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Integrated Three Phase Hybrid Cascaded MLI Fed Induction Motor Drive for Energy Management in Electric Vehicles

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Abstract: Plug in Hybrid Electric Vehicle (PHEV) requires a number of battery cells, for that these cells are connected in cascade to get the required voltage. To improve the output voltage of the driving motor we require energy storage systems like battery cells. Normally battery works based on the principle of electro chemical reaction. The difference in electrochemical reactions will cause state-of-charge (SOC) and terminal voltage imbalance between different cells. In this paper, a hybrid cascaded multilevel converter which serves both battery energy management and motor drive is proposed for hybrid EV. In the proposed topology, each battery cell can be controlled and can be connected to the circuit or to be bypassed by a half-bridge converter. All half-bridges are cascaded to output a staircase shape DC voltage. Then, an H-bridge converter is used to change the direction of the DC bus voltages to make up AC voltages. The output of the converter is algebraic sum of multilevel voltages with less harmonic content and lower dv/dt stress, which is helpful to improve the performance of the motor drives. The energy utilization ratio of batteries is improved by the individual control according to the SOC of each storage cell. The imbalance of terminal voltage and SOC can also be avoided, fault-tolerant can be easily realized by modular cascaded circuit, so the life of the battery stack will be extended. The simulation model is implemented to verify the performance of the proposed converter.
Keywords: PHEV, ESS, SOC, H-bridge converter, Multi –level Inverter (MLI).

I. INTRODUCTION

The role of energy storage system (ESS) in electric vehicles (EV) is significant. The energy storage system (ESS) contains batteries made up of lead-acid and lithium-ion. These are used because of their advantages of cost and density of energy. As this kind of batteries has a very low voltage capacity, a number of batteries are to be cascaded to reach the required voltage rating of the electric drive.These cascaded batteries differ in properties like resistance, volume, manufacturing, the architecture of cells and their usage. As we know that basic general methods to increase the voltage capacity, connect the required number of battery cells in cascade to reach the demand of voltage. In this method, while charging and discharging, the amount of current passing through them is almost equal but state ofcharge (SOC) and the voltage values are different because of the variations in the characteristics of the electro chemicals among the battery cells. There is a requirement to stop charging even one of the cells among the cascaded reaches to cutoff voltage. And also if a cell is badly damaged in these cascaded cells then the entire stack of batteries will be damaged forever. Hence screening battery cells must be adopted to decrease those difficulties and to protect cells from over discharging and over charging we require SOC equalization circuit or voltage circuit. Usually, equalization circuits are two types the very first type is in order to control the terminal voltage of stack of cells on parallel resistance. Multilevel inverters have been pulling in wide mechanical intrigue. They are seen as a charming choice remembering the ultimate objective to diminishing switch stretch. The essential typical for these converters is a yield waveform with various voltage levels. In late decades, a wide bunch of multilevel structures appeared for theevent, the fell H-connect, fair point cut, and flying capacitor. The Cascaded H-connect multilevel inverter is a notable topology and has found no matter how you look at it applications in industry, for theevent, in high power medium-voltage drives and open power pay. Most multilevel inverters have a stratagem of switches & voltage sources are capacitors.

