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A futuristic digital interface with a glowing Earth globe in the center. The background is dark blue with various data visualizations, including bar charts, line graphs, and text boxes. The text 'BUSINESS', 'NETWORK SEARCH', and 'WORLD' is visible. A hand is shown at the bottom, interacting with the interface.

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Five Level Reduce Switch Count Boost PFC Rectifier with Multicarrier PWM

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ABSTRACT: The high efficiency and uninterpretable power supply are the most important criteria in the power distribution system due to the regular shortfalls in fossil fuels and extreme emission regulations. The distributed generating systems are the promising solutions and gaining more attention towards renewable energy which provides a flexible system configuration to integrate the DERs which include solar Photo-voltaic, wind, fuel cell, super capacitors and energy reserves etc. The recent advancement in power electronic converters is grasped much attention in the field of distributed generation, electric vehicle applications and integration of generating systems with islanded/grid-tied. In two-stage EV charging systems, the grid power input is first transformed by an AC-to-DC converter into a constant DC output voltage. In the case of single-phase boost rectifiers, the output voltage varies from 400 VDC to 500 VDC. In this design, the rectifier's and the DC-DC converter's power switches' combined total standing voltage (TSV) equals the DC-link voltage.

KEYWORDS: Multi-level Inverter, 5-level, Boost Factor, Rectifier, EV Charging

I. INTRODUCTION

Power Electronics is the innovation behind the transformation of electrical energy from a source to the prerequisites of the end-user. Despite the fact that it is of vital significance to both industry and the individual resident is present. The necessary hardware for vitality transformation can be isolated into four types namely AC-DC rectifiers, DC-DC converters, DC-AC inverters and AC-AC transformers [1]. DC-AC inverters can be separated into two group: Pulse Width Modulation (PWM) inverters and Multilevel Inverters (MLIs). MLIs were designed in the mid-1980 and grew rapidly. Numerous new topologies have been composed and connected to modern applications, particularly in sustainable power source frameworks. Common circuits incorporate diode clamped inverters, capacitor clamped inverters and hybrid H-bridge MLIs. MLIs overcame the drawbacks of the PWM inverter and paved the way for industrial applications [2, 3]. To date, DC-AC conversion techniques can be sorted into two categories: Pulse Width Modulation and multilevel modulation. Each category has many circuits to implement the modulation. The PWM method is suitable for DC-AC conversion, since the input voltage is usually a constant DC voltage [4]. The Pulse Phase Modulation (PPM) method is also possible but is less convenient. The Pulse Amplitude Modulation (PAM) method is not suitable for DC-AC conversion since the input voltage is usually a constant DC voltage. PWM operation has all the pulses. Leading edge starting from the beginning of the pulse period and their trailer edge is adjustable. Multilevel inverters were invented in the late 1970's [5]. The first MLI was constructed using diode-clamped and capacitor clamped circuits. Later, different MLIs were developed. MLIs are an appealing contrasting option to enhance the output by blending a staircase waveform mimicking a sinusoidal waveform. Such a waveform has a low distortion, as well as lowers the dv/dt stress. Also, MLIs can operate at both fundamental switching and high frequency switching using PWM. In this manner, for high power/high voltage applications, a MLI can accomplish better output waveform utilizing medium voltage control switches and henceforth favours over established two-level inverters.

II. BOOST PFC RECTIFIER

The operation of boost PFC converter is involved in a single stage as shown in Fig. 1 with a combined structure of diode bridge rectifier along with DC to DC boost converter. Hence the conversion of AC to DC is done by the rectifier unit and the DC to DC transformation is done through boost converter for enhanced DC-bus voltage.

The key function of the PFC boost topology is to convert AC into DC with an improved input power factor. This kind of converters is suitable for input side harmonic reduction of the system with a filter design of combined inductance (L) and capacitance (C). The operation of the converter can be expressed in two modes as follows, Mode.1: In this case, switch S is in ON state then the input inductor L_i ($L_i = L_A, B, C$) start charging from input through the switch and the output capacitors C discharge through the load R, where diode 'D' is inactive [6, 7].

