Harmonic Mitigation System In Grid Connected EV Charging Station

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Abstract: With the rapid adoption of Electric vehicles, the demand for Electric vehicle charging stations has increased.However, these stations pose unique challenges in terms of power quality and harmonic distortion due to the high-power charging equipment. Due to electric vehicles are viewed as nonlinear loads and have a knack to utilise enormous quantities of power in a brief period, they have the potential to create instability in the power system. In addition, a notable increase in the numberof EVsconnected to the grid can make the power system more vulnerable to disruptions. This abstract presents a solution for harmonic mitigation in EV Charging Stations through the implementation of a multilevel inverter system. This multilevel inverters can provide high-quality output voltage with reducedharmonic content. It not only improves power quality but also contributes tothe sustainable growth of the EV ecosystem by enhancing the reliability and performance of charging stations. A sophisticated fifth order cascaded inverter approach is presented in this research. The Offset-Based Carrier Pulse Width Modulation (PWM) technique is a method used in inverter control to optimize the generation of pulse-width modulated signals. The intentional introduction of offsets contributes to the reduction of harmonic distortions in the output waveform. By adjusting the pulse timings, the technique can minimize unwanted harmonics, resulting in a cleaner and more sinusoidal output. MATLAB Simulation is used to validate the suggested control. Simulation results demonstrate that the suggested solution reduces the total amount of harmonic distortion (THD) of voltage and current within acceptable bounds.

INTRODUCTION

As the manufacturing and usage of electric vehicles are expanding, Electric vehicle (EV) charging stationsare fundamental framework for supporting the development of electric vehicles. The charging station is associated with the electrical lattice. The electrical grid is a complex system of power generation, transmission, and distribution. At the point when you plug your EV into a charging station, you're basically interfacing your vehicleto the electrical network's power supply. In general, the types of charging stations are Level 1 (110V, Standard family source for slow charging), Level 2 (240V, Normal for private and public charging, offering quicker charging) and DC Quick Charging (High-power chargers for fast re-energizing on roadways and at a few public stations) . Power quality in EV charging stations begins with the voltage quality supplied by the electrical grid. Voltage fluctuations, sags, surges, and imbalances can all affect the stability of the charging process. These voltageissues can lead to reduced charging rates, interruptions, and potential damage to charging equipment. There are many power quality issues such as voltage fluctuations, voltage sags, voltage spikes, harmonics and poor power factor that affects the end users. In this power quality issues, harmonics are a common concern in EV charging stations, primarily due to the presence of non-linear loads and power electronics. The equipment within chargingstations, such as power conversion and rectification systems, can generate harmonic currents and voltage distortions. Harmonics are non-sinusoidal currents or voltages at frequencies that are multiples of the fundamental frequency (usually 50 or 60 Hz). The performance of electric vehicle charging stations are affected due to the presence of harmonics. So the presence of harmonics should be reduced. Filters and inverters are commonly usedto reduce harmonics in electrical systems, especially in applications where the quality of the power supply is critical. The most often spotted types of filters are passive filters and active filters. Passive filters consist of passive components such as inductors,capacitors and resistors. Passive filters and active filters are the most frequently encountered types of filters.Passive filters consist of passive elements like inductors, capacitors, and resistors. They are designed to provide impedance to specific harmonic frequencies. Active filters employ active components like transistors and operational amplifiersto generate currents that counter act harmonics. The inverters used are multilevel inverters such as 5-level or 7- level inverters that can generate more sinusoidal output wave forms with fewer harmonics than traditional 2- levelinverters. They achieve this by creating multiple voltage levels, which results in a smoother output. The choice between filters and inverters for harmonic reduction depends on the specific application, load characteristics, andbudget constraints. Filters can be used only in situations where the load is relatively constant, while inverters can beused in variable load sand precise control of the output waveform are necessary.

