RESEARCH ARTICLE

SAMRIDDHI Volume 14, Issue 2, 2022 Print ISSN: 2229-7111 Online ISSN: 2454-5767

Multi-level Pulse Width Modulation, Inverter for PV Systems Improving the Total Harmonics Distortion

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Abstract

In the last few years, the use of semiconductors in the electronic market has increased a lot, due to which its utilization in power electronic devices has also increased greatly, including UPS, AC drives, high voltage direct current (HVDC)transmission line rectifiers, inverters and many more. We categorize the inverter in many ways like diode line capacitor cascade h-bridge diode climb like this but we do voltage source inverter in two ways if we look like multi-level inverter then two-level inverter multi-level letter Maybe and we are using multi-level inverter here. In this paper, we are discussing the performance of second level inverter using space vector PWM and further using for mains performance using disposition multicarrier moderation. In this paper we are using fuzzy logic to control WM, the factors we are working out are the total harmonics distortion switching frequency switching losses and the number of switching devices. Here the complete simulation is using MATLAB/Simulink software.

Keyword: AC drives, Cascaded H-bridge, Fuzzy logic, HVDC transmission, Multi-level inverter, UPS.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2022); DOI: 10.18090/samriddhi.v14i02.15

Introduction

The 70's power electronic controller has lot of potential whose improve the performance of the system. Now, power electronic controller are more accurate and advance, so that energy consumption, power quality and efficiency has more suitable.

It is problem to connect medium range voltage system in the grid so that need the some type of power electronic devices. This type of semiconductors devices that directly used in high performance and it utilizes to directly control of high power and medium power voltage such as mills, compressor, conveyor, pumps and many more. Multi-level inverter has not only cost effective but also achieve the high power. It consume the low power so that it can be use in low power application such as solar cell, wind turbine, and wave power conversion so on.

The most common early application of multi-level converters has been in traction in both locomotive and trackside static converters. More recent applications have been for power system converters for VAR compensation and stability enhancement, active filtering, high-voltage motor drives, high-voltage DC transmission, and more recently medium voltage induction motor variable speed drives. Industrial medium-voltage for many multistage converter applications renewable energy systems, flexible AC transmission systems (FACTS), and traction drive systems

Discription

The proposed system is designed to improve the accuracy of the multi-level inverter. In which, fuzzy logic controls the inverter controller. The proposed paper has based on renewable energy i.e. solar energy. Solar modules have design at various irradiance values that vary from 100 to 1000 W/m^2 at a constant temperature. Solar panels generated power to deliver the system, where the dc link purified the presented fluctuation. And DC-DC boost converter has a controller controlled by using incremental conductance (MPPT technique). Boost converter has provided the required voltage. After that, the neutral point junction has created a point, i.e., neutral point. Inverter requires three supply positive supply, negative supply, and neutral point, generating three phase AC supply. And this supply is connected to the grid using transmission line.

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How to cite this article: Simran, S., Nayak, R. (2022). Multi-level Pulse Width Modulation, Inverter for PV Systems Improving the Total Harmonics Distortion. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology,* 14(2), 211-215.

Source of support: Nil

Conflict of interest: None

Cascaded H-bridge MLI Topologies

An advantage of Cascade H-bridge (CHB) (MLI) over other topology types is that they have a balanced DC-link voltage, require a minimum number of components per phase, the circuit layout is modular, and it is less Offers switching

frequency and low THD. By increasing the number of its production levels. But this CHB MLI needs independent DC power supply where isolation and balancing is required. Where this topology produces 2n+1 output voltage level from n DC power supplies which are another drawback of CHB. To overcome the above-mentioned drawback many types of research have been done in the field of power electronics. Using different DC voltage supplies (asymmetrical) is one of the solutions to overcome the drawbacks. Used flying-capacitor with a CHB to overcome the mentioned drawbacks of CHB.