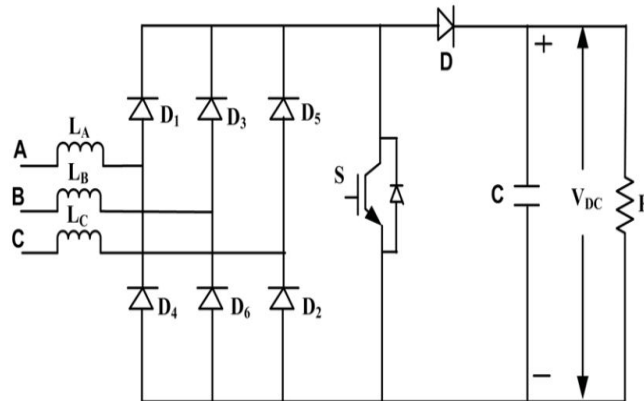


Fig. 1: Single switch boost PFC converter

Six Switch PWM Rectifier

A three phase six pulse PWM rectifier as depicted in Fig. 2 has an ability to operate in rectifier mode and inverter mode due to bidirectional power flow capability. And also it can operate with unidirectional switch mode with simple structure. This kind of converters has a capability to regulate and control the voltage and current [8, 9]. The converter is controlled via outer control loop for output voltage and the inner control loop for output current. The input inductors form a boost configuration to enhance the voltage parameter for the required level at desired duty cycle and switching frequency. It can provide the low ripple current at the front-end of the network which results in power factor improvement at the AC side of system.

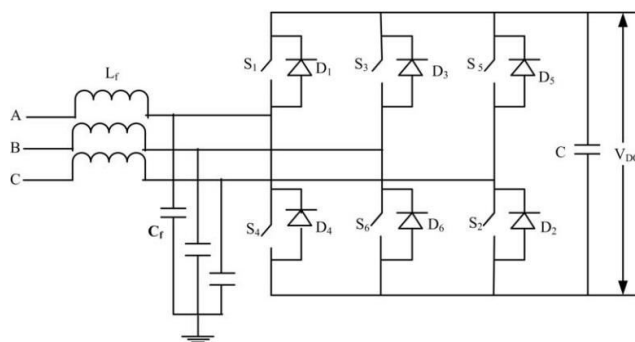


Fig. 2: Six-pulse PWM converter

Three-phase PWM converter with a neutral point configuration as depicted in Fig. 3, is preferred for AC to DC conversion where bidirectional power flow is adequate. It can offer reduced switching losses and improved power factor. This kind of converters is essential for the power conversion (AC to DC) from the utility grid to feed the low voltage DC distribution networks. The drawback of unbalanced DC-link voltage of the six switch PWM converter configuration is overcome by the six-pulse PWM converter with voltage balancer but the circuit complexity increased as increase in number of devices. The 6-pulse PWM converter with a neutral point connection with voltage balancer is the front-end and as well as back-end conversion solution to get the balanced voltage in the system [10].

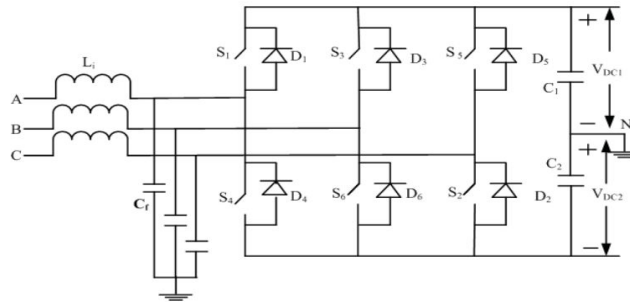


Fig. 3: Six-pulse PWM converter with a neutral point

III. PROPOSED METHODOLOGY

In this work proposed a novel 5 level rectifier which is suitable to connect EV and transmit a power to the grid. Proposed rectifier generates a five level at the output of the inverter as V_{dc} , $V_{dc}/2$, 0 , $-V_{dc}/2$, V_{dc} . Proposed topology is represented in figure 4. This topology has 4 unidirectional switch and 1 bidirectional switch and it have 2 capacitors as a dc-bus capacitor which is connected after the first stage which is DC-DC boost converter. Levelled voltage as a five-level voltage occurs at the output of the inverter.