There are three main varieties of multilevel inverter. topologies namely diode-clamped multilevel inverters

(DCMI), flying capacitor multilevel inverters (FCMI) and cascaded inverters. Diode-Clamp (Neutral-Point Clamped) multi-level inverter uses diode or voltage clamps to create multiple voltage levels. Flying Capacitor multilevel inverter uses flying capacitors to create additional voltage levels. The cascaded multilevel inverters are combination of more than one H-Bridge modules. Each H-bridge module can produce two voltage levels. The number of voltage levels is determined by the number of cascaded modules. This paper deals with thecascade multilevel inverters. Cascaded multilevel inverters are often preferred for reducing harmonics over othermultilevel inverter topologies due to their inherent advantages in terms of harmonic mitigation. The main advantage of cascaded multilevel inverter is that they have a larger number of voltage levels compared to other multilevel inverter topologies. The increased number of voltage levels allows for finer control of the output waveform. This means they can generate a more sinusoidal-like output, reducing harmonic distortion. The other reasons for selecting this inverter are reduced component stress, fault tolerance, scalability and good efficiency.

PROPOSED METHOD

There are many ways to reduce the harmonics such as filters, multilevel inverters. The active filter is only appropriate for frequencies that are low or moderate. It is not capable of handling a significant quantity of electricity. They need a DC power supply to operate. The benefits of multilevel inverter are improved power quality, reduced switching losses, minimal electromagnetic interference, and increased voltage capabilities. The multilayer inverters are employed to enhance the power quality in power network by reducing harmonics produced by nonlinear loads. There are many types of multilevel inverters but cascaded multilevel is used in this system because cascaded H-bridge inverters offer several advantages, including improved efficiency, lower harmonic distortion, and better performance in high- power applications. In addition, they have the capability to manage increased voltage and power levels by incorporating additional H-bridge modules in a sequential manner. A Cascaded H-bridge inverter is a particular sort of multilayer inverter employed in high-power applications including renewable energy systems and motor drives. It consists of many H-bridge inverter modules connected together. Typically, each H-bridge module includes four power electronic switches, usually insulated gate bipolar transistors (IGBTs) or MOSFETs. Here 5 level cascaded multilevel inverter is used and 2 H-bridge module areused and connected in series. Each H-Bridge module consists of four MOSFETs that are connected to gate driver circuit. By controlling the switching states of the individual H- bridge inverters, it is possible to generate multipleoutput voltage levels. The most common modulation technique used in cascaded H-bridge inverters is PWM. PWM controls the width of the pulses in the output waveform to regulate the average voltage applied to the load. By adjusting the duty cycle of the PWM signals, the output voltage can be controlled. The following techniques formsystems that are frequently employed for cascading multilevel inverters: 1) space vector PWM (SVPWM); (2) sinusoidal PWM (SPWM); (3) non sinusoidal carrier PWM4) mixed PWM; (5) unique cell connection topology;(6) sinusoidal carrier PWM; and (7) selected harmonic PWM removal (SHEPWM) Here offset based carrier PWM technique is used. Offset- based Carrier PWM (Pulse Width Modulation) isa modulation techniquecommonly used in power electronic converters to control the switching of the power semiconductor devices, suchas IGBTs (Insulated Gate Bipolar Transistors) or MOSFETs, in applications like voltage source inverters (VSIs).

It involves introducing a time offset or phase shift in the carrier signalto modulate the width of the PWM pulses. This technique is used to control the output voltage of inverters and is particularly valuable for reducing harmonic distortion and achieving better control of the output waveform

BLOCK DIAGRAM

The AC power supply is switched on and then AC is converted into DC using rectifier circuit whichis given to both H- Bridge modules that consists of four switches each. H-bridges can be susceptible to shoot-through, a condition where both the upper and lower switches on one side are turned on simultaneously. Thisshould be avoided, and circuitry to prevent shoot-through, such as dead-time control, is often included. To control an H-bridge, you need to use a microcontroller, microprocessor, or specialized motor control IC. These devices provide the necessary signals to control the switches.

