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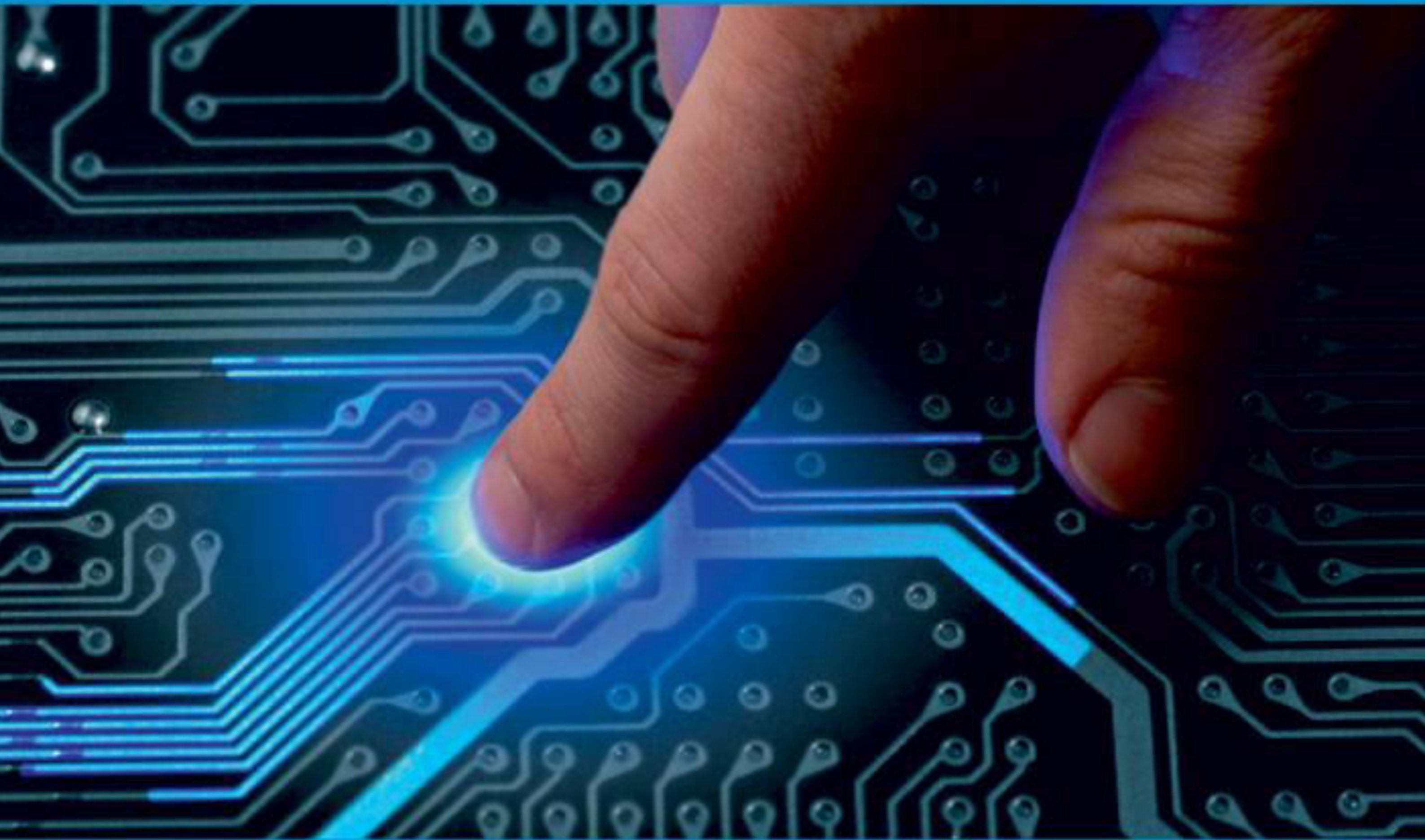

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Review paper on Multi-level PFC Rectifier for EVcharging Application

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ABSTRACT: - The ever growing research on power conversion technology has led to drastic growth in wind power generation. A recent study indicates that the wind energy conversion system is becoming more prominent in the power sector. Due to more feasibility in islanded or grid-connected wind energy systems technology, the wind energy system installations are getting more attraction towards clean energy production. In addition to that, the rapid advancement in the aerodynamic design of small size wind turbines, power converters, and MPPT algorithms can enhance the extraction of maximum wind energy. Therefore, the grid side converter controller regulates the flow of active power at the grid through which the balanced DC-bus voltage is achieved. Since the total harmonic distortion is maintained at low, the power quality of system is improved to maximum extent.