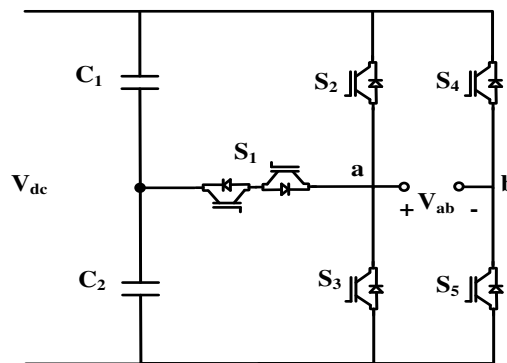


Fig. 4: Proposed five level topologies

+V_{dc} level

By turning ON switch S2 and S5 and other switch OFF, capacitors C1 and C2 are connected in series through the load and it gives +V_{dc} voltage at the output of inverter. This stage specified in Figure 5.

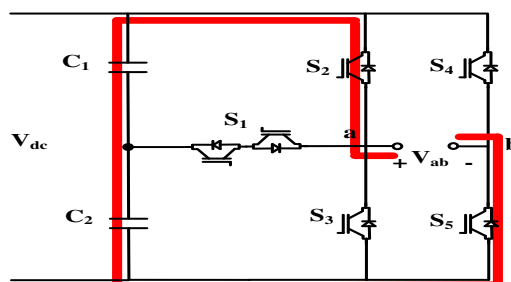


Fig. 5: +V_{dc} Level

+V_{dc}/2 Level

By turning ON switch S1 and S5 and other switch OFF, capacitors C2 is connected in series through the load and C1 is by passed and it gives +V_{dc}/2 voltage at the output of inverter. This stage specified in Figure 6.

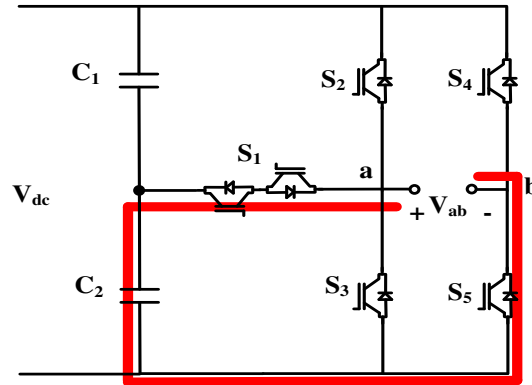


Fig. 6: +V_{dc}/2 Level

0 Level

By turning ON switch S2 and S4 and other switch OFF, capacitors C1 and C2 are by passed and it gives 0 voltage at the output of inverter. This stage specified in Figure 7.

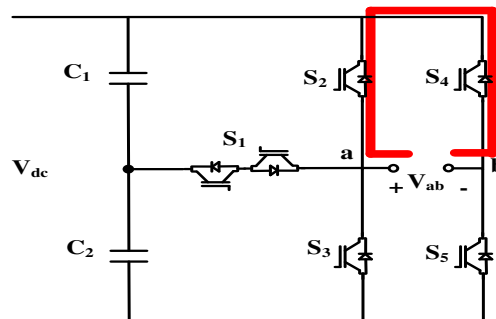


Fig. 7: 0 Level

-V_{dc}/2 Level

By turning ON switch S1 and S4 and other switch OFF, capacitors C1 is connected in series through the load and C2 is by passed and it gives -V_{dc}/2 voltage at the output of inverter. This stage specified in Figure 8.

