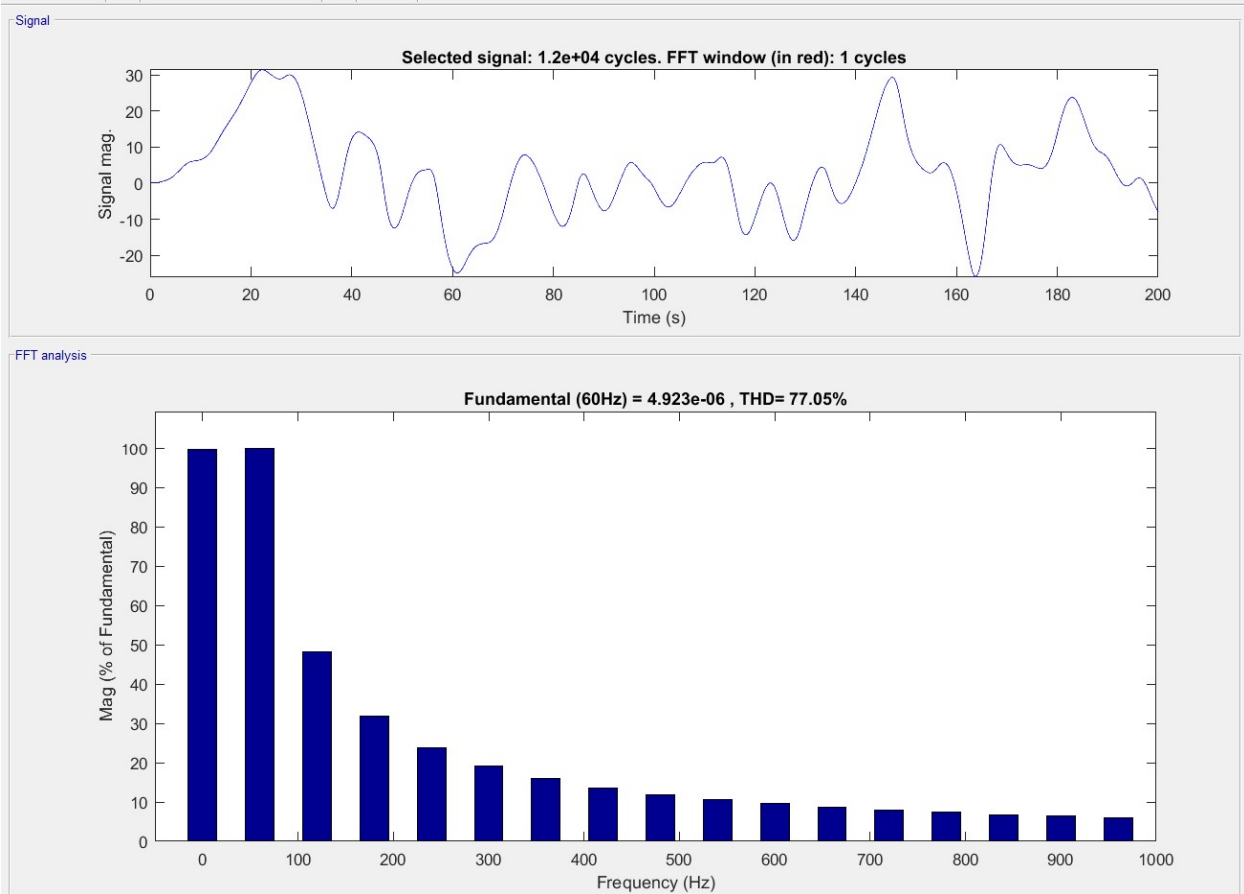


Figure 4.23: Graph diagram of ANN power of the supercapacitor and li-ion battery

In figure 4.23 shows the graph diagram of power UC ANN. here we can see the ANN of THD (Display From MATLAB).