KEYWORDS:- H-bridge Rectifier, Power Factor Correction, EV Charging

I. INTRODUCTION

Renewable energy plays a significant role in the global energy contribution and it is an appropriate and viable solution for supplying power to the un-electrified areas and to feed the existing power system. There has been a great impact on global energy scenario with the effective utilization of renewable energy resources during the recent years. With the advancement in microgrid technology, the energy conversion from the renewable energy resources is reached to Gigawatts of power and it is an extreme contribution to the global power production. Therefore it has been realized that the renewable energy has to play a vital role in achieving global power security for the years ahead. As per the global energy statistics, the power contribution from the non-conventional energy resources is around 26.5% in which the major contribution is from hydro-power is around 16.4%, wind power generation is around 5.64% for the year end of 2017 and the remaining power production is from solar, Bio-power, Geo-thermal, ocean etc. The power production from the conventional energy resources is around 73.5% for the year end 2017 and the usage of these have to be reduced by utilizing the renewable energy resources [1, 2]. The percentage of renewable power generation in the global energy scenario is shown in Fig.1 along with the traditional power production [3].

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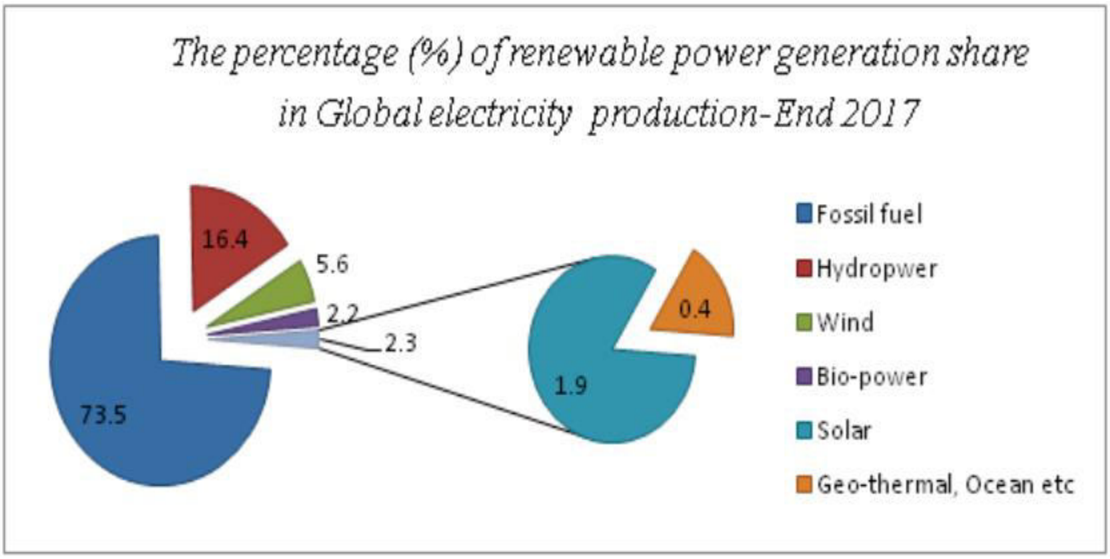

Fig. 1: The percentage of global renewable power production

The major renewable power generation in GW of few countries is shown in Fig.2, including hydropower generation. As per the statistics, the China has achieved top place with 647 gigawatts of power generation from renewable energy resources for the year end of 2017. Similarly, United State has got second place with 241 gigawatts, Germany has got third place with 112 GW, India has got fourth place with 106 GW, Japan has got fifth place with 79 GW and United Kingdom (UK) has got sixth place with 39 GW of power generation respectively.

Apart from aforementioned energy conversion systems, there are several technologies evolved in parallel with renewable energy which includes energy storage, electric vehicles and heat pumps etc for the transport sector and are feasible to integrate into the existing power system as they work on vehicle-to-grid and grid-to-vehicle technology. The storage of energy mainly in the form of pumped storage has been used for the decades in the grid reliability in conjunction with renewable energy results in system resilience. The commercial and residential energy storage capacity is getting increased nowadays in some of the countries, particularly with combined structure of solar PV and storage systems.