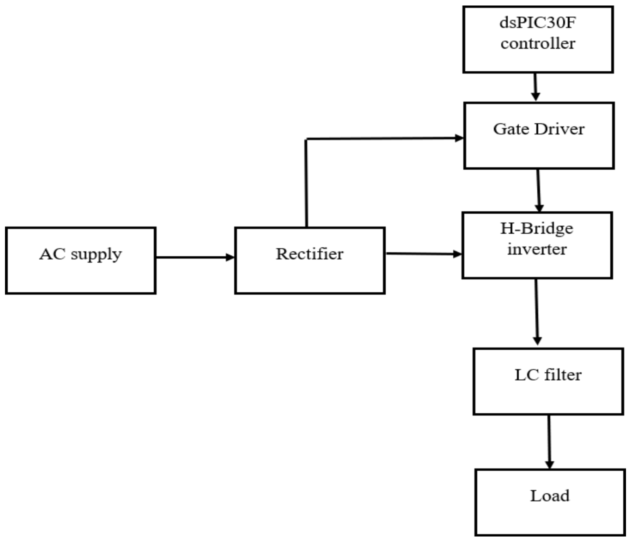

FIGURE 1. BLOCK DIAGRAM

Here the controller named dsPIC30F2010isused.The dsPIC30F2010 is built around a 16-bit microcontroller core with enhanced digital signal processing (DSP) capabilities. The device utilises a Harvard architecture, which allows for rapid data transport and programme execution by having distinct buses for programme memory (flash) and data memory (RAM). The dsPIC30F2010 comes with different integrated peripheral modules, like timers, analog-to-digital converters (ADC), pulse-width modulation (PWM), UARTs, and others.

Here the ultimate aim of using this controller is to generate pulse to trigger the H-bridge modules. The PWM module in the controller enables the generation of PWM signals for requiring precise control of output waveforms. Then the pulse is fed to the MOSFETs through gate drivers. Each MOSFETs in the H-Bridge module have individual gate drivers. Thegate driver used isTLP250 gate driver.

WORKING

The AC power supply is given to the stepdown transformer. A step-down transformer is a device designed to reduce the voltage level of an AC power supply. Here 230V AC is converted into 12V AC using step down transformer. And then it is connected to the rectifier circuit. The rectifier circuit consists of four diodes and capacitor shown in FIGURE 2. There are two rectifier circuits that are connected to two H-bridge modules.