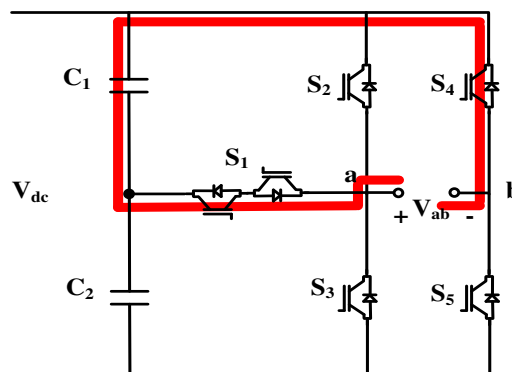


Fig. 8: -V_{dc}/2 Level

-V_{dc} Level

By turning ON switch S3 and S4 and other switch OFF, capacitors C1 and C2 are connected in series through the load and it gives -V_{dc} voltage at the output of inverter. This stage specified in Figure 9.

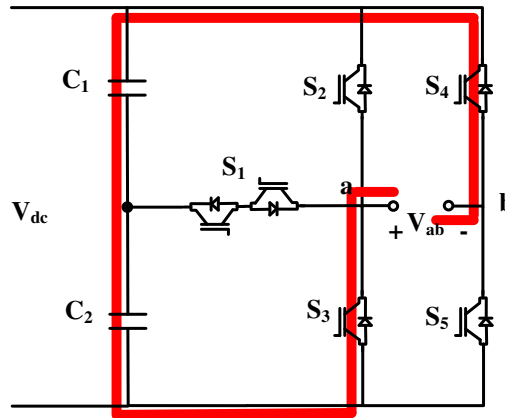


Fig. 9: -Vdc Level

Generation of PWM signal for the proposed converter described in Table 1

Table 1: Switching States of the Proposed 5-Level Converter

State	Voltage Level	S1	S2	S3	S4	S5
1	+Vdc	0	1	0	0	1
2	+Vdc/2	1	0	0	0	1
3	0	0	1	0	1	0
4	0	0	0	1	0	1
5	-Vdc/2	1	0	0	1	0
6	-Vdc	0	0	1	1	0

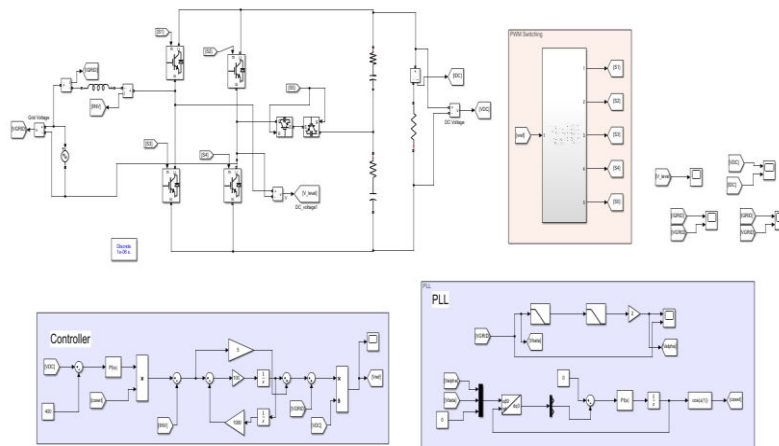


Fig. 10: Simulation of proposed boost PFC rectifier

IV. SIMULATION RESULT

A Vehicle to Grid that is a bidirectional flow of energy between the EVs and the grid. This work gives a detailed and thorough description of the V2G technology with a broad focus. For electric vehicle charging need to required AC-DC converter for the PFC and DC voltage regulation and DC-DC converter for state of charge (SOC) control. For AC-DC rectification proposed a converter that is operate as a buck mode for charging and boost mode for discharging. Figure xx shows the charging and discharging process. In the case of charging (before the time $t < 1$) grid voltage is in phase with grid current that means angle between both is 0° i.e., the power factor is unity and current direction is from grid to vehicle. Furthermore, in the discharging mode the grid current direction is reversed so both are in 180° out of phase. That means the current direction is from vehicle to grid. Figure 11 and 12 show the phase angle between grid voltage and current for V2G and G2V operation.