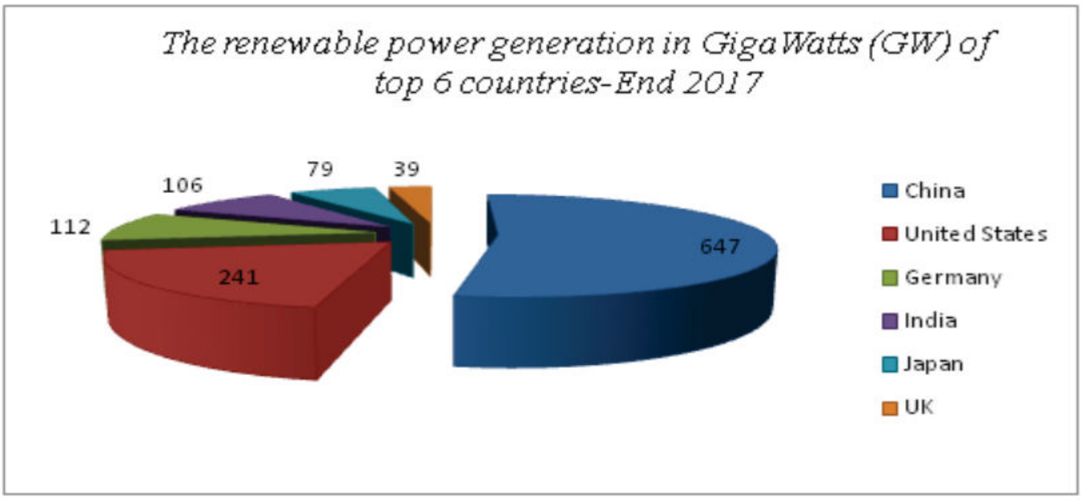

Fig. 2: The global renewable power production in giga watts

As per India renewable energy statistics, the cumulative installed grid tied renewable energy capacity has reached 62,732.83 MW as on 31 Dec.2017, estimated by MNRE survey. From the Fig.3, it is clear that the major contribution

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of power from the wind energy has an high impact on total energy demand and it has reached to 32,848.46MW for the year end of 2017. The government of India has framed a target to achieve 175 GW of power generation from renewable energy by 2022. India already attained fourth position in wind and sixth in solar power installed capacity in the global market.

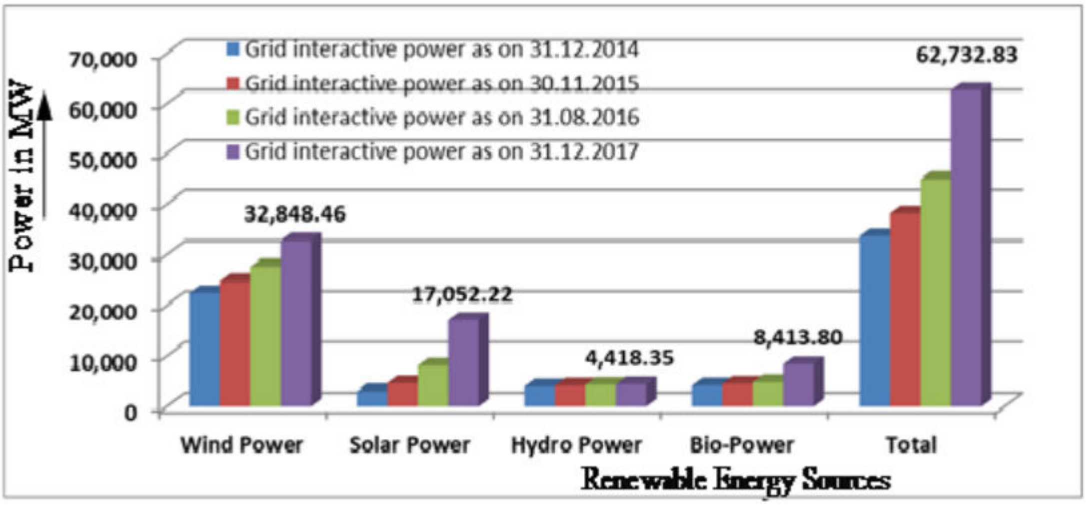

Fig. 3: Indian energy scenario in Megawatts

II. LITERATURE REVIEW

Anekant Jain et al. [1], the two-stage charging interface of electric vehicle (EV) batteries includes AC-to-DC conversion. Using multilevel rectifiers (MLRs) reduces power switch voltage ratings while producing a high-quality input voltage waveform for these chargers. However, balancing the capacitors in MLRs is a significant challenge. A self-balanced switched capacitor power factor correction (PFC) five-level rectifier is proposed in this work. The presented topology has five power switches and one switched capacitor for each leg, with power switch voltage ratings equal to the dc output voltage. Because the load always appears in parallel with a switched capacitor of one of the legs, it does not require an additional filter capacitor on the dc side. The capacitive filter on the ac side and the inductive filter on the dc side are eliminated by the five-level operation with continuous conduction. This article presents the working guideline, adjustment system, shut circle control, and plan parts of the proposed rectifier. Experiment results validate the proposed topology, and other topologies are compared to it. Following three highlights of the proposed geography make it reasonable for EV battery charging applications — buck activity with a wide result guideline, the chance of bidirectional progression of force required for vehicle-to-matrix frameworks, and simple acknowledgment of its three-stage variant by essentially adding another leg. Experiments have also demonstrated these characteristics.

