International Journal of Leading Research Publication (IJLRP)

E-ISSN: 2582-8010 ● Website: www.ijlrp.com ● Email: editor@ijlrp.com

7 LEVEL MLI INVERTER WITH REDUCE NUMBER OF SWITCHES

CHINNADANLURU NAGA JYOTHI[1], K ANITHA[2]

[1]M.Tech Scholar, [2]Assistant Professor
Department Of Electrical and Electronics Engineering
Tadipatri Engineering College, Tadipatri.

Abstract:
Over the beyond two a long time, multi-degree inverting (MLI) strategies have grown to be increasingly more suitable for excessive-energy business packages. Multi-degree inversion (MLI) combines a couple of DC sources. For this motive, it is advocated to apply exchanges with higher nominal values. All topologies are simulated accurately/simulated and the results are checked and in comparison. The responsibility cycle of person cells in the multi-level converter cascade varies based on the alternate inside the illumination electricity of the cells. But MPPT is maintained during the system. On the opposite hand, the distinction is the function of mobile cycle suppression, as it is related to the development and cutting-edge discount. To obtain this intention, multi-cellular photovoltaic (PV) applications were proposed, wherein H6 strength bridge cells are used instead of H-bridges. Without sun radiation mismatch between the electricity cells, the proposed converter could be used to deliver strength from the shaded cells at a lower voltage without changing the PV voltage, as a consequence preserving the MPPT characteristic. This amendment permits retaining the identical obligation cycle across all of the strength cells, irrespective of the weather conditions, and therefore preserves the output voltage and cutting-edge fluctuation traits of the energy cells. To evaluate the overall performance of the proposed tool, both a complex laptop version and a discipline experiment have been used. After analysis, it became shown that the proposed topology gives plenty better voltage and contemporary characteristics in a production environment in comparison to the conventional H-bridge topology. The proposed topology become in comparison with a topology that improved harmonic illustration constant with European instructional requirements, resulting in a 2.64 percentage improvement in universal performance first-class.

Keywords: Multi-Degree Inverting (MLI); Distribution Network; Loss Allocation; Network Reconfiguration.

INTRODUCTION

Renewable strength generation has advanced substantially over the past three a long time. Photovoltaic (PV) systems are one of the maximum promising and quickest growing resources of renewable power. The total installed ability of PV systems has accelerated unexpectedly over the past decade, presently reaching 178 GW. There are four forms of PV system topologies: (1) relevant inverter, (2) modular inverter, (3) string inverter, and (4) multi-strand inverter. Multiple PV strings (PV panels connected in series) are connected in parallel with a diode through a string closure to shape a DC link and are related to the grid via a central inverter in a valuable topology. This topology offers simple blessings, dependable management, and occasional initial funding. With most effective one significant most strength factor monitoring (MPPT) controller, the power output can without problems be decreased through the results of panel mismatch and partial leaf failure. The trouble may be reduced by using dividing the PV panels into small companies with separate MPPT controllers. In this configuration, the inverter operates with most effective one or some PV panels. As a result, the capability losses because of panel mismatch can be reduced and the consequences of partial leaf failure may be decreased.

Multi-stage converters (MLCs) are very promising candidates for electricity electronic converters due to the fact they provide reliable, green and coffee-loss features. On the other hand, the extraordinary voltage lets in using a small output clear out. They consist of the cascaded H-bridge (CHB) converter topology, which consists of a chain of H-linked bridges, every of which is powered by using a separate DC voltage supply. This feature permits photovoltaic panels to be related to each H-bridge; this creates independent most power factor tracking (MPPT), which improves the efficiency of the complete machine.

The maximum not unusual pulse width modulation (PWM) layout used in MLC is the phase-shifted PWM (PS-PWM). PSPW Min CHB software is described as a multi-provider software wherein one service is assigned to the H-bridge, in which these carriers are primarily based on the relative Ts/n. Where Ts is the service period and n is the range of H-bridges.