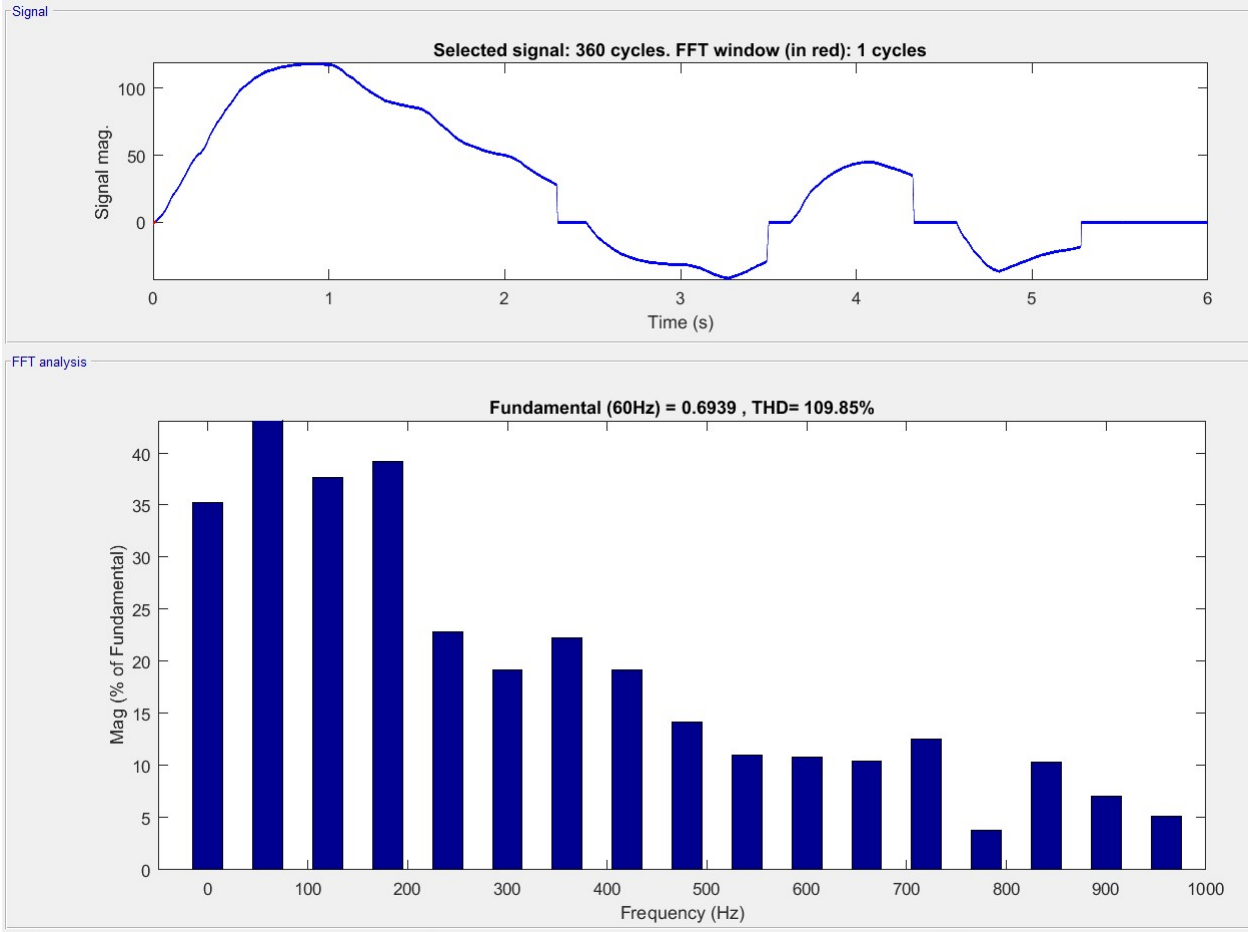


Figure 4.24 PI THD Battery Current

The above figure 4.24 shows the Battery Current pi controller. The total harmonic distortion is 109.85%.