H. Abu-Rub et al. [2],brings together the most recent knowledge and cutting-edge methods from various stages of research, with an emphasis on the significance and long-term viability of Power Electronics for Renewable Energy. The content aims to enable the reader to directly apply the knowledge gained to their designs and covers topics that are currently unavailable to practicing professionals. The book focuses primarily on power electronics and motor drives-based solutions for electric vehicle (EV) technologies and addresses the practical issues of current and future electric and plug-in hybrid electric vehicles (PHEVs). Drive framework necessities and engine estimating for EVs is examined, alongside useful framework measuring models. Key EV battery technologies and related battery management issues are discussed. The advanced power electronics-intensive charging infrastructures for EVs and PHEVs are detailed, as are the power system architectures for PHEVs. With examples, the EV/PHEV interface with renewable energy is explained. This book defines existing challenges, concerns, and selected problems in accordance with international trends, standards, and programs for electric power conversion, distribution, and sustainable energy development as well as explores new topics that call for additional global research. It will help add experience in the various industries and academia regarding energy conversion technology and distributed energy sources and advance the current state-of-the-art applications of power electronics for industrial, transportation, and renewable energy.

H.Vahedi et al. [3],cascade H-Bridge, which includes full-bridge single-phase inverters, is one of the best topologies for multilevel inverters. In this paper a comparable flowed structure is proposed which is made by half-span single-

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stage inverters. The proposed geography creates higher result voltage and power utilizing similar switches and DC transports as full-span one. In other word, it can create a similar voltage at the result while utilizing DC transports with half extent. The Half-bridge multilevel inverter also has the advantage of producing even levels like 4, 6, 8,... as well as odd levels like 3, 5,... The introduced reproduction results show the effectiveness of the proposed Half-span geography in the event of a three level inverter as an option in contrast to CHB. Three-level NPC and CHB are used to compare the results.

H.Vahedi et al. [4], in order to meet the voltage and current limitations of high power applications, high efficiency devices are required to produce lower power losses and harmonics. Staggered inverters produce smoother and higher voltage at the result with lower sounds. They can use switches with a medium voltage to deliver high power. In this paper a Stuck Mid-Focuses (PMP) staggered inverter geography is presented and concentrated on which is gotten from a Bidirectional Unbiased Point Clasped (BNPC) three-level inverter. In comparison to the BNPC and Cascaded H-bridge (CHB) inverters, the proposed PMP multilevel inverter has fewer switches and clamping diodes, as well as fewer bidirectional switches. Also, it very well may be reached out to three-stage inverter same as a NPC just utilizing three legs and normal DC interface. Matlab/SimPowerSystems validates the proposed topology for a five-level inverter. It displays the appropriate voltage and current results as well as their THD percentage.

H.Vahedi et al. [5], because they offer consumers environmentally friendly and economical energy, renewable energy sources are widely used. Because multilevel inverters produce low-harmonic waveforms at their output, they are ideal for converting energy into efficient power for photovoltaic systems and other renewable energy sources. In this paper another dc source less geography has been presented for staggered inverters. The highest levels of output voltage are generated by means of crossover switches. The Hybrid Switches Cell (CSC) staggered inverter can create all conceivable voltage level among the DC supply and controlled DC voltage capacitor. A voltage regulator has been proposed to keep the DC capacitor voltage controlled in the event of burden changes. The simulation results demonstrate that the controller can balance the capacitor voltage even when the DC supply voltage changes, and that the CSC can produce maximum voltage levels.

H.Vahedi et al. [6], because they produce low harmonic waveforms at their output, multilevel inverters are well-suited for high voltage energy conversion schemes that aim to efficiently supply loads with high power from renewable energy sources like photovoltaic systems, which are increasingly entering the electric grid. A single-phase hybrid multilevel inverter with cascading full bridge and half bridge cells is described in this paper. Additionally, the multicarrier PWM-associated switching method is intended to produce a five-level voltage at the output. Also, the planned exchanging strategy permits the capacitors of the half extension cell to have adjusted voltage regardless of burden changes. In addition, more cells with unequal DC sources are used in this study to generate higher voltage levels. To demonstrate the effectiveness of the presented cascaded inverter with equal and unequal DC sources and switching technique, simulations on two and three cells were carried out.

M. Sharifzade et al. [7],the particular symphonious end beat width adjustment (SHE-PWM) strategy is proposed to control the three-level four-leg unbiased point cinched (NPC) inverter to enjoy the two benefits of low exchanging recurrence of SHE and nonpartisan place of fourth leg in four wire frameworks. The non-triplen, 5th to 23rd harmonic orders from the output voltage are removed from the voltage using the proposed method, which makes use of the inverter phase legs' obtained switching angles. Triplen harmonics of the 3rd, 9th, 15th, 21st, and 27th orders are thought to be eliminated from phase voltage by calculating switching angles for the fourth leg. The effectiveness of the proposed balance strategy is checked by recreations of a four leg NPC inverter as an UPS taking care of various sorts of dynamic and uneven burdens.

H.Vahedi et al. [8],an original model of the stuffed U-cell (PUC) inverter is determined thinking about the idea of single-stage staggered converters. In light of the proposed model, a voltage adjusting regulator is intended to apply on the 7-level PUC inverter. The applied controller is in charge of setting the PUC structure's capacitor voltage to the desired level so that the output can have seven levels of voltage. The associated pulses for firing the PUC switches are generated using the 7-level pulse width modulation (PWM) method. Through simulations, the introduced controller's performance is examined under a variety of conditions, including load and DC bus voltage variations. The outcomes demonstrate that the controller is capable of excellent dynamic performance and quick response under both stable and unstable conditions.