The equivalent circuit of a PV module is shown in the Figure 2. It consists of a shunt resistance (R_{sh}), series Resistance (R_s) and a diode. Iph is the light generated current, which changes as solar radiation and temperature vary. The output powerP_{ph} extracted from the module can be calculated as;

$$P_{ph} = \mathbf{V_{pv}} * I_{ph} \quad (1)$$

Following Figure 2 current equation can be drive as

$$I = I_{pv} - I_D - I_{sh} \quad (2)$$

Where the total current is generated from the solar cell and is denoted as "I", photon current as "I_{pv}", diode current flows as I_D and marked as "i_{sh}" through the shunt resistor has been "".

For solar cell [1]:

$$I_D = I_0\left[\exp^{\left(\frac{V+IR_s}{aV_{th}}\right)} - 1\right] \quad (3)$$

$$I_{sh} = \frac{V + IR_s}{R_{sh}} \quad (4)$$

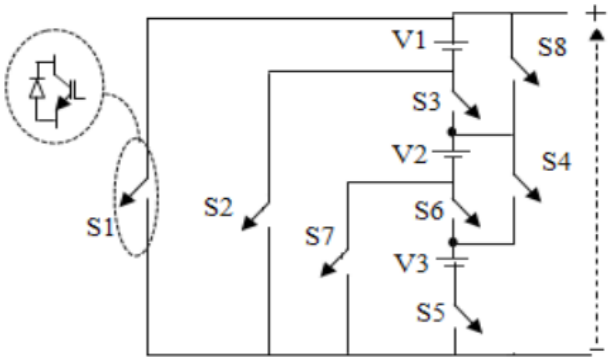

Figure 1: Basic unit of proposed topology

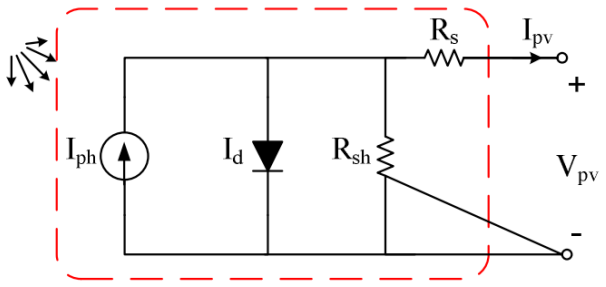

Figure 2: Characteristic of the Solar cell

Equation (1) can be written now,

$$I = I_{pv} - I_0\left[\exp^{\left(\frac{V+IR_s}{aV_{th}}\right)} - 1\right] - \frac{V + IR_s}{R_{sh}} \quad (5)$$

where, "I_0" is the reverse saturation current, "R_s" is the series of a PV cell and "R_{sh}" is the resistance shunt of a PV cell, the diode ideal factor is denoted as "a", and the thermal voltage Marked as "V_{th}". It is given here.

$$V_{th} = \frac{KT}{q} \quad (6)$$

Where, the Boltzmann constant denoted as "K" and its value 1.23 x $10^{(-23)}$ J/K, the cell temperature denoted as "T", and the charge of an electron as "Q" and its value Marked as 1.6 x 10^{19} c. Know the total number of solar-linked series N, which is marked as "Ns" by solar modules and number series and number of parallels is denoted as "N_p" connected solar panels, the current equation for PV array mathematically is shown:

$$I = N_p I_{pv} - N_p I_0\left[\exp\left(\frac{V + IR_s}{\frac{N_s}{aNV_{th}}}\right) - 1\right] - \frac{V + IR_s}{R_{sh}} \quad (7)$$

Fuzzy Logic Controller

Fuzzy logic is the latest type of control system that optimizes any system, which becomes the system's efficiency, and this is how it is used. We are proposing it in the paper and explaining more about it below.