II. MODULE CROSS BREED ELECTRIC VEHICLE (PHEV)

In recent days because of contamination and availability of the fossil fuels researchers are concentrating on alternatives like electrically driven vehicles (EDVs), including battery electric vehicle (BEV), half and half electric vehicle (HEV), and module cross breed electric vehicle (PHEV).These have taken off around the world.Over the past few years, research in the hybrid electric vehicles (HEV) development has been focused on various aspects of the design, such that the architecture, the efficiency of the engine, reduces emissions of fuel, equipment for components lighter, PE, energy-efficient engines and a high power density of the batteries. To respond to some of the aspects of the multilevel ups in cascade HEV is used in such a way as to meet the requirements of high power. Exclusion of the transformers is made possible by inverters. The multilevel inverters can easily provide the necessary power for a large electrical drive. As the number of levels increases, the wave output has synthesizedseveral steps, which produces a wave which s approach of a staircase desired curve. While several procedural points are added to the curve, the harmonic warp of the wave result diminishes, close to null, by the ascending number of levels.With the increase in a numberof stages,the voltage which can be obtained is the summation of diverse levels of voltages. The primary device of EDVs is storage batteries. So the innovation has drawn attention on consideration of battery charging current.The battery Management system (BMS), with the elements of battery displaying, state estimation of the battery, battery adjusting isone of the key focuses to ensure that the battery capacity is enhanced for the usage of the battery in EDVs.Battery displaying and state estimation are among the most mainstream themes for BMS, and this section will play amajor role in thecase of battery operation. Battery Adjusting (BA) is additionally essential in a BMS, considering the "Container Effects" for a lot of battery cells in a battery string. Firstly, battery displaying strategies will be explored including the equal circuit techniques and impedance techniques. The examination between the proposed impedance model and the deliberate impedance spectra will be appeared and investigated. Furthermore, the state estimation strategy for the battery utilized as a part of EDVs, including the condition of charge (SOC) estimation, will be examined. Mainly a novel versatile relative necessary SOC estimation technique will be proposed. Thirdly, the battery adjusting strategy will be investigated. The positive adjusting techniques and dynamic adjusting strategies will be presented. A novel adjusting topology will be proposed.stockpiling systems for car applications can be clarified from [8]Use of synergic electric power supply in HEV can be clarified from [1].Power hardware and engine drives in electric can be clarified from [2].Stable design of a Li-Ion arrangement battery can be clarified from [3].Hybrid Electric Vehicles (HEV) have series, parallel, and series–parallel configurations to enhance efficiency and better driving force.

III. HYBRID CASCADED MLI AND FUZZY CONTROLLER:

A. *Cascaded MLI*

Cascade MLIs plays a vital role in high and medium output voltage motor drive application. The MLIs uses input like flying capacitor or isolated source DC. In theexistingsystem, the flying capacitor is replaced with battery cells. Instead of directly connecting the battery cells, those can be cascaded in series combination with cascade converter. In cascade connection, H-bridge converter voltage balancing can be done by cascade battery cells. In charging and discharging process each H-bridge is used to control one of the battery cells and thereby balancing the voltage. This can also isolate control of charging and discharging.

The converter output voltage is multilevel so it is used for motor drive.The cascade topology has good fault tolerant capability with the use of modular design and it doesn’t have any limit on a number of cascade battery cells and it’s very appropriate to obtain more output voltage with less usage of batterycell voltages. When the modulation ratio of H-bridge converter will be adjustable, the balance control voltage of battery cells will be obtained. Here an Ultra capacitor combination is used in the MLI for power density problem of batteries. This ultra-capacitor combination improves the density of power. Multilevel converters with battery cells are more suitable for the battery and ultra-capacitor combination. Terminal voltage and state of charge will be balanced in battery cells by using hybrid cascaded MLI. MLI also controls the charge and discharge of cells of the batteries. The required AC output voltage will be at the load side of H-bridge to drive the Electric vehicle. In this MLI additional battery charger or inverter, themotor drive is used. The output voltage of theconverter is multilevel AC voltage. The number of multilevel AC voltage is proportional to the cascade battery cells. In order to increase the AC level, we have to increase the number of cascade batteries. The application of electric vehicle with ahigh amount of battery cells, the AC output voltage is nearly pure sinusoidal. The content of harmonics and dv/dt will be highly decreased compared with the2-level converter. In existing MLI with designed modular will realize the redundancy of fault and highest amount of reliability. The result of hybrid cascade MLI can be simulated by Matlab/Simulink.