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III. POWER FACTOR CORRECTION FOR SINGLE PHASE SYSTEM

In the recent years, various PFC techniques have been developed with different DC-DC converters [13]. The boost converter operated in CCM (Continuous Conduction Mode) is the most popular active PFC topology and the same is presented and described in this research work. It provides many advantages over the other types of DC - DC converters. It has excellent features like smooth input current waveform, which reduces filtering requirements and produces less electromagnetic interference. The boost inductor is connected in series with the source so that the inductor current is the replica of source current which makes the control easier. In order to achieve the objectives of input current wave shaping for power factor improvement and output voltage regulation, a nested control configuration is used with outer PI Controller for output voltage regulation and inner current loop, utilizing fixed or variable frequency current controllers for shaping the input current waveform [14]. The PFC techniques for single-phase and three-phase systems developed in this work cover the design and implementation of appropriate DC - DC boost converters using Linear and Non Linear Controllers such as Linear Quadratic Controller (LQC), Hysteresis Controller (HC) and Non-Linear Carrier (NLC) Controller. In order to achieve PFC in single-phase systems, sensing of input voltage, inductor current and output load voltage is required. The schematic of front end active PFC as in Figure 1 consists of an outer voltage control loop, where the output voltage is scaled down suitably for comparison with a set reference voltage and the error is processed using a PI controller. The output of this controller is multiplied by the rectified input voltage so as to generate reference current template. In the inner current loop, the inductor current is compared with the above reference current for obtaining the instantaneous error signal, which acts as a modulating signal in the PWM circuit of the DC boost converter, thereby determining the duty ratio and forcing the converter to attain the required control objectives.
To achieve input current wave shaping which makes the power factor nearer to unity and to obtain a regulated DC output voltage, the Boost Converter is followed by a simple Hysteresis Controller (HC). The major advantages of this control technique are (a) there is no need of compensation ramp as in peak current mode control and (b) the input current is less distorted. In hysteresis current control, two in-phase sinusoidal current references are generated corresponding to maximum and minimum boundary limits and the switch is turned on when the inductor current goes below the lower reference (IL,ref) and is turned off when the inductor current goes above the upper reference (IU,ref) giving rise to a variable frequency control. To achieve smaller ripple in the input current, a narrow hysteresis band is needed.

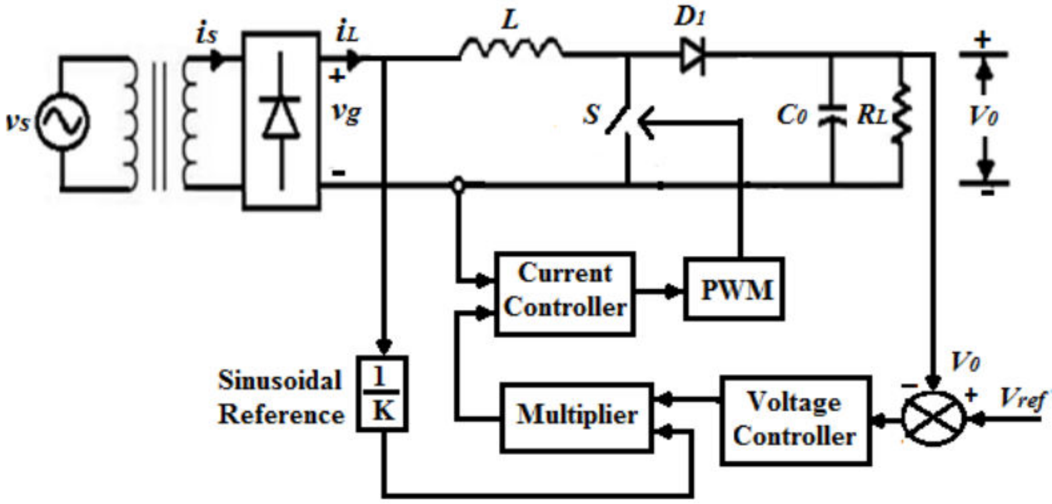

Fig. 4: Single Phase Front End Active PFC Circuit using Boost Converter

The potency of the HC is proved by the simulation results. In spite of its simplicity, variable switching frequency operation of this controller requires complicated filter design and generates more chattering noise and increased level of EMI on the operational side.