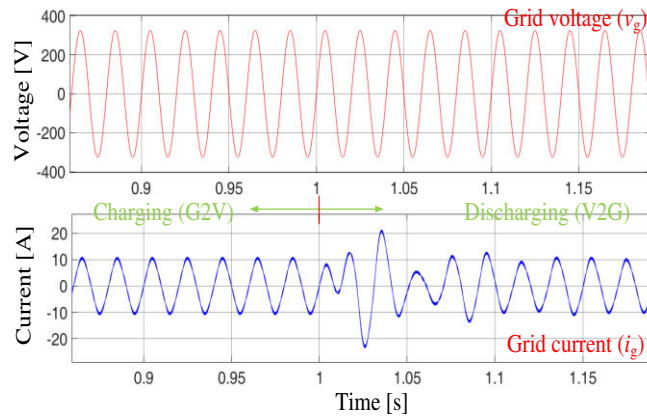


Fig. 11: Grid voltage and grid current to verifying the charging and discharging mode

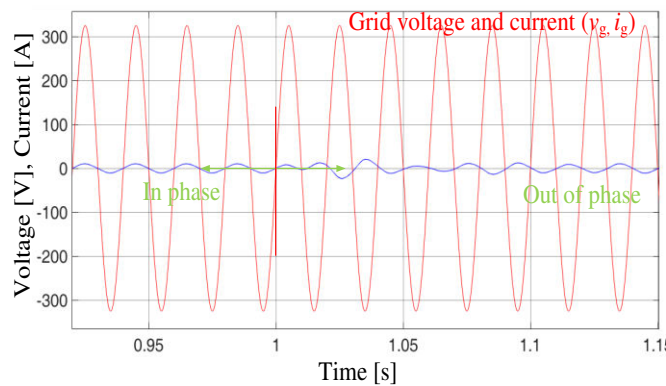


Fig. 12: Grid voltage and grid current to validate PFC

For the battery charging operation, the battery current is positive and in the discharging operation battery current is negative. In both cases the DC output voltage, which is regulated by the rectifier is balanced to the 400V. Also, the battery voltage changes as the discharging mode operate. Voltages and currents are balanced in the fraction of time so it shows the controller tracking accuracy. Figure 13 shows the rectifier regulated voltage, battery voltage and battery current for charging and discharging mode of operation.

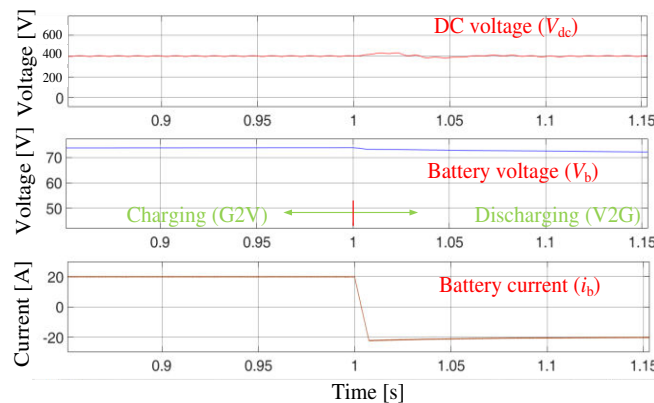


Fig. 13: V2G operation with output voltage of rectifier, battery voltage and battery current for charging and discharging mode

For charging mode state of charge (SOC) is increases and for discharging process SOC is decreases. Figure 14 shows the SOC battery voltage and battery current where the slop of the SOC i.e., charging power and discharging power is



same and it can be regulated by the controller. A grid current and grid voltage are stable in the fraction of time and improving the performance of the operation. Figure 15 shows the grid voltage, rectifier regulated DC voltage and the terminal five-level voltage. At the time $t=1$ the mode changes from charging to the discharging. In this mode change operation the waveforms are stabilized at the fraction of time.