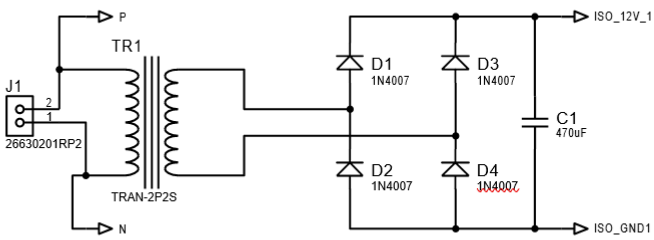

FIGURE 2. POWER CIRCUIT

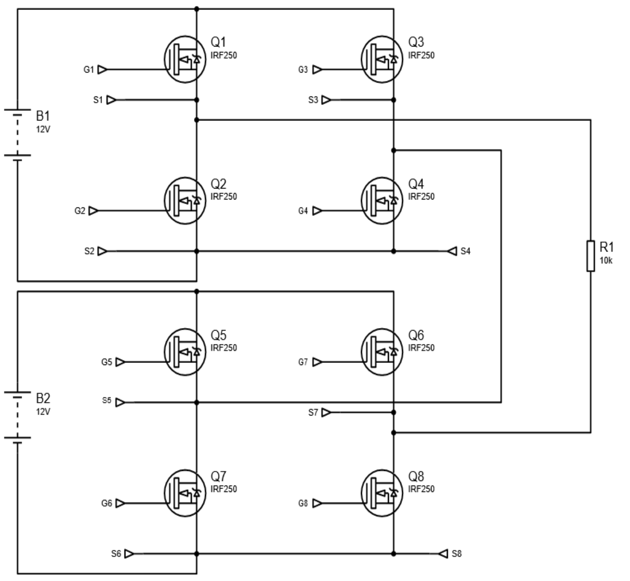

FIGURE 3. CASCADED H-BRIDGE INVERTER

The control strategy for a 5-level multilevel inverter often involves PWM. PWM signals are generated by a controller and are sent to the gate driver circuit. The controller used is dsPIC30F2010 and the circuit is shown in FIGURE 4. There are eight gate drivers to control the eight MOSFETs.

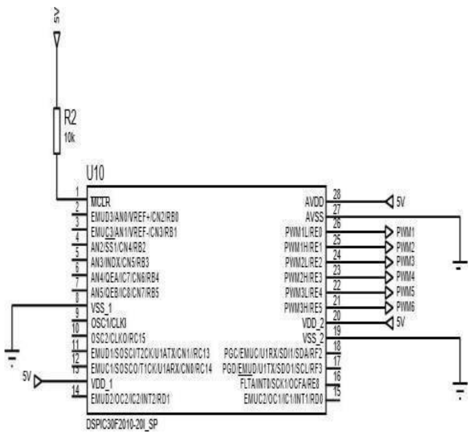

FIGURE 4. dsPIC30F2010 CONTROLLER

The gate driver circuit receives the PWM signals and controls the gate-source voltages of the MOSFETs accordingly. The circuit for gate driver is shown in Figure5. This rapid switching of the MOSFETs generates the desired output voltage levels.

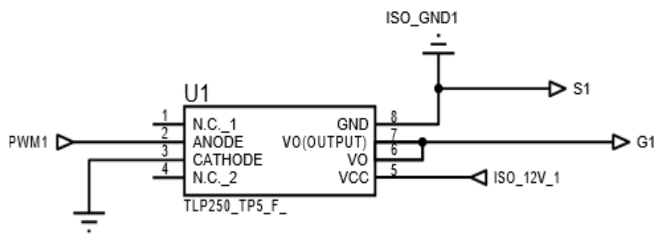

FIGURE 5. GATE DRIVER CIRCUIT

The load is connected between the H-Bridge modules. The LC filter diminishes particular harmonic frequencies through establishing a path with minimal resistance for the flow of harmonic currents. Inductors exhibit high impedance to high-frequencyharmonics, while capacitors provide low impedance, effectively filtering out undesirable harmonics. The output waveform can be seen through digital storage oscilloscope.

SIMULATION AND RESULT

The simulation diagram of 5- level multilevel inverter can be done using MATLAB software and is shown in FIGURE 6.