- *Input Scaling or Normalization:* Number of Input set, i.e., categorized into error(e) and change or error, scaling Factor are used to simplify the mapped sets of input.
- *Fuzzification:* Set of Input transferred into a fuzzy logic set, fuzzy logic set make to rules statement to compatible to it.
- *Inferencing (inference engine):* inferencing Converts all inputs received and checks them equally and the inputs are set through a rule base. For this logic gate, equality OR and AND operator are used.
- *Deffuzzication:* Defuzzification evaluates the output result of inference and converts the several logic sets into a single output. The inferencing work is based on logic rules.
- *Output scaling or denormalization:* the defuzzied normalized control output is mapped into physical value by the output scaling factor Gu.

Fuzzy logic control is an artificial intelligence control algorithm whose utilize without solving any mathematics equation improves the performance. Input and output are non-fuzzy values. The block diagram of FLC is shown in Figure 3.

Here Mamdani is used to type fuzzy reasoning motion controller. Speed error (E) and change of speed error (CE) are inputs to fuzzy controller. The speed is calculated by comparing the error reference speed (ΩREF) with actual speed (Ω). The controller's output is treated as a reference current (ref i).

Fuzzy membership functions for (a) speed error (b) change in speed error (c) reference current

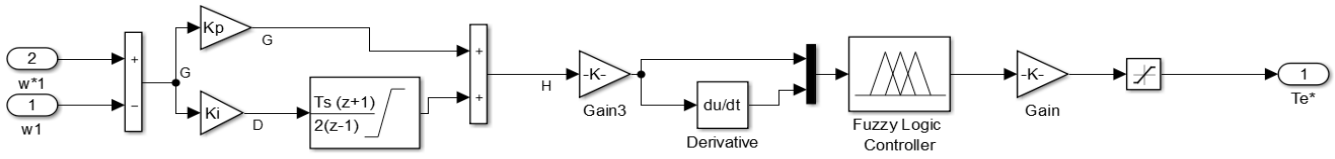

Figure 3: Fuzzy Logic Controller

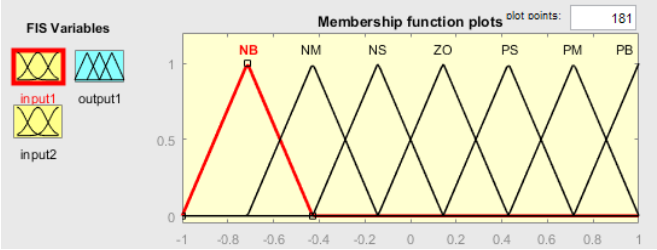

Figure 4: (a) fuzzy logic membership function

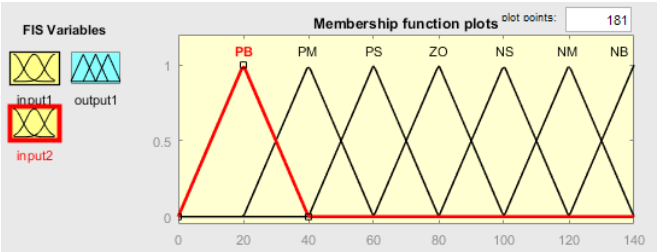

Figure 4: (b) fuzzy logic membership function

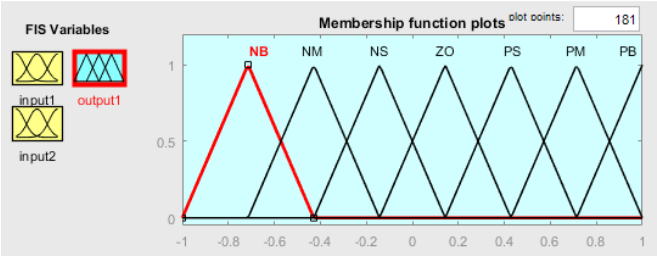

Figure 4(c): Fuzzy logic Membership function

Harmonic Reduction in Inverter

In case of inverter, it is very important to remove harmonics from AC output. The harmonics present in a DC to AC inverter are much clearer than the harmonics that can be introduced in an AC to DC converter. The reason for this is the output from DC to AC inverter. Thus, the filters used in a DC to AC inverter have a different design than the filters used in AC to DC converters. In the case of AC to DC converters its main purpose is to improve the output voltage ripple. Thus, passive filters can easily be used to improve the output of the AC to DC converter. Whereas, in the case of DC to AC inverter, harmonic deduction is difficult and involves using active filters. One such technique is described below.

