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Signal Transmission for Electric Vehicles Using Cascaded Multilevel Inverter

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Abstract— Signal multiplex transmission (SMT) leverages power electronic circuits to transmit corresponding signals. A suggested three-stage flowing staggered inverter-based SMT architecture is presented in this study. This new method reduces the wire cost of the conventional electric car (EV) correspondence framework by sending signals without relying on a regulator zone organization transport. With the proposed system in place, electric vehicles will be able to achieve engine speed guideline and battery balance release. Power with correspondence signals are conveyed successfully in a reproduction model conducted in Matlab/Simulink using the combined beat width regulating plan and recurrent shift keying approach. According to the evaluation of the transmitted signal's error rate, the maximum allowable sign rate for the suggested not-quite-finalized arrangement is 600 piece/s.

Keywords—Electric vehicle, Battery discharge, Signal transmission

Introduction

The study suggests a mechanism called signal multiplex transmission (SMT) for electric vehicles' three-phase multilevel inverter circuits, which can carry both power and communication signals. Bypassing a DC/DC converter is possible due to the cascaded multilayer inverter's ability to increase the battery voltage, and the switching losses among the inverter's individual components are far lower than those of a 2-level inverter. PWM, or pulse width modulation, accomplishes the power conversion in the suggested system, while frequency shifting keying (FSK) modulates the sent signals. By sending both power and signals over the same power line, the suggested method may significantly cut down on communication system expense, unlike modern EVs that utilize a may bus as their communication route. The overall layout of an electric vehicle's powertrain is shown in Figure 1. In order to increase the voltage of the battery for a 2-level inverter, some traditional electric vehicle power systems use a DC/DC converter [8], [9]. High switching losses may be caused by this method's elevated voltage changing rates (dV/dt) [8]. The use of large inductors in the DC/DC boosting converters makes the system both costly and power-poor [9]. Even though conventional EVs use the CAN bus for internal communication, there is still room for optimization as the means of communication and electrical power line are two separate components. Numerous ways for transmitting electricity and signals have found use in several domains. As an example, the standard procedure for data transmission over a power line involves ampliying the signal, modulating it into a high frequency signals carrier, and then coupling it to the line using a coupling circuit [10].

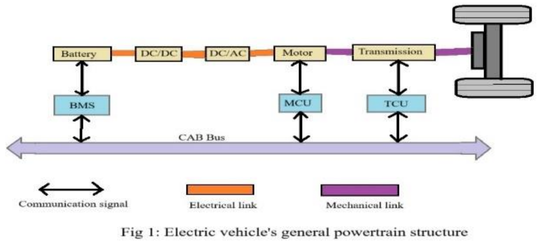


Fig 1: Electric vehicle's general powertrain structure.

The electrical power line channel may become more complicated when additional signals are sent over it, as the power line was not originally intended to transport communication data. Broadband electric power communication (PLC) models should also take electromagnetic interference into account when they are being designed, as the carrier frequency, which may range from 2 MHz to 32 MHz, may overlap with the frequency range of short-wave radios [11]. Some IP-based endpoints, such VoIP phones and IP cameras, may receive both data and electricity with Power over Ethernet (PoE) technology, which use twisted-pair Ethernet cables [12]. On the other hand, this method isn't ideal for high-power applications like pan-tilt-zoom cameras since the highest allowed power output of PoE power supply equipment exceeds 15.4W according to the IEEE802.3af standard

Proposed Signal Multiplex Transmission

A. System Structure

This study uses the transmitted motor speed control signal and battery status of charge (SOC) signal to explain the basic idea of the suggested SMT approach.

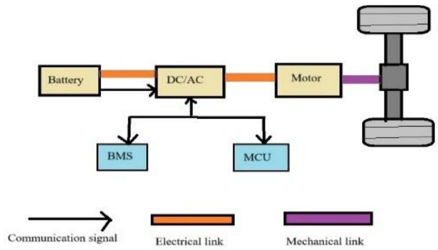


Fig. 2. The proposed system structure of an EV using the SMT method

Figure 2 depicts the suggested EV system architecture using the SMT approach. An inverter circuit with three phases allows signals to be sent among the power supply and BMS as well as between the microcontroller unit and the motor. Figure 2 shows the suggested layout of a three phases SMT system. Inverter topologies include four seriesconnected H-bridge cells in each phase; one of these cells receives its power from a DC voltage source and transmits signals, while the other three cells consume energy from batteries. Phase A carries the signal for adjusting the motor's speed, whereas phase B carries the signal for starting the engine. An inverter topology load, a synchronous motor with permanent magnets (PMSM), is used in this model

B. Signal Transmission

Figure 3 shows the signal transmission architecture and the modulation technique used in the proposed system, which is the FSK approach. To modulate digital '1' and digital '0', multiple carriers having different frequencies represented in SC may be used if the sent 4-bit signal SI is '1010'. Every phase of the signal is supposed to pass through an H-bridge cell, which allows for quick switching of the four switches inside the cell to modulate the signal. In particular, a gate signal of digital '1' will activate a switch, whereas digital '0' will cause it to deactivate.