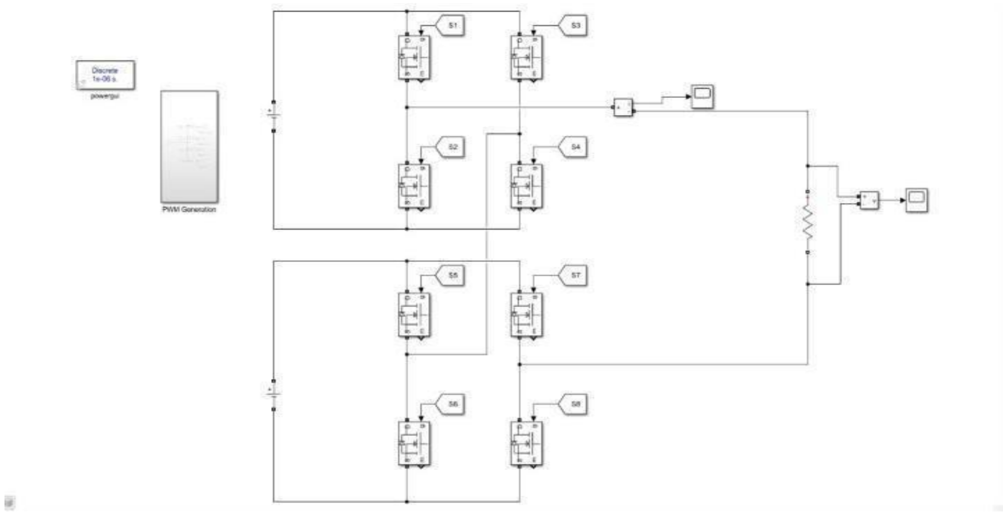

FIGURE 6. SIMULATION DIAGRAM

FIGURE 7 Determines the total amount of Harmonic Distortion (THD) of the final voltage waveform. THD is a method used for assessing the proportion of harmonic content in the voltage waveform compared to the fundamental frequency. Assessing the total harmonic distortion (THD) of the output voltage waveform is crucial for establishing the power delivery quality in electrical systems. Elevated THD levels can cause a range of problems, including higher energy losses, equipment overheating, and disruption to communication systems.

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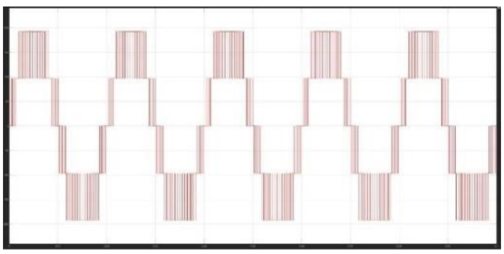

FIGURE 7. OUTPUT VOLTAGE WAVEFORM

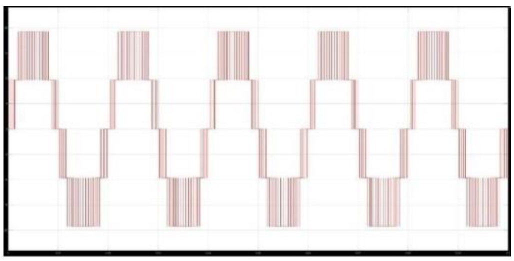

FIGURE 8. OUTPUT CURRENT WAVEFORM

FIGURE 8 Displays the total amount of harmonic distortion (THD) of the output current waveform. THD is metric that quantifies the harmonic components in the current waveform relative to the fundamental frequency. The graph displays the THD levels at various harmonic orders, illustrating the impact of each harmonic frequency on the overall distortion in the output current waveform. Greater THD values at particular harmonic orders indicate the existence of notable harmonic content at those frequencies.

The total amount of harmonic distortion in the final waveform of 5-level inverter with multiple levels is less compared to that of a 3-level or 2-level inverter. Figure 9 displays the Total harmonic Distortion (THD) of the final voltage waveform following the implementation of an LC filter. The LC filter is a passive filtering device that consists of an inductor (L) and a capacitor (C) connected either in series or parallel.

Before using LC Filter THD level:25%After using LC Filter THD level: 1.26%

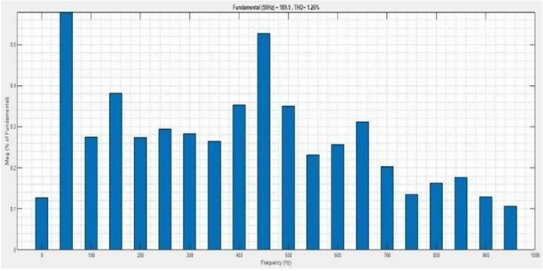

FIGURE 9. FILTER OUTPUT

CONCLUSION

The cascaded multilevel inverter with a LC Filter is used to reduce the Total Harmonic Distortion (THD) level from 25% to 1.26% it offers a promising balance between improved output waveform quality and efficient power conversion. The relatively low THD indicates reduced harmonic content, enhancing the inverter's performance and minimizing potential adverse effects on connected systems. This makes the cascaded multilevel inverter a favorable choice for applications where clean power output is crucial.

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