The ratio of Vr/Vc is called the modulation index (MI) and it controls the harmonic content of the output voltage waveform. The magnitude of the fundamental component

Rule base table used in the system

Table 1: Rule base table

e/ce	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PS	PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

of the output voltage is proportional to Mi, but Mi can never exceed unity. Thus, the output voltage is separately controlled by the MI.

Multicarrier Pulse Width Modulation

The most common and popular digital purine wave generation technique is pulse width modulation. PWM technology involves the production of a digital waveform for which the duty cycle is modulated such that the average voltage of the wave corresponds to the pure sine wave. The simplest way to produce a PWM signal is through comparison of a low power reference with a triangular wave. Multicarrier PWM methods use higher switching frequency carrier waves than the reference wave to generate a sinusoidal output wave. Multicarrier PWM waveform for cascade multi-level inverter. The ratio of Vr/Vc is called modulation index (MI) and it controls the harmonic content of the output voltage waveform. The magnitude of the fundamental component of the output voltage is proportional to Mi, but Mi can never exceed unity. Thus, the output voltage is separately controlled by the MI.

Simulation Results

This proposed system simulated on Matlab/Simulink as shown in fig. 5. Here, the Photovoltaic array has generated the maximum power and applied the maximum power generation use incremental technique (MPPT). The proposed system is categorized into several parts: Solar PV system, DC-DC boost converter, (incremental conductance) maximum power point controller, multi-level inverter, transmission line, and grid. This PV system was simulated at 33kV grid. This propose system has been designed, the total power of the system is 100kW at 1000 W/m2 solar