IV. MULTI-LEVEL INVERTER

Figure 5 shows the multilevel converter modulation methods. The modulation control schemes for the multilevel inverter can be divided into two categories, fundamental switching frequency and high switching frequency PWM such as multilevel carrier-based PWM, selective harmonic elimination and multilevel space vector PWM Multilevel SPWM needs multiple carriers. Each DC source needs its own carrier. Several multi-carrier techniques have been developed to

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reduce the distortion in multilevel converters, based on the conventional SPWM with triangular carriers. Some methods use carrier disposition and others use phase shifting of multiple carrier signals. By generalizing, for an 'n' level multilevel inverter, (n-1) carriers are needed. The implementation of the various carrier PWM techniques that is possible for multi-level inverters are [5, 6]:

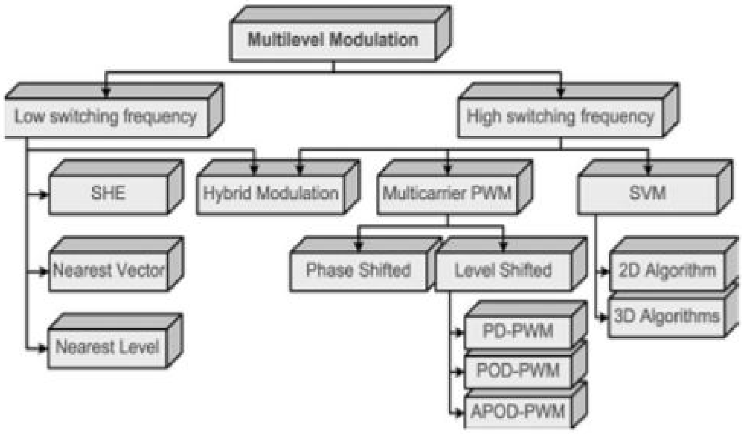

Fig. 5: Multilevel converter modulation methods

Level Shifted PWM (LSPWM)

This modulation method is especially useful for NPC converters, since each carrier can be easily associated to two power switches of the converter. LSPWM leads to less distorted line voltages since all the carriers are in phase compared to PSPWM [7]. In addition, since it is based on the output voltage levels of an inverter, this principle can be adapted to any multilevel converter topology. However, this method is not preferred for CHB and FC, since it causes an uneven power distribution among the different cells. This generates input current distortion in the CHB and capacitor unbalance in the FC compared to PSPWM [8, 9]. Figure 3 shows the LS-PWM carrier arrangements.

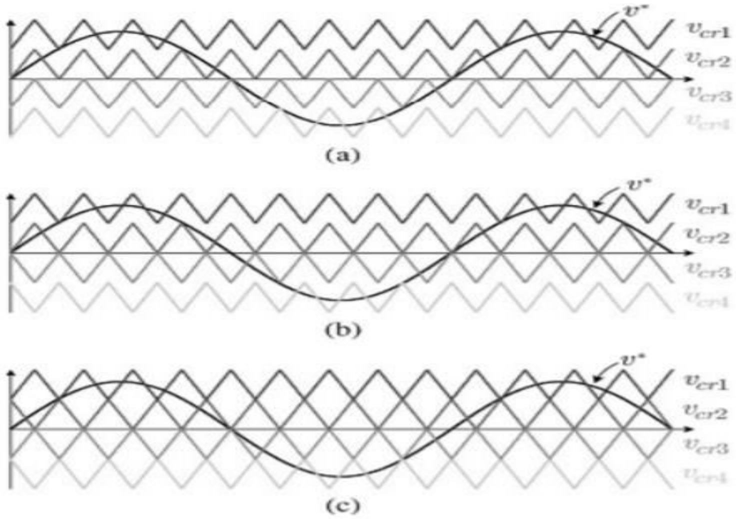

Fig. 6: LS-PWM carrier arrangements: (a) PD, (b) POD, and (c) APOD.

Phase Shift Pulse Width Modulation

PWM signals are pulse trains which are applied to the gate of switches to perform the operation of converter. The pulse trains are fixed frequency and magnitude and variable pulse width [10]. There is one beat of settled extent in each PWM period. In any case, the width of the beats changes from period to period as indicated by a regulating signal. At the point when a PWM flag is connected to the entryway of a power transistor, it causes the turn on and kills interims of the transistor to change starting with one PWM period then onto the next PWM period as indicated by the same

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regulating signal and thus working of converter begins. The recurrence of a PWM flag must be substantially higher than that of the regulating signal, the major recurrence, with the end goal that the vitality conveyed to the heap depends generally on the tweaking signal. The control of yield voltage is done utilizing beat width balance [11, 12].