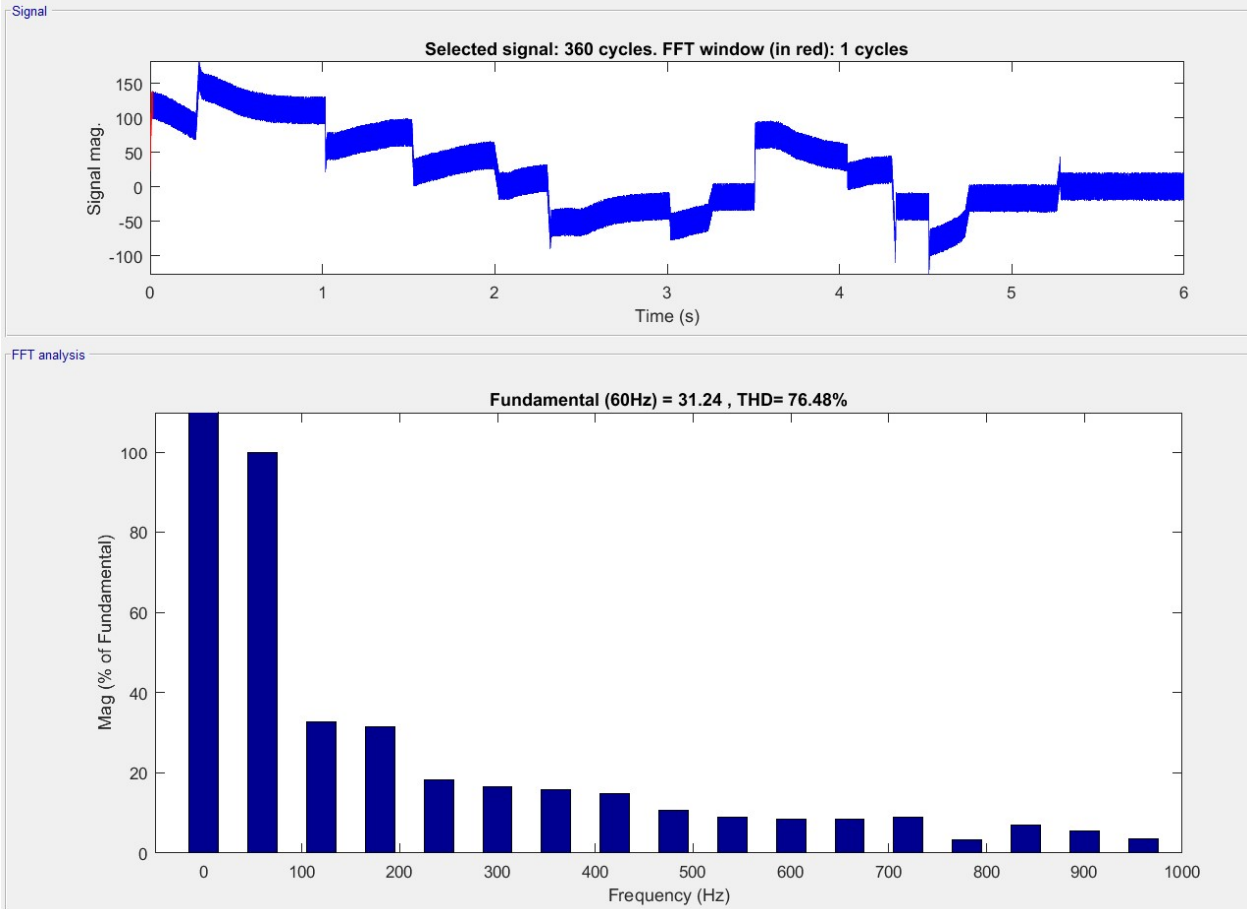


Figure 4.22 PI THD Supercapacitor current

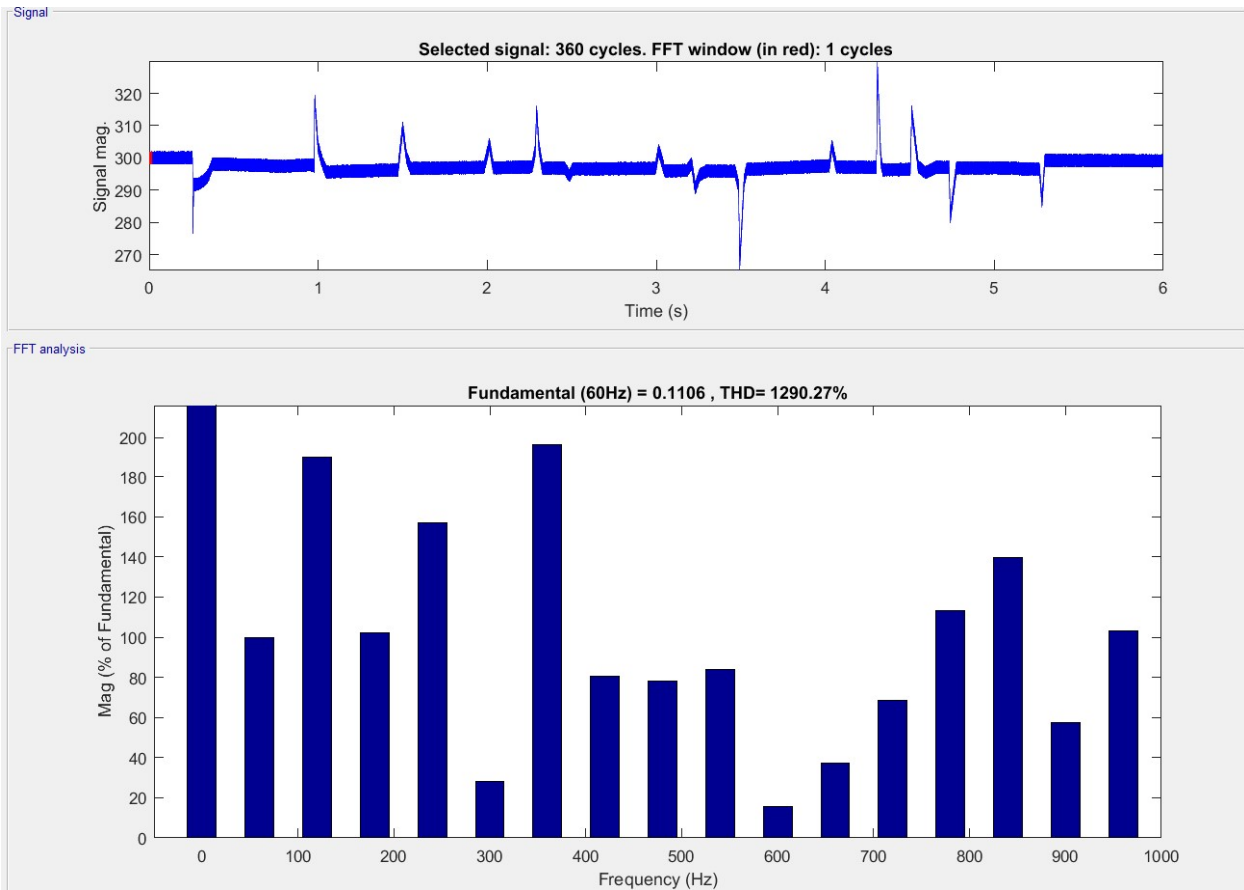


Fig 4.23 PI THD load voltage

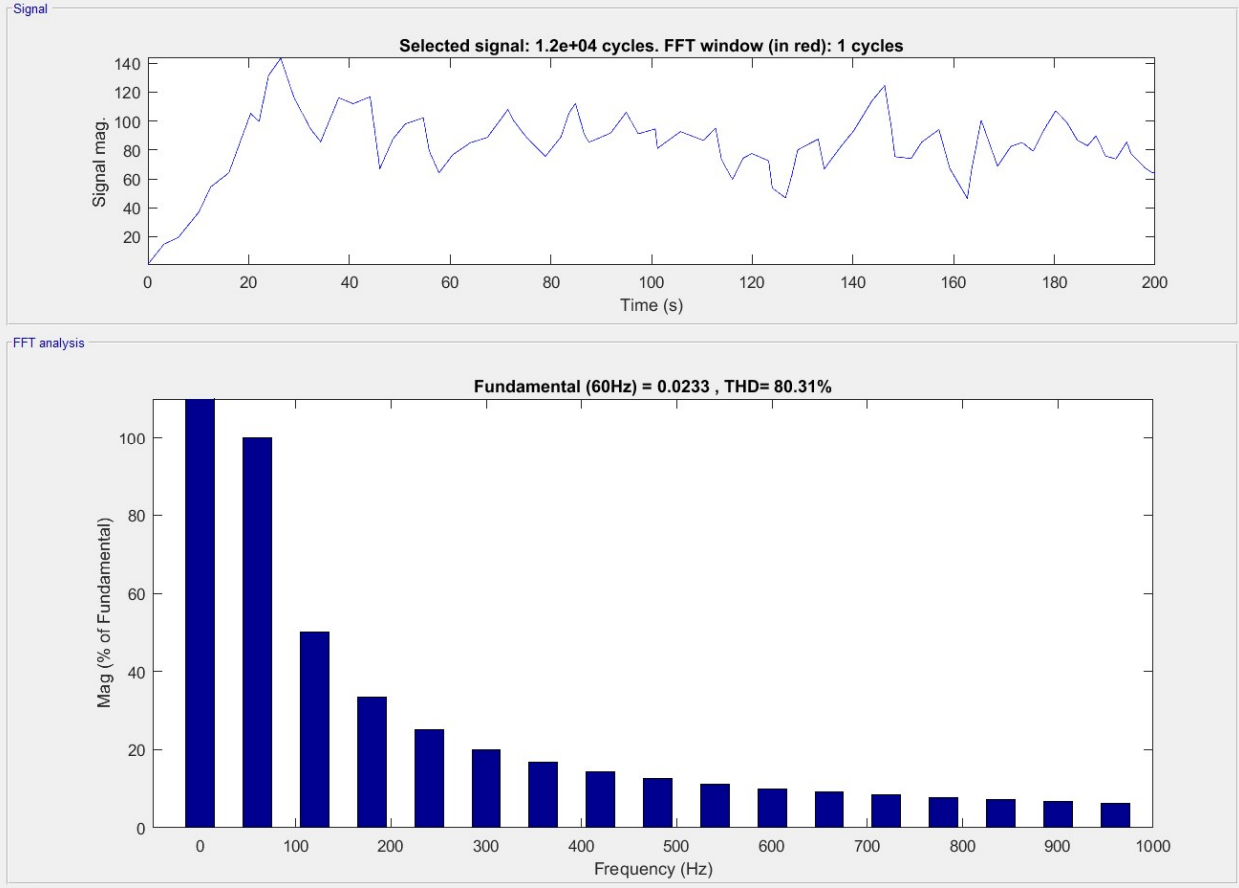


Fig 4.24 PI THD power command and actual power

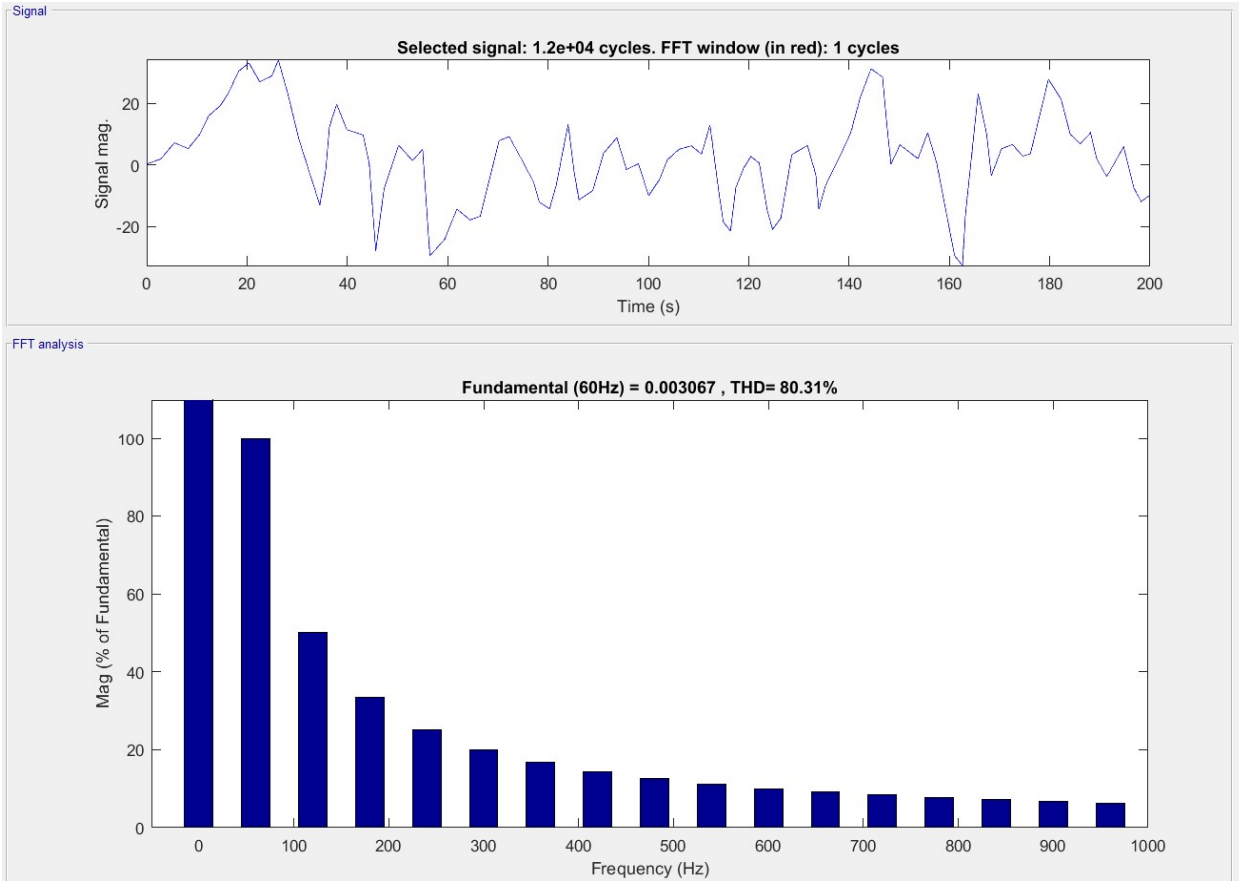


Fig 4.25 PI THD power of the super capacitor and li-ion battery

CHAPTER 5

CONCLUSIONS AND FUTURE SCOPE

5.1 CONCLUSIONS:

Consequently, contemplated and executed hybrid vitality storage framework in electrical vehicle utilizing artificial neural network. Another hybrid imperativeness accumulating structure for electric vehicles is