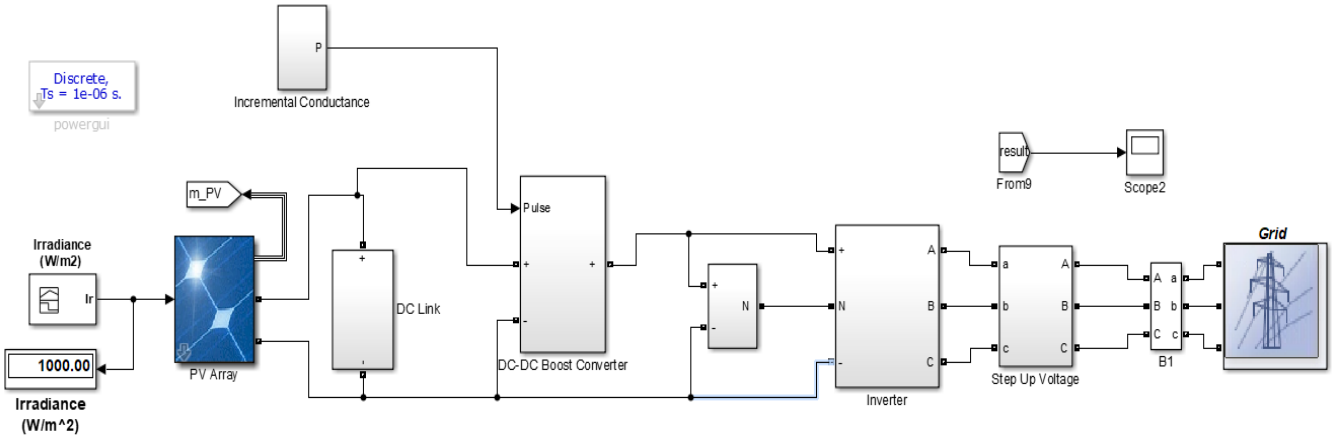

Figure 5: Simulation model of the proposed system

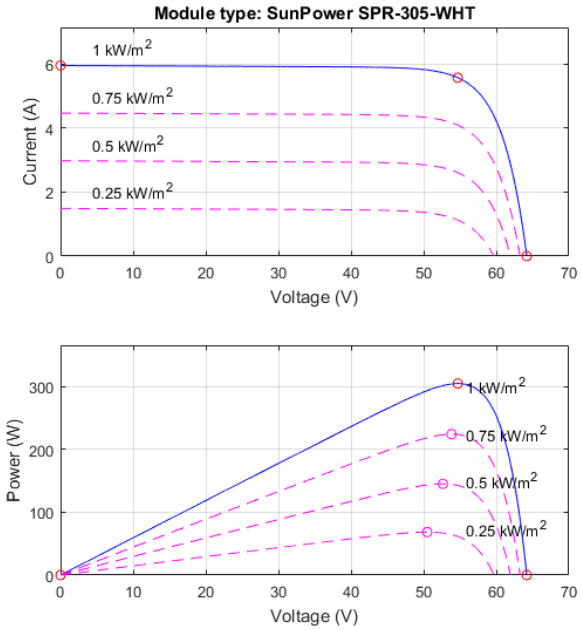

Figure 6: (a) PV Panel Curve Gragh

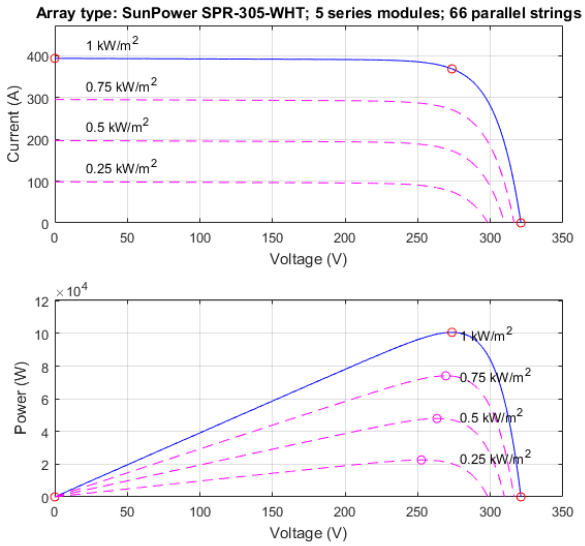

Fig 6: (b) PV Array Curve Gragh

irradiance and the maximum voltage generated about 220V.

The graph shows how much value can be generated by the solar panel. In this proposed system, we take solar panel of the SunPower compony, and it's model number is SPR-305-WHT. And it means, it can generate 305 Watts on only one solar panel. Both curves have denoted as maximum output get at the solar PV panel. And as shown, in sinple PV module, 6 amp current and 65 volts can draw on the 1kW/m^2 irradiance. And same as 305W power can draw in a single module

As shown in Fig. 7 the voltage graph shows that the voltage is constant at different positions as the radiation of the system must vary at different points so that its value also varies figurative form. Turns out that three-phase AC supplies provide a continuous signal on the grid. In the first figure,

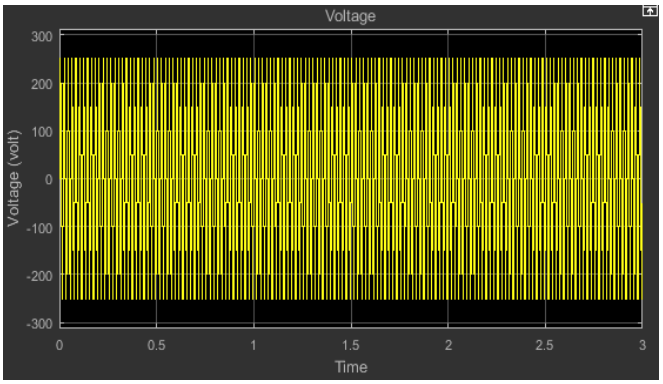

Figure 7: Simulation Result of Multi-level PWM Inverter

single line shows fluctuations due to changes in voltage and second, single phase current shows without radiation.