However, if the energy cells are uncovered to uneven sun radiation due to dust or partial shading at the PV panel, the system turns into unbalanced. This imbalance may be divided into kinds: interstitial imbalance and interstatic imbalance. The first query is taken into consideration antique, which, like all medium difficulty, has hundreds of solutions. However, interphase mismatch is a present day hassle that has emerge as a hassle in MLC. When the solar radiation is uneven among the electricity cells, the principle cause for the formation of harmonics in the converter output alerts is the difference in cellular cycle and DC hyperlink voltage. It regulates and adjusts the solar cellular responsibility cycle to suit its new MPP present day while the sun radiation decreases; therefore, the modulator adopts distinct duty cycles. In this case, the shaded strength cell starts off evolved turning in strength with a sure postpone (TD) and stops delivering it until the expected TD time. But in MLC, the cells are grouped consistent with the output signal of the converter (output current and voltage), and synchronization is the maximum crucial parameter. Several tries had been reported to overcome this hassle. With variable displacement perspective - this is the simple operating precept, this design gives a low-cost answer; however, it's miles handiest valid for n = 3 due to the desired composite ratio. Each power cell consists of a step-down DC-DC converter, which presents a changed modulation strategy to keep the power on the identical stage throughout the DC coupling capacitor. Since the H-bridge voltage is impartial of the PV voltage, the modular multi-degree quasi-Z-source cascade inverter gives flexibility in energy high-quality problems, with only a few changes in its modulation and control as consistent with the design. This layout proposes an MLC-based totally electricity cell, which solves the obligation cycle hassle.

RELATED WORK

Asymmetric Nine-Stage Inverter Circuit Using Power Semiconductors M. S. Arif, S. M. Ayub and Z. Salam (2018). This study presents a brand new structure of unmarried-stage multi-degree inverter. With a low range of devices, the proposed architecture can generate a nine-level voltage range. It arranges the to be had switches and assets in the sort of manner that most addition and subtraction of DC enter assets may be achieved. A low-frequency switching approach is used in this undertaking. The outcomes show that the proposed structure can provide nine output voltage ranges, force inductive masses and have low harmonic distortion content [1].

Multi-Level Inverter (MLI) Adil Sarwar, MD Irfan Sarwar, MD Shahbaz Alam, Sirin Ahmed and Muhammad Tariq (2019) proposed a nine-level multi-degree inverter with reduced segment and small harmonics. The modular design of the MLI allows it to improve its energy dealing with capabilities without the want for a brand new converter. This study describes a cascaded H-bridge (CHB) converter with some switches that uses a single strong DC supply (AlTilium) to generate a nine-step output. The consequences of simulation and experiments affirm the mathematical evaluation. The modulation index is likewise investigated in terms of general harmonic distortion (THD) [2].

A nine-level multi-stage H-bridge inverter changed into proposed through Divya Subramanian and Rebia Rashid (2013). This paintings demonstrates a multi-level inverting circuit created with the aid of putting a bidirectional switch between a capacitive voltage source and a conventional H-bridge module. By increasing the quantity of outside voltage tiers, the reconstructed inverter can produce a better waveform without distortion. By connecting two changed H-bridge modules in collection, it's miles viable to obtain a 9-step output voltage with zero. To make sure uniform strength distribution the various cells, a multi-carrier pulse width modulation (PWM) section shift method is used. A examine of the harmonic output voltage is achieved. According to the outcomes, compared to different traditional inverters with the same output, the proposed inverter affords higher output satisfactory with much less energy loss [3].

M. Carried out a comparative evaluation of a nine-stage inverter with two distinct topologies. Nagaraju and D. Ravikiran (2016) proposed. Due to its advantages over opportunity topologies, the H-bridge multi-stage cascade inverter is pretty endorsed. The variety of tiers of the H-bridge topology in a stack can be increased by increasing the quantity of H-bridges, which increases the quantity of rods. The higher the number of output voltage levels, the higher the sine wave form and the lower the full harmonic distortion (THD). But due to the better wide variety of rods, the scale and price of the inverter growth. From the studies, they commenced to lessen the number of collection adjustments through growing the space. In this observe, a multi-stage H-bridge inverting cascade with 9 levels and reduced rods is proposed and analyzed. Compared to diode clamp, floating capacitor and cascaded H-bridge inverters, the proposed 9-stage multi-stage inverters use fewer inverters to achieve the equal variety of voltage stages. As a end result, the switching losses and charges are reduced. This makes the periodic voltage waveform from a couple of DC assets greater normal. The practical principles and waveforms are discussed, and the overall performance of the proposed multi-degree inverter is evaluated via simulation [4].