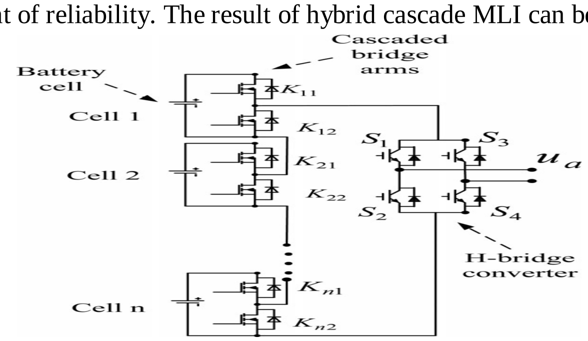

Figure 3:Single Phase Cascaded MLI

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Figure 3 shows the removed voltage balance circuit through thetransfer of energy. For each pair of battery cells, a half bridge arm and an inductance are present between them. The balance circuit has switching devices of 2*(n-2) & the no of inductance is (n-1) here n denotes battery cells quantity. For the above circuit, an extra inverter is required to amotor device with a charger is required for charging thebattery. If a 3-phase AC source with some filter inductances is connected to the output of inverter the charging of battery can also bedone by an additional control block as similar to PWM rectifier.

The voltage & recharging current can be altered by the power control of the rectifier or closed loop voltage. The proposed hybrid cascaded MLI is shown in figure 4. In this figure 4, we have 2 parts those are cascaded half bridges with battery cells and half bridge inverters. The cascaded half bridge output is a DC bus and it is connected to H-bridge DC input. Every one-half bridge makes the battery cell to be involved in voltage by passing or to produce voltage. So that the cascaded half bridges control the requirement of no of battery cells used in the circuit. This is used to produce a variable voltage at the DC bus. The purpose of using H-bridge is to change the DC voltage direction for producing AC waveforms. Hence, H-bridge contains devices in which the switching frequencies are equal to the base frequency of the desired AC voltage. The existing circuit has 2 types of power electronic devices. Firstly the low voltage devices arecascaded in half bridges to reduce the voltage ripples in the output waveform at thehigher switching frequency. Such as MOSFETs with low on state resistance. Secondly, the H-bridgecontain high voltage devices which will work at the base frequency. GTO and IGBT having high voltage capacity are used for H-bridges.

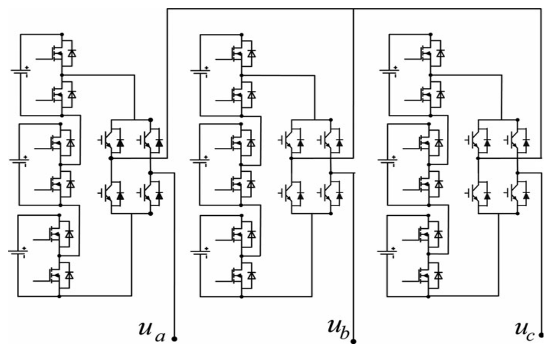

Figure 4:Three phase hybrid cascaded multilevel converter

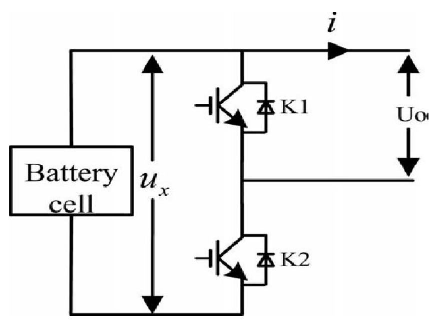

Figure 5: Output voltage and current of the battery cell

The control of the converter and voltage equalization canbe realized by a modified carrier-cascaded PWM method. The position of the battery cells in the carrierwave is determined by their terminal voltages. In the dischargingprocess, the battery cells with higher voltage are placed at thebottom layer of the carrier wave while the cells with alowervoltage at the top layer. Then, the cells at the top layer will beused less and less energy is consumed by these cells.In the proposed PWM method, the carrier arranged by terminalvoltage can realize the terminal voltage balance, while theCarrier arranged by SOC can realize the SOC balance. Since theSOC is difficult to be estimated in the batteries in practice, theterminal voltage balance is usually used. Normally, the cut-offvoltage during charge and discharge will not change in spite ofthe variation of manufacturing variability, cell architecture, anddegradation with use. So the overcharge and overdischarge canalso be eliminated even the terminal voltages are used insteadof the SOC for the carrier-wave arrangement.To reduce the *dv/dt*and EMI, only one half-bridge is allowedto change its switching state at the same time for the continuousreference voltage. Therefore, the carrier wave is only rearrangedwhen the modulation wave is zero and the rearranged carrieronly becomes effective when the carrier wave is zero. So thecarrier wave is only rearranged at most twice during one referenceac voltage cycle. If the number of the cascaded cells is large enough, all thehalf-bridges can just work in switch-on or switch-off state toform the staircase shape voltage. So the switching frequencyof all the half-bridges can only be base frequency.