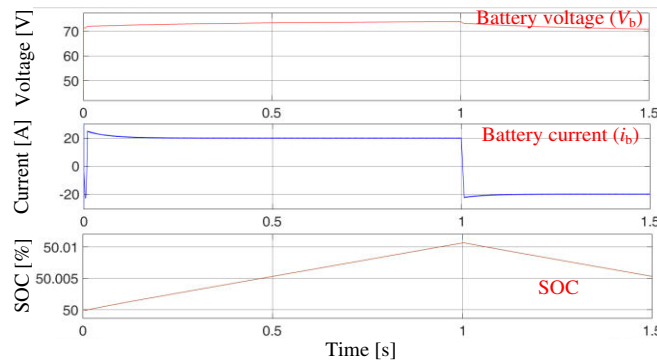


Fig. 14: V2G operation with battery voltage, battery current and state of charge (SOC)

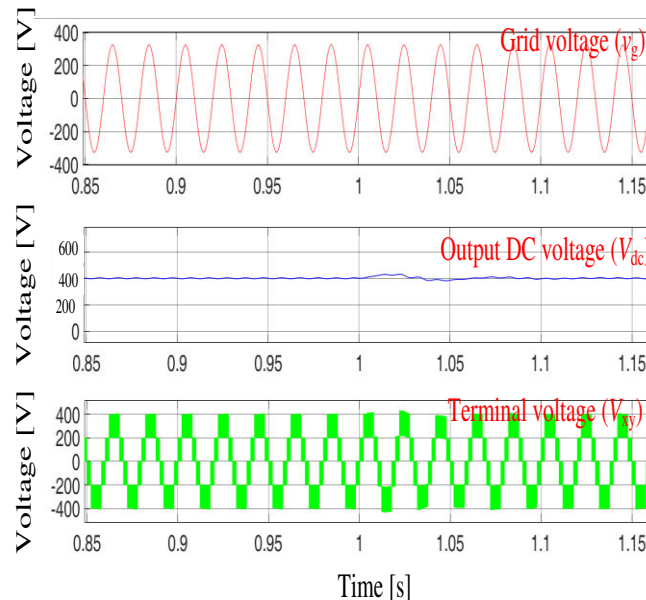


Fig. 15: Waveforms for V2G operation in charging and discharging mode

V. CONCLUSION

Multilevel Inverters (MLI) have been under innovative work for over three decades and have discovered useful modern applications. Be that as it may, this is yet an innovation being worked on and numerous new commitments and new commercial topologies have been accounted for over the most recent couple of years. MLI have been drawing in expanding interest because of the fundamental reasons like improved power ratings, harmonic performance and reduced Electromagnetic Interference (EMI) discharge that can be filled with various DC levels that are a combination of the output voltage waveform. Specifically, MLI have an adequate usage in applications such as medium- voltage industrial drives, electric vehicles and photovoltaic systems. The present work gives a solution for planning an active multilevel topology which is suited for medium and high power industrial applications.

REFERENCES

- [1] Jain, A.; Gupta, K.K.; Jain, S.K.; Bhatnagar, P., “A Bidirectional Five-Level Buck PFC Rectifier with Wide Output Range for EV Charging Application”, IEEE Trans. Power Electron, vol. 37, pp. 13439–13455, 2022.