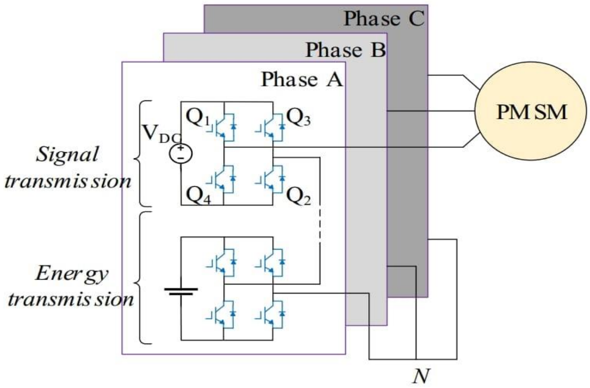
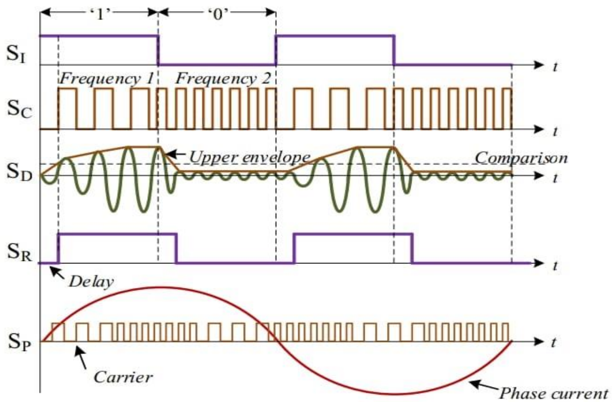


Figure 3: Topology of proposed P&SMT system for EVs.

Both Q1 and Q2 switches are active at the same time in Figure 2. Figure 3. Topology of the proposed SMT system for EVs together with the simultaneous on/off operation of switches Q3 and Q4. In addition, in order to prevent a short circuit, switches Q1 as well as Q2 work in the opposite way as switches Q3 and Q4. It is possible to think of the sent signal as overlaid on the current output waveform due to the series connection between the four cells used for energy transmission and the one employed for signal transmission, an H-bridge cell. Figure 4 shows the proposed system's signal transmission scheme, with components such as the initial 4-bit signal '1010' (SI), the carrier waveform (SC), the restored signal (SR), and the output phase current waveform (SP) superimposed on top of the signal's carrier.

C. Motor Speed Regulation and Battery Balance Discharging

The suggested method controls the motor speed by modulating the transmitted signal's power frequency. For a PMSM, the connection between motor speed (n), pole-pair (p), and power frequency (f) is shown explicitly as



where 60 is the value for 60 seconds per minute. Figure 4: The signal transmission scheme of the proposed system, where SI is the initial 4-bit signal ‘1010’; Sc is the carrier waveform; SD represents the extracted carrier for digital ‘1’ after using a band-pass filter; Sr shows there stored signal; Sp is the output phase current waveform superimposed with the signal’s carrier.

A 2-pole pair motor's theoretical speed range, with a power frequency variation between 40 Hz & 60 Hz, should be 1200 r/min to 1800 r/min. It is thus possible to determine the power frequencies f using the sent signal s by The transmitted signal s will have a power frequency of 40 Hz if a digital '0' appears and 60 Hz if a digital '1' appears. Then, we pull the sinusoidal reference waves in three phases from Here, A is the amplitude, while Pa, Pb, and Pc are the reference waves in phases A, B, and C, respectivly. The reference waves for phase B & phase C are 2π/3 & 4π/3 radians behind the reference wave for phase A, respectively.

n = 60f ÷ p (1)

At last, the motor's speed may be adjusted by driving it with modulating variable frequency sine waves. By measuring the reference waveform with a triangular carrier, the triggering signals of a switch is created using the usual sinusoidal PWM approach.

f = 20s + 40 (2)

The duty cycle varies from switch to switch due to the fact that the reference wave and different carriers meet atdifferent locations.

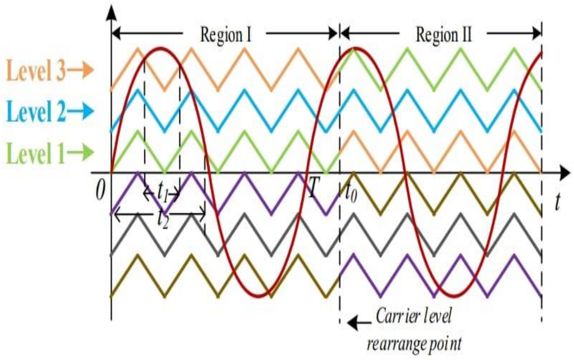


Figure 5: Carrier level rearrangement in the PWM process

As shown in Figure 5, the rate of duty cycle of a

$$\begin{cases} P_a = A\sin(2\pi f) \\ P_b = A\sin\left(2\pi f - \frac{2}{3}\pi\right) \\ P_c = A\sin\left(2\pi f - \frac{4}{3}\pi\right) \end{cases} \quad (3)$$

toggle switch controlled by a 'Level 3' carrier is less than that of another switch modulated by a 'Level 1' carrier.