B. Fuzzy Control technique:

A fuzzy logic controller is the multi valued logic which resembles human being thinking. The fuzzy logic regulator application is appropriate when the presence of uncertainty arises in deciding the output results. In thefuzzy logic technique,the obtained output should be almost equal to the decision of human. This fuzzy logic is applied when there is achance of confusion occurs while estimating the output results. The decision making of human can be reached nearly by using the fuzzy control technique when compared to the different types of controllers like P, PI & PID. In recent daysmost of the people are using this fuzzy logiccontroller technique because of its accuracy.

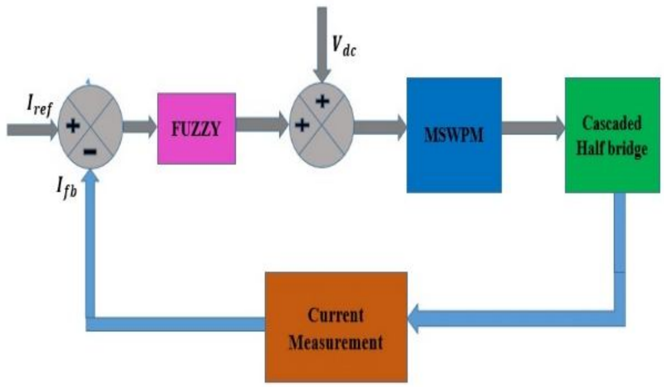

Figure 6:control technique block with Fuzzy

Figure 6 deals with fuzzy logic control technique. A computer program only understands the binary values like 0 and 1.But the fuzzy logic is not like that, itis different from normal controllers. The IbrahimMamdani created afuzzy controller with a procedure of 3 stages.

1) Fuzzification
2) Evolution of rules
3) Defuzzification.

Fuzzification is a process in which membership functions are used to converts crisp values to fuzzy sets, then theevolution of rule applies fuzzy rules for those inputs. Defuzzification is areverse process of fuzzification that is converting the fuzzy sets to crisp values.

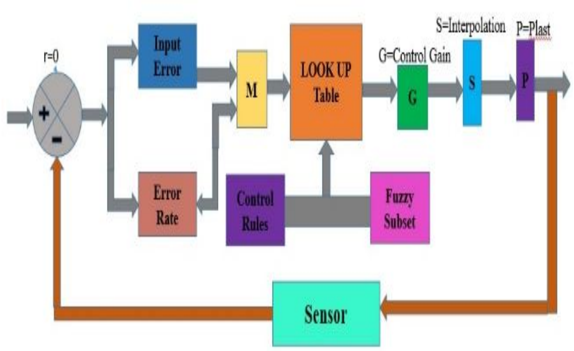

Figure 7**:** closed loop control technique

Figure 7 represents the closed loop Fuzzy control technique. This closed loop control technique uses the control of current for charging and discharging of the batteries. Here the current directions are changed to perform charging and discharging process of batteries.