THD checks the availability of harmonic in the signal as consider five cycles in the signal and check the harmonic

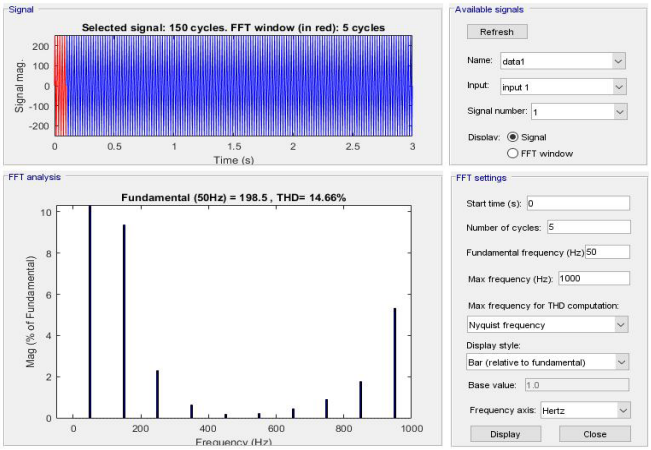

Figure 8: Chart of the Total Hormonic Distortion

distortion of the system, i.e., good and value increase 14.66%.

Conclusion

The present paper focuses on a cascaded multi-level inverter based on fuzzy logic controller. An analysis employing multicarrier PWM modulation and Fuzzy logic technique has been performed by using MATLAB SIMULINK, which verifies that multi-level inverter is the best-suited topology for DC to AC conversion. It has improved the over all efficiency as shown the result and which can be obtained by THD analysis. It is concluded that the multi carrier PWM modulation technique provides lower total harmonic distortion (THD) compared to novel PWM technique. With lower THD level, the heating of industrial drives can be reduced so that the industrial drives operate with better efficiency.

The level of THD has been reduced up to 14.66% for different loads. To enhance the research in the field of multi-level inverters. Nowadays, worldwide research and development on multi-level inverter-related technologies are going on. The focus of the present paper is limited to fundamental principles of different multi-level inverters, modulation techniques, and harmonic analysis of induction motor drives.

Reference

[1] Liao, Yi-Hung, and Ching-Ming Lai. "Newly-constructed simplified single-phase multistring multi-level inverter topology for distributed energy resources." *IEEE Transactions on Power Electronics*, vol. 26, no. 9, pp. 2386-2392, September 2011.

[2] Angirekula, Bhanu Naga V., and OlorunfemiOjo. "A Karnaugh mapping technique for the modeling of single phase multi string multi-level inverter." Applied *Power Electronics Conference and Exposition (APEC),* 2014 Twenty-Ninth Annual IEEE. IEEE, 2014.

[3] Deepa, K., Savitha, P. and Vinodhini, B.,"Harmonic analysis of a modified cascaded multi-level inverter". *In Electrical Energy Systems (ICEES), 2011 1st International Conference* on (pp. 92-97). IEEE.

[4] F.Z. Peng,Wei Qian, and Dong Cao, "Recent advances in multi-level converter/inverter topologies and applications," *2010 InternationalPower Electronics Conference (IPEC)*, pp.492-501, 21-24, June 2010

[5] P. P. Rajeevan, K. Sivakumar, K. Gopakumar, C. Patel, and H. AbuRub, "A nine-level inverter topology for medium-voltage induction motor drive with open-end stator winding," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 9, pp. 3627–3636, 2013.

[6] S. Kumar and P. Agarwal, "A Hybrid Nine-level Inverter Topology for an Open- end Stator Winding Induction Motor," *Taylor & Francis "Electric Power Components and Systems*," vol. 44(16), no. 1532–5008, pp. 1801–1814, 2016.