III RELATED WORK:

"Evaluation of emissions of CO2 and air pollutants from electric vehicles in italian cities," T. Donateo, F. Licci, (2015) The paper analyzes data about recharge of electric cars in Rome during 2013 as a part of a national research project (P.R.I.M.E.). The electric vehicles were recharged through the public Enel Distribuzione recharging infrastructure. For each recharge, the initial and final time were registered together with the electricity absorbed from the grid. The total number of recharges was about 7700. The first step of the investigation is the statistical analysis of the distribution of recharges in daily time slots in order to analyze the recharge behavior of Italian drivers. For each day and for each time slot, literature data from the Italian national grid operator (Terna) were used to retrieve the energy mix used to produce electricity in that day and in that time slot. In the third step, electricity generation mixes were used to obtain emission factors for greenhouse (CO2) and pollutant emissions (CO, NOx, HC and particulate). Using information about the electric consumption of vehicles registered in Rome, the emission factors in g/km were obtained and compared with the limits set by European legislation for conventional (gasoline and diesel). "Sound quality evaluation of the interior noise of pure electric vehicle based on neural network model," C. Ma, C. Chen, Q. Liu (2017). Based on neural network model, a method for quantitative sound quality (SQ) evaluation of the interior noise of a pure electric vehicle (PEV) is presented in this paper. The method can be divided into four steps. First, the interior noises under different speeds of a PEV are collected through the interior noise test of the PEV. Subsequently, one physical acoustic parameter (A-weighted sound pressure level) and six psychoacoustic parameters (loudness, fluctuation strength, tonality, roughness, articulation index, and sharpness) are applied to describe the noise samples for objective evaluation of SQ. In the third step, five semantic evaluation indexes, namely, "annoying or pleasing," "harsh or sweet," "weak or powerful," "promiscuous and pure," and "unobservable or perceptible," are proposed based on semantic differential method, which are used for subjective evaluation of SQ by jury tests. Finally, the neural network model for SQ evaluation of the interior noise of the PEV is established, the SQ characteristics of the interior noise of the PEV are evaluated, as well as revealing the coefficient weight of influencing factors. This model can be used for SQ prediction and evaluation of the interior noise of the PEV considering that the average error is 9%. "Review of the impact of vehicle-togrid technologies on distribution systems and utility interfaces," M. Yilmaz and P. T. Krein (2013) Plug-in vehicles can behave either as loads or as a distributed energy and power resource in a concept known as vehicle-to-grid (V2G) connection. This paper reviews the current status and implementation impact of V2G/grid-tovehicle (G2V) technologies on distributed systems, requirements, benefits, challenges, and strategies for V2G interfaces of both individual vehicles and fleets. The V2G concept can improve the performance of the electricity grid in areas such as efficiency, stability, and reliability. A V2G-capable vehicle offers reactive power support, active power regulation, tracking of variable renewable energy sources, load balancing, and current harmonic filtering. These technologies can enable ancillary services, such as voltage and frequency control and spinning reserve. Costs of V2G include battery degradation, the need for intensive communication between the vehicles and the grid, effects on grid distribution equipment, infrastructure changes, and social, political, cultural, and technical obstacles. Although V2G operation can reduce the lifetime of vehicle batteries, it is projected to become economical for vehicle owners and grid operators. Components and unidirectional/bidirectional power flow technologies of V2G systems, individual and aggregated structures, and charging/recharging frequency and strategies (uncoordinated/coordinated smart) are addressed. Three elements are required for successful V2G operation: power connection to the grid, control and communication between vehicles and the grid operator, and on-board/off-board intelligent metering. Success of the V2G concept depends on standardization of requirements and infrastructure decisions, battery technology, and efficient and smart scheduling of limited fast-charge infrastructure. A charging/discharging infrastructure must be deployed. Economic benefits of V2G technologies depend on vehicle aggregation and charging/recharging frequency and strategies. "A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units," K.Ç. Bayindir, M.A. Gözüküçük (2013) The studies for hybrid electrical vehicle (HEV) have attracted considerable attention because of the necessity of developing alternative methods to generate energy for vehicles due to limited fuel based energy, global warming and exhaust emission limits in the last century. HEV incorporates internal composition engine, electric machines and power electronic equipments. In this study, overview of HEVs with a focus on hybrid configurations, energy management strategies and electronic control units are presented. Advantages and disadvantages of each configuration are clearly emphasized. The existing powertrain control techniques for HEVs are classified and comprehensively described. Electronic control units used in HEV configuration are also elaborated. The latest trends and technological challenges in the near future for HEVs are discussed.

Ⅳ Conclusion :

The suggested method streamlines the system's wiring whileusing a portion of the power electrical circuits as a means of communication, hence reducing the overall system complexity. In order to ensure that the suggested P&SMT approach is feasible, a Matlab/Simulink simulation model is used to provide signals for the motor speed adjustment and the battery state of charge via phaseA and phase-B currents, respectively. Looking at the correlation between signal bit peed and error rate, we also find that the suggested approach can transmit signals at a rate of 600 bit/s.

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