- [2] Ebrahimi, J.; Karshenas, H.; Bakhshai, A., “A Five-Level Nested Diode-Clamped Converter for Medium-Voltage Applications”, *IEEE Trans. Power Electron*, vol. 69, pp. 6471–6483, 2022.
- [3] Lee, M.; Lai, J.S., “Fixed-Frequency Hybrid Conduction Mode Control for Three-Level Boost PFC Converter”, *IEEE Trans. Power Electron*, vol. 36, pp. 8334–8346, 2021.
- [4] Zhang, P.; Wu, X.; Chen, Z.; Xu, W.; Liu, J.; Qi, J. A., “Multizero-Sequence Component Injection Algorithm for a Five-Level Flying Capacitor Rectifier under Unbalanced DC-Link Voltages”, *IEEE Trans. Power Electron*, vol. 36, pp. 11967–11983, 2021.
- [5] De Souza Kohler, M.A.F.; Cortez, D.F., “Single-Phase Five-Level Flying-Capacitor Rectifier Using Three Switches”, *IEEE Open J. Power Electron*. Vol. 1, pp. 383–392, 2020.
- [6] Lee, M.; Kim, J.W.; Lai, J.S., “Digital-Based Critical Conduction Mode Control for Three-Level Boost PFC Converter”, *IEEE Trans. Power Electron*, vol. 35, pp. 7689–7701, 2020.
- [7] Zhang, X.; Tan, G.; Xia, T.; Wang, Q.; Wu, X., “Optimized Switching Finite Control Set Model Predictive Control of NPC Single-Phase Three-Level Rectifiers”, *IEEE Trans. Power Electron*, vol. 35, pp. 10097–10108, 2020.
- [8] He, X.; Yu, H.; Han, P.; Zhao, Z.; Peng, X.; Shu, Z.; Koh, L.; Wang, P., “Fixed and Smooth-Switch-Sequence Modulation for Voltage Balancing Based on Single-Phase Three-Level Neutral-Point-Clamped Cascaded Rectifier”, *IEEE Trans. Ind. Electron*, vol. 56, pp. 3889–3903, 2020.
- [9] Qi, W.; Li, S.; Yuan, H.; Tan, S.C.; Hui, S.Y., “High-Power-Density Single-Phase Three-Level Flying-Capacitor Buck PFC Rectifier”, *IEEE Trans. Power Electron*, vol. 34, pp. 10833–10844, 2019.
- [10] Mukherjee, D.; Kastha, D. A., “Reduced Switch Hybrid Multilevel Unidirectional Rectifier”, *IEEE Trans. Power Electron*, vol. 34, pp. 2070–2081, 2019.
- [11] Jang, Y.; Jovanović, M.M.; Kumar, M.; Ruiz, J.M., “Three-Level TAIPEI Rectifier—Analysis of Operation, Design Considerations, and Performance Evaluation”, *IEEE Trans. Power Electron*, vol. 32, pp. 942–956, 2017.
- [12] Monteiro, V.; Pinto, J.G.; Meléndez, A.A.N.; Afonso, J.L., “A novel single-phase five-level active rectifier for on-board EV battery chargers.”, In *Proceedings of the IEEE 26th International Symposium on Industrial Electronics (ISIE)*, Edinburgh, pp. 582–587, 2017.
- [13] Kim, J.-S.; Lee, S.-H.; Cha, W.-J.; Kwon, B.-H., “High-Efficiency Bridgeless Three-Level Power Factor Correction Rectifier”, *IEEE Trans. Ind. Electron*, vol. 64, pp. 1130–1136, 2017.
- [14] Zhang, L.; Sun, K.; Xing, Y.; Zhao, J. A., “Family of Five-Level Dual-Buck Full-Bridge Inverters for Grid-Tied Applications”, *IEEE Trans. Power Electron*, vol. 31, pp. 7029–7042, 2016.
- [15] Vahedi, H.; Shojaei, A.A.; Chandra, A.; Al-Haddad, K., “Five-Level Reduced-Switch-Count Boost PFC Rectifier with Multicarrier PWM”, *IEEE Trans. Ind. Appl.*, vol. 52, pp. 4201–4207, 2016.



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