IV. MATLAB/SIMULINK MODELS:

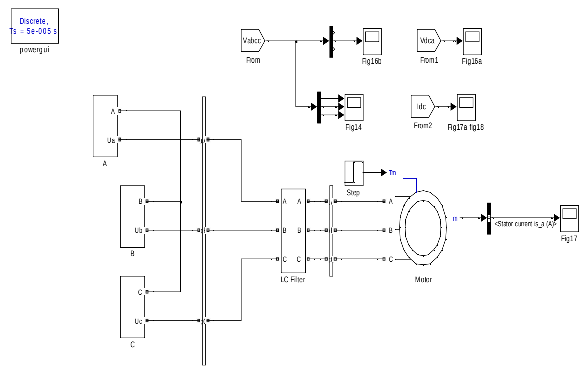

Figure 8: Simulation circuit of motor case

Figure8 represents the Matlab/Simulink circuit model for three-phase MLI connected to the motor drive. In which one LC filter is used for the removal of the harmonic content present and the output of the inverter and the output of the LC filter is fed to the drive.

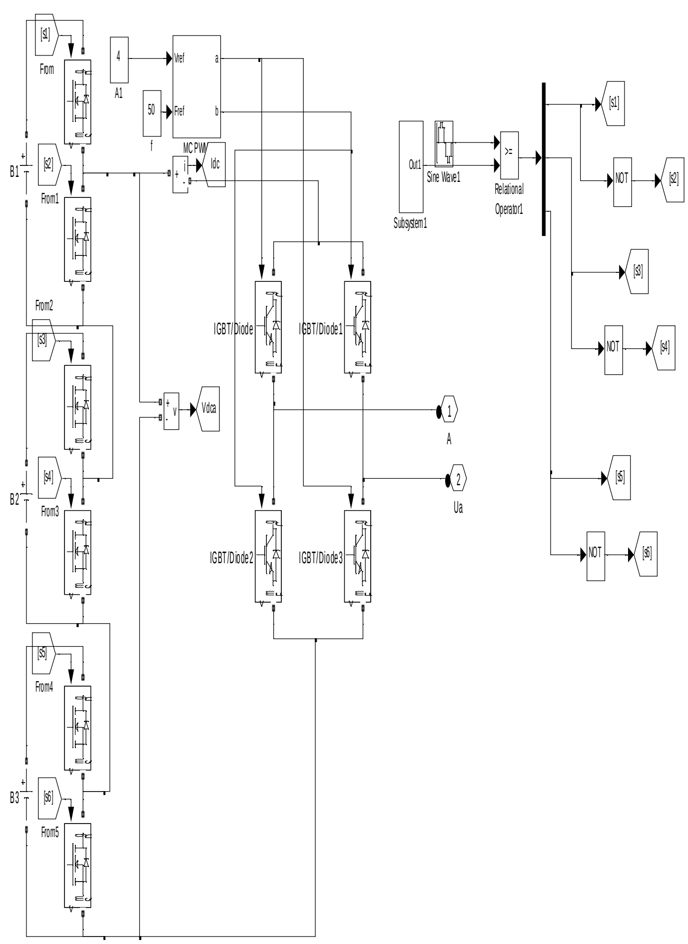

Figure 9:Simulation circuit of cascaded MLI with DC bus voltage for single phase

Figure 9 represents the Simulation circuit of cascaded MLI with DC bus voltage for single phase operation in which four Half bridges are used to get the required output voltage.

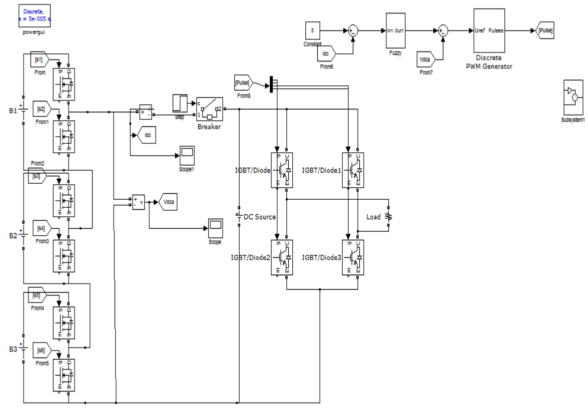

Figure10:Simulation circuit of DC cascaded bus voltage & charging current

Figure 10 represents the Simulation circuit of DC cascaded bus voltage & charging current when the charging current reference is given.