Dr. Praveen M. Sonawane and Shraddha S. Lohagare (2019) proposed a comparative study of five and 9 level MLI to reduce the share of THD. This look at makes use of section-shift pulse width modulation (PWM) era to compare 3-segment, 5-phase, and 9-section multi-section H-bridge inverters implemented in solar power applications. The harmonic content material decreases as the extent of multi-layer inverter increases, although this gain has a few hazards. To explore those exchange-offs, the theoretical analysis on this paper compares grid-related five-stage and 9-stage bridge multi-stage inverters [5].

Cascade H-bridge a couple of inverter topology has reduced wide variety of poles and THD evaluation. Proposed with the aid of B. Satyavaniya, K. Rajeswar Reddy and Dr. No. Kamala Murthy (2021). In a multi-stage inverter, the favored output value is decided via the harmonic price to increase the output level. This look at shows that during inverting a nine-level H-bridge with much less variable additives. The THD values of the designed inverted H-bridge are investigated underneath special masses. In phrases of THD values, the inverted H-bridge is compared with PD, POD and APOD techniques. From the simulation consequences, the designed H-bridge inverter system plays properly in phrases of voltage and contemporary THD values, and additionally achieves high efficiency due to low losses [6].

An asymmetric multi-degree inverted H-bridge with one DC source according to level was proposed by way of Rajesh Vasu, Sumit Kumar Chattopadhyay and Chandan Chakravarthy (2020). This paper proposes a binary uneven self-balancing multiplier along with a cascaded multi-degree H-bridge inverter. To obtain the maximum DC voltage in the inverted H-bridge (referred to as the primary bridge), handiest one DC source is used at a time. Floating DC capacitors shape the relationship of all different H-bridges (also called sub-bridges). The concept of a kingdom-duplication network permits the floating capacitors to be incorporated into their fixed voltages, without the want for any technical control. The DC voltage of every sub-bridge is

1/2 the DC voltage of the bridge inside the steady nation. As a result, there could be internal binary asymmetry [7].

EXISTING SYSTEM

To attain the favoured voltage in this topology, numerous H-kind mid-bridges are linked in collection with the H-bridge. A half-bridge H-type has two rods that need to be pushed simultaneously. This architecture uses ten rods and 3 DC resources for a seven hundred milliampere input. Topological map in Figure 1. Topological transition technique in Table 1.

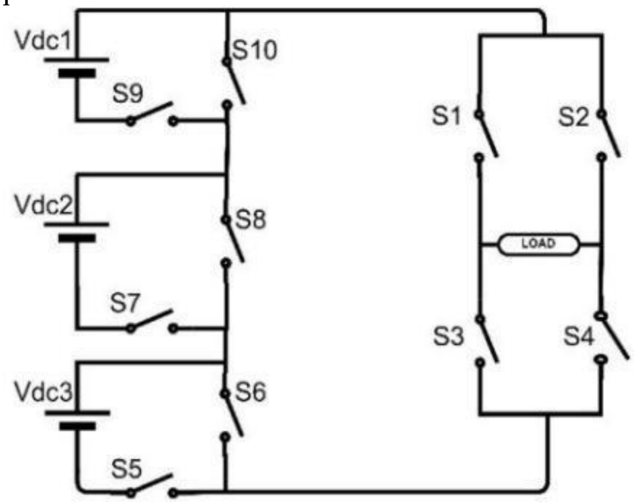

Fig 1: Topology 1 Circuit Diagram

S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Output Level
ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON	OFF	Vdc1
ON	OFF	OFF	ON	OFF	ON	ON	OFF	ON	OFF	Vdc1 + Vdc2
ON	OFF	OFF	ON	ON	OFF	ON	OFF	ON	OFF	Vdc1 + Vdc2 + Vdc3
OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	0
OFF	ON	ON	OFF	OFF	ON	OFF	ON	ON	OFF	-Vdc1
OFF	ON	ON	OFF	OFF	ON	ON	OFF	ON	OFF	-(Vdc1 + Vdc2)
OFF	ON	ON	OFF	ON	OFF	ON	OFF	ON	OFF	-(Vdc1 + Vdc2 + Vdc3)

Table 1: Topology 1 Switching Pattern

Depending at the switching mechanism, this shape produces 4 extraordinary states of decreased MLI output. It has nine rods and 3 DC sources on the enter aspect. Topological map in Figure2. Topological transition map2 (Table 2).