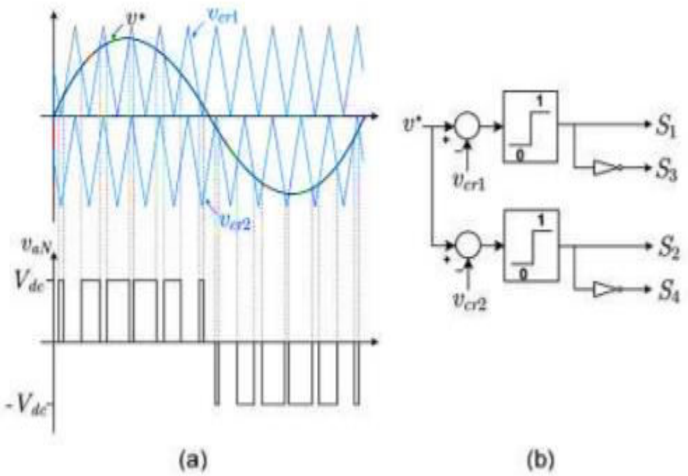

Fig. 7: Phase Shift PWM

This technique uses a set of carriers that are all phase-shifted. The four triangular carriers are phase-shifted by 90^o. Using the same sampling period, it has four times larger switching frequency than that of other techniques. This technique is specially conceived for FC and CHB converters. Since each FC cell is a two-level converter, and each CHB cell is a three-level inverter, the traditional bipolar and unipolar PWM techniques can be used, respectively. Due to the modularity of these topologies, each cell can be modulated independently using the same reference signal [13].

Total Harmonic Distortion

The total harmonic distortion (THD or THDi) is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Distortion factor, a closely related term, is sometimes used as a synonym.

In audio systems, lower distortion means the components in a loudspeaker, amplifier or microphone or other equipment produce a more accurate reproduction of an audio recording.

In radio communications, devices with lower THD tend to produce less unintentional interference with other electronic devices. Since harmonic distortion tends to widen the frequency spectrum of the output emissions from a device by adding signals at multiples of the input frequency, devices with high THD are less suitable in applications such as spectrum sharing and spectrum sensing [14, 15].

In power systems, lower THD implies lower peak currents, less heating, lower electromagnetic emissions, and less core loss in motors.

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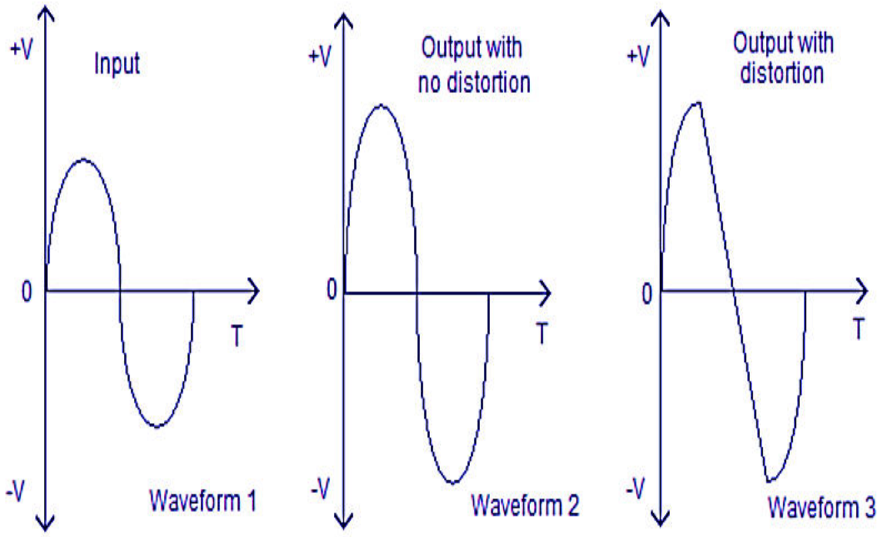

Fig. 8: Output Waveform of Distortion

V. CONCLUSION

The power distribution line problems such as ripples, harmonics and power factor has paved significant interest to researchers for improvisation of algorithms and circuit designs in power converters and inverters. The nonlinear loads cause ripple voltage across the power electronic circuits and results in distorted voltage, line current and reduces power factor in the supply. The ripples increase power loss, and results in low efficiency.

REFERENCES

[1] A. Jain, K. K. Gupta, S. K. Jain and P. Bhatnagar, "A Bidirectional Five-Level Buck PFCRectifierWithWideOutputRangeforEVChargingApplication,"in*IEEETransactionsonPowerElectronics*,vol .37,no.11,pp.13439-13455,Nov.2022,doi:10.1109/TPEL.2022.3185239.

[2] H. Abu-Rub, M. Malinowski, and K. Al-Haddad, Power electronics for renewable energysystems,transportationandindustrialapplications:JohnWiley&Sons,2014.

[3] H. Vahedi and K. Al-Haddad, "Half-Bridge Based Multilevel Inverter Generating HigherVoltage and Power," in Electric Power and Energy Conference (EPEC), Canada, 2013, pp.51-56.

[4] H. Vahedi, S. Rahmani, and K. Al-Haddad, "Pinned Mid-Points Multilevel Inverter (PMP):Three-PhaseTopologywithHighVoltageLevelsandOneBidirectionalSwitch,"inIECON2013-39th Annual Conference on IEEE Industrial Electronics Society, Austria, 2013, pp.100-105.