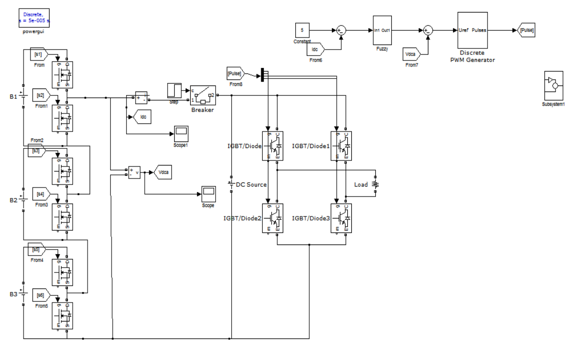

Figure 11:Simulation circuit of cascade MLI with DC bus voltage & charging current isadjusted using DC source voltage

Figure 11 represents the Simulation circuit of cascade MLI with DC bus voltage & charging current is adjusted using DC source voltage.

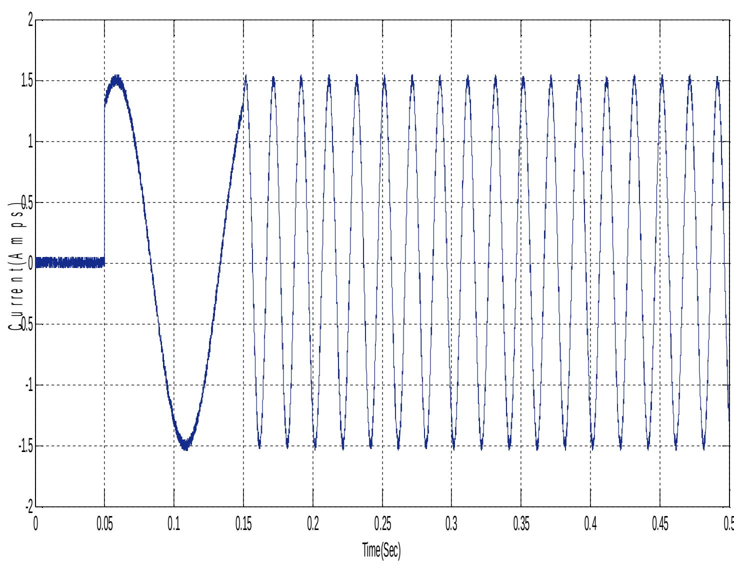

Figure 12**:** Stator Current of Induction Motor

Figure 12represents the stator current of the induction drive fed to MLI.

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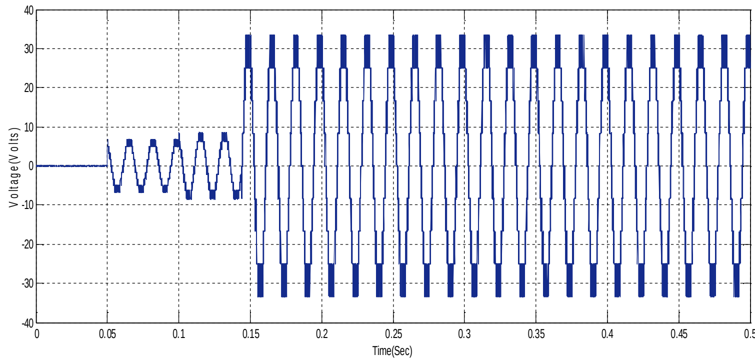

Figure 13:Output Voltage waveform of Single Phase model

Figure 13 represents the output voltage for the single phase MLI.