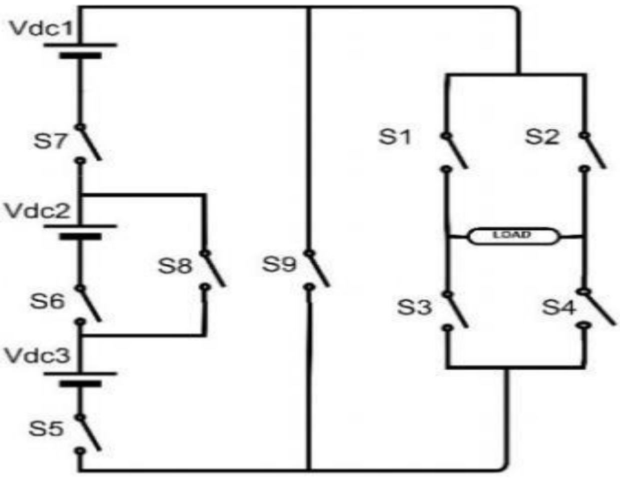

Fig 2: Topology 2 Circuit Diagram

A simple tool together with two rods and a regular contemporary supply may be linked in series to growth the voltage level to a better degree. These modules can be connected in series to boom the output voltage. Thus, the output voltage level can be increased the use of fewer switches.

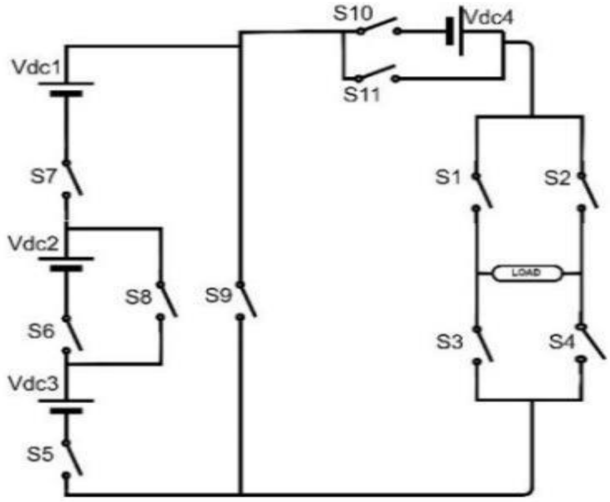

Fig 3: Topology 2 Extension

S1	S2	S3	S4	S5	S6	S7	S8	S9	Output Level
ON	OFF	OFF	ON	ON	OFF	ON	ON	OFF	Vdc1 + Vdc2
ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF	Vdc1 + Vdc2 + Vdc3
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	0
OFF	ON	ON	OFF	ON	OFF	ON	ON	OFF	-(Vdc1 + Vdc2)
OFF	ON	ON	OFF	ON	ON	ON	OFF	OFF	-(Vdc1 + Vdc2 + Vdc3)

Table 3: Topology 2 Switching scheme

This very last topology with nine switches and 3 DC resources for seven levels, and the effects of the proposed topology might be compared with it.
For a 7-degree voltage level, this configuration makes use of 5 rods, three steady voltage assets, and an H-bridge for 9 rods and three consistent voltage sources. An H-bridge is used to change the polarity, and this topology creates three high quality, three negative, and a floor. The circuit of Topology 3 is shown in Figure 4. The topology table trade is proven in Table 3.