organized dependent upon a Li-i battery control dynamic restriction rule-based HESS essentialness the chairmen and another bi-directional DC/DC converter with Artificial Neural Network. The system is showed up contrastingly comparable to ordinary crossbreed imperativeness accumulating structure, indicating it has essential supported perspective of diminished counts and gives consistent voltage to the electric vehicle. Moreover, the swell of yield current is decreased and thusly the life of battery is expanded.

5.2 FUTURE SCOPE:

As of late, expanded emanations guidelines and a push for less reliance on petroleum derivatives are factors that have lured a development in the piece of the pie of elective vitality vehicles. Promptly accessible vitality stockpiling frameworks (ESSs) represent a test for the mass market infiltration of half and half electric vehicles (HEVs), module HEVs, and EVs. This is chiefly because of the mind-boggling expense of ESS accessible today. In any case, huge research endeavors are going into lessening the expense of these capacity gadgets, expanding their life expectancy, and improving their vitality thickness. This paper means to give a review of the present condition of promptly accessible battery and ultracapacitor (UC) innovations just as a look forward toward encouraging propelled battery sciences and cutting edge ESS. Vitality the executives frameworks and different battery adjusting designs are talked about notwithstanding battery state/parameter estimation and assurance components. At long last, cross breed ESSs are assessed as a relief system to the deficiencies of customary battery and UC advancements. Thought is given to the blend of cutting-edge battery sciences with UCs to depict HESS execution, which can meet and surpass the exhibition of current ESS advances.

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