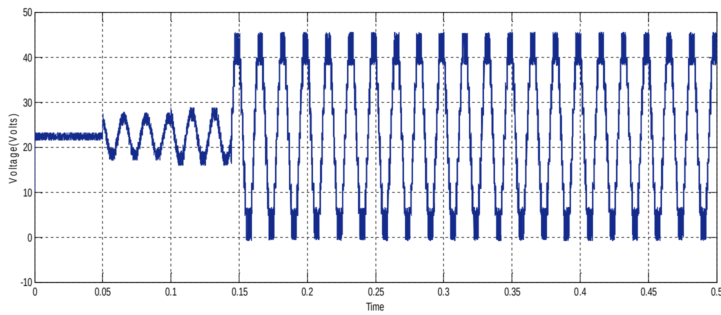

Figure 14:Simulation result in AC output voltage

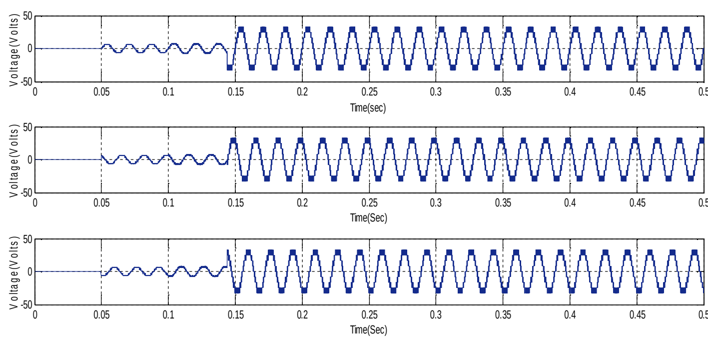

Figure 15: Simulation result of 3-phase output voltage of multilevel cascaded circuit

Figure 15 represents the simulated result for the three phase cascaded MLI.

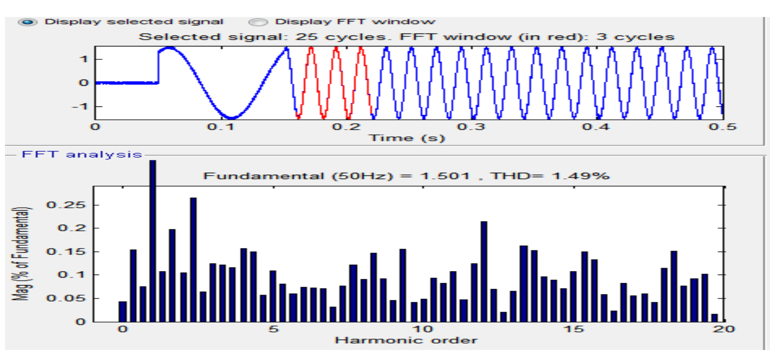

Figure 16:FFT of the MLI with PI controller for inductive load

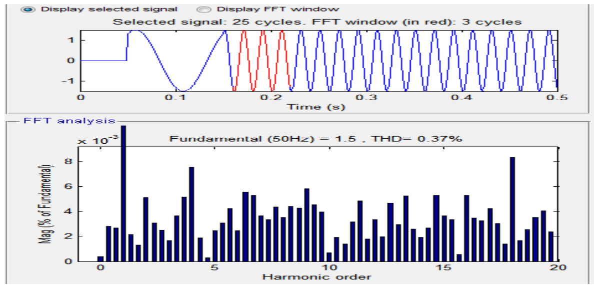

Figure 17**:** FFT analysis forthe MLI with fuzzy logic controller with inductive load

V. CONCLUSION

The existing hybrid cascade MLI for charging and discharging of the battery cells can be realized. Simultaneously the control of terminal voltage or state of charge balance can also be realized. The proposed method is suitable for all cascade battery level applications and also for low voltage energy storage system of battery cells or module of battery and fault mode, the current will be bypassed without affecting the running of other, hence the converter contains a good fault tolerance character, so by this system reliability is increased significantly. The adapted MSPWM having low switching loss, balance the control of charging & discharging control at the same time. The circuit output is AC output voltage at multilevel, where the no of themultilevelis proportional to the no of battery cells. So the AC output voltage is nearer to pure sin wave to increase controlling of motor control in theelectric vehicle. For battery charging mode a current external DC bus method with an external DC or AC source is also seen, where we realized the constant current control and do not require extra charger in proposed system. Simulationresults and desired control methods are verified in Matlab/Simulink software.

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