[5] H. Vahedi, K. Al-Haddad, Y. Ounejjar, and K. Addoweesh, "Crossover Switches Cell(CSC):ANew MultilevelInverterTopologywith MaximumVoltageLevels andMinimumDC Sources," in IECON 2013-39th Annual Conference on IEEE Industrial ElectronicsSociety,Austria,2013,pp. 54-59.

[6] H.Vahedi,K.Al-Haddad,P.-A.Labbe,andS.Rahmani,"CascadedMultilevelInverterwithMulticarrier PWM Technique and Voltage Balancing Feature," in ISIE 2014-23rd IEEEInternationalSymposium on IndustrialElectronics,Turkey, 2014, pp. 2151-2156.

[7] M. Sharifzade, H. Vahedi, A. Sheikholeslami, H. Ghoreishy, and K. Al-Haddad, "SelectiveHarmonicEliminationModulationTechniqueAppliedonFour-LegNPC,"inISIE2014 23rd IEEE International Symposium on Industrial Electronics, Turkey, 2014, pp. 2163-2168.

[8] H.Vahedi,K.Al-Haddad,andH.Y.Kanaan,"ANewVoltageBalancingControllerAppliedon 7-Level PUC Inverter," in IECON 2014-40th Annual Conference on IEEE IndustrialElectronicsSociety, USA,2014, pp. 5082-5087.

[9] H. Vahedi, P.-A. Labbe, H. Y. Kanaan, H. F. Blanchette, and K. AlHaddad, "A New Five-LevelBuck-BoostActiveRectifier,"inIEEEInternationalConferenceonIndustrialTechnology (ICIT), Spain, 2015, pp. 2559-2564.

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| DOI: 10.15680/IJIRCCE.2023.1105341 |

[10] M. Sharifzadeh, H. Vahedi, A. Sheikholeslami, P.-A. Labbé, and K. Al-Haddad, "HybridSHM-SHE Modulation Technique for Four-Leg NPC Inverter with DC Capacitors Self-Voltage-Balancing,"IEEETrans.Ind.Electron.,vol.62,pp.4890-4899,2015.

[11] M. T. Chebbah, H. Vahedi, and K. Al-Haddad, "Real-Time Simulation of 7-Level PackedU-Cell Shunt Active Power Filter," in ISIE 2014-24th IEEE International Symposium onIndustrialElectronics, Brazil, 2015, pp. 1251-1256.

[12] M. Sharifzade, H. Vahedi, A. Sheikholeslami, H. Ghoreyshi, and K. Al-Haddad, "Modifiedselective harmonic elimination employed in four-leg NPC inverters," in IECON 2014-40thAnnualConference of the IEEE Industrial Electronics Society, 2014, pp. 5196-5201

[13] P. Kong, Y. Jiang, and F. C. Lee, "Common mode EMI noise characteristics of low-powerAC–DCconverters," PowerElectronics, IEEETransactionson, vol.27,pp.731-738, 2012.

[14] H. Y. Kanaan and K. Al-Haddad, "Three-Phase Current-Injection Rectifiers: CompetitiveTopologiesforPowerFactorCorrection,"IEEEInd.Electron.Mag.,vol.6,pp.24-40,2012.

[15] H.VahediandK.Al-Haddad,"ANovelmultilevelmultioutputbidirectionalactivebuckpfcrectifier,"IEEE Trans. Ind. Electron., vol. 63, no.9, pp. 5442–5450, 2016.

[16] A.Kaymanesh,A.Chandra,andC.Mulligan,"ANovelBidirectionalSingle-PhaseFifteen-LevelBuck-BoostRectifierforPowerFactorCorrectionwithReducedSwitchCount,"IEEEInt.Symp. Ind. Electron., vol. 2021-June,2021.

[17] J. S. Lee, U. M. Choi, and K. B. Lee, "Comparison of tolerance controls for open-switchfaultinagrid-connectedT-typerectifier,"IEEETrans. PowerElectron.,vol.30,no.10,pp.5810–5820, 2015.

[18] S. K. Chattopadhyay and C. Chakraborty, "A New Multilevel Inverter Topology With Self-Balancing Level Doubling Network," IEEE Trans. Ind. Electron., vol. 61, no. 9, pp. 4622-4631, Sept. 2014.

[19] R.Vasu,S.K. Chattopadhyayand C.Chakraborty, "Asymmetric CascadedH-BridgeMultilevel Inverter With Single DC Source per Phase," IEEE Trans. Ind. Electron., vol. 67,no. 7, pp. 5398-5409, July 2020.

[20] Jain, A.; Gupta, K.K.; Jain, S.K.; Bhatnagar, P.; Vahedi, H. A V2G Enabled BidirectionalSingle/Three-Phase EV Charging Interface Using Modular Multilevel Buck PFC Rectifier.Electronics 2022, 11, 1891. https://doi.org/10.3390/electronics11121891

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