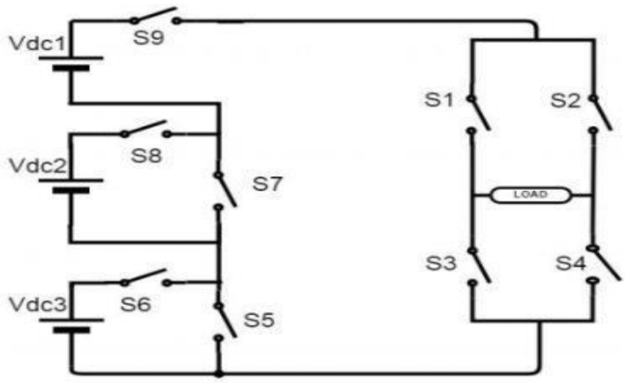

Fig 4: Topology 3 Circuit Diagram

S1	S2	S3	S4	S5	S6	S7	S8	S9	Output Level
ON	OFF	OFF	ON	ON	OFF	ON	OFF	ON	Vdc1
ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	Vdc1+Vdc2
ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON	Vdc1+Vdc2+Vdc3
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	0
OFF	ON	ON	OFF	ON	OFF	ON	OFF	ON	-Vdc1
OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON	-Vdc1-Vdc2
OFF	ON	ON	OFF	OFF	ON	OFF	ON	ON	- Vdc1-Vdc2-Vdc3

Table 4: Topology 3 Switching Scheme

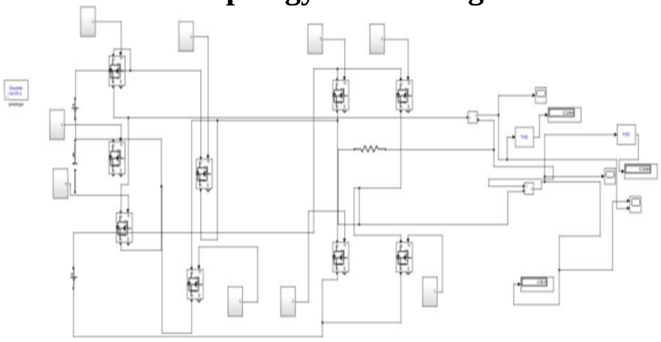

Fig 5: Simulink model

Efficiency Calculation:

$$\eta = P_{out} / P_{in}$$

$$= (V_{out} * I_{out} / V_{in} * I_{in}) *100$$

$$= (430 * 4.5 / 400 * 9) * 100$$

$$= 50 \%$$

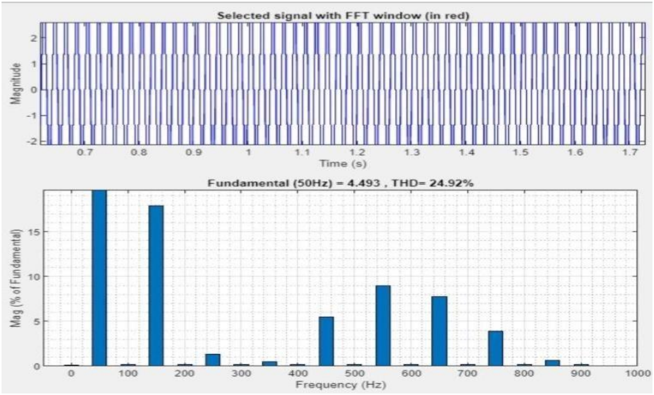

Fig 6: Topology 3 – 7 level THD output

THD=24.92%

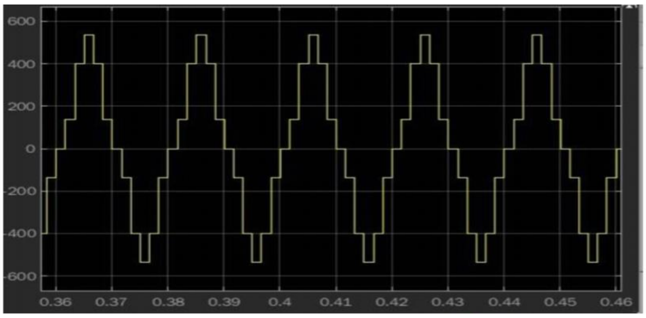

Fig 7: level Simulink output

Proposed System

The proposed topology overcomes all the shortcomings of the prevailing topology. It has 8 rods and uses 2 DC springs for 9 positions.