[7] P. P. Rajeevan, K. Sivakumar, C. Patel, R. Ramchand, and K. Gopakumar, "A Seven-Level Inverter Topology for Induction Motor Drive Using Two-Level Inverters and Floating Capacitor Fed HBridges," *IEEE Transactions on Power Electronics*, vol. 26, no. 6, pp. 1733–1740, 2011.

[8] S. Kumar and P. Agarwal, "A Novel Eighteen-Level Inverter for an Open-End Winding Induction Motor," in *IEEE India International Conference on Power Electronics (IICPE),* 2014, pp. 1–6.

[9] S. Tamai, "High Power Converter Technologies for Saving and Sustaining Energy," in *IEEE International Symposium on Power Semiconductor Devices & IC's (ISPSD)*, 2014, pp. 12–18.

[10] S. Kouro, M. Malinowski, K. Gopalkumar, J. Pou, L. G. Franquelo, and B. Wu, "Recent Advances and Industrial Applications of Multilevel Converters," *IEEE Transactions on Industrial Electronics*, vol. 57, no. 8, pp. 2553–2580, 2010.

[11] J. Rodríguez, S. Bernet, B. Wu, J. O. Pontt, and S. Kouro, "Multi-level Voltage-Source-Converter Topologies for Industrial Medium-Voltage Drives," *IEEE Transactions on Industrial Electronics*, vol. 54, no. 6, pp. 2930–2945, 2007.

[12] J. R. Espinoza, "Inverter," Power Electronics Handbook, M.H. Rashid, Ed. New York, NY, USA: Elsevier, 2001, pp. 225–269.

[13] K. K. Gupta, A. Ranjan, P. Bhatnagar, L. K. Sahu, and S. Jain, "Multi-level inverter topologies with reduced device count: A review," *IEEE Trans.Power Electron*., vol. 31, no. 1, pp. 135–151, 2016.

[14] R. S. Kaarthik, K. Gopakumar, J. Mathey and T. Underland, "Medium Voltage Drive for Induction Machine with Multilevel Dodecagon Voltage Space Vectors with Symmetric Triangles," *IEEE Trans. On Ind. Electronics*, vol. 62, no. 1, pp. 79-87, Jan. 2015.

[15] S. Pramanick, N. A. Azeez, R. S. Kaarthik, K. Gopakumar, C. Cecati, "Low Order Harmonic Suppression for Open-end Winding IM with Dodecagonal Space Vector using a Single DC-link Supply," *IEEE Trans. On Ind. Electronics*, vol. 62, no. 9, pp. 5340-5347, Sept. 2015.

[16] S. Pramanick, R. S. Karthik, Na. A. Azeez, K. Gopakumar, S. S.Williamson, K. S. Rajashekara, " and A Harmonic Suppression Scheme for Full Speed Range of a Two Level Inverter Fed Induction Motor Drive using Switched Capacitive Filter," *IEEE Trans. On Power. Electronics*, vol. 32, no. 3, pp. 2064-2071, March. 2017.

[17] S. Kouro, M. Malinowski, K. Gopakumar, J. Pou, L. G. Franquelo, W. Bin, J. Rodriguez, M.A. Perez and J.I. Leon, " Recent Advances and Industrial Applications of Multilevel Converters," *IEEE Trans. on Ind.Electronics*, vol.57, no.8, pp. 2553-2580, Aug. 2010.

[18] N. Thombre, R. S. Rawat, P. Rana, and S. Umashankar, "New cost effective cascaded twenty one level asymmetrical inverter with reduced number of switches and DC sources," *2014 Int. Conf. Adv. Electr. Eng.ICAEE 2014*, 2014.

[19] J. D. J. Pereda, "High-Frequency Link: A Solution for Using Only One DC Source in Asymmetric Cascaded Multilevel Inverters," *IEEE Trans. Ind. Electron*., vol. 58, no. 9, pp. 3884–3892, 2011.