To validate this framework, the outcomes have been in comparison using MATLAB/Simulink. A schematic diagram of the proposed topology is shown in Figure 8. The Simulink version of the proposed machine is proven in Figure 9.

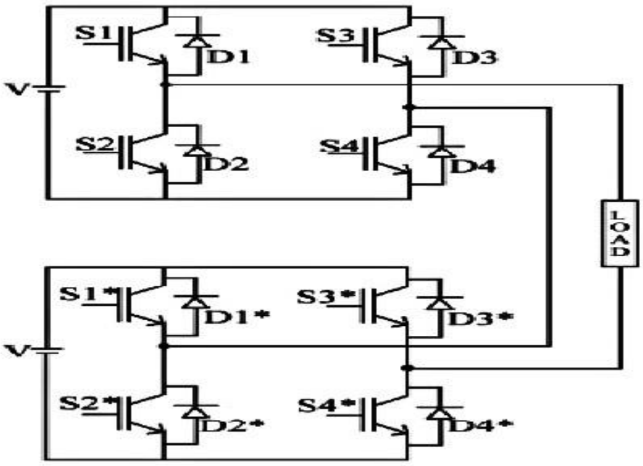

Fig 8: Circuit Diagram of Proposed Topology

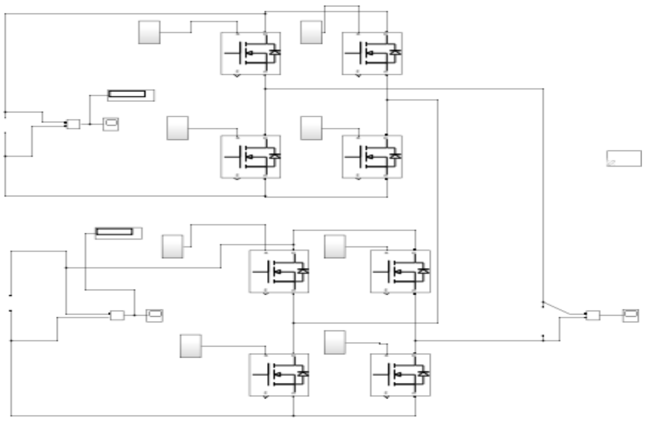

Fig 9: Simulink Model

Efficiency Calculation:

$$\eta = P_{out} / P_{in}$$

$$= (V_{out} * I_{out} / V_{in} * I_{in}) *100$$

$$= (530 * 1.7 / 500 * 27) * 100$$

$$= 64 \%$$

VOLTAGES	0	1	2	3	4	3	2	1	0	-1	-2	-3	-4	-3	-2	-1	0
s1	1	1	0	0	1	0	1	1	0	0	1	0	0	0	1	0	1
s2	1	1	0	0	0	0	1	0	1	1	0	1	0	0	0	1	1
s3	0	1	1	0	1	1	0	0	1	0	0	1	1	1	0	1	0
s4	0	1	0	1	1	1	0	1	0	0	1	1	0	1	1	0	0
s5	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1
s6	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	1
s7	1	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0
s8	0	1	1	1	1	1	1	1	0	1	0	0	0	0	0	1	0
MODES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Table 9: Level Switching Scheme

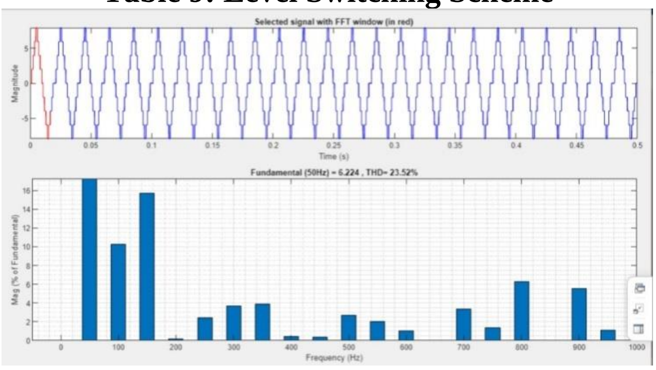

Fig 10: 9 level THD output

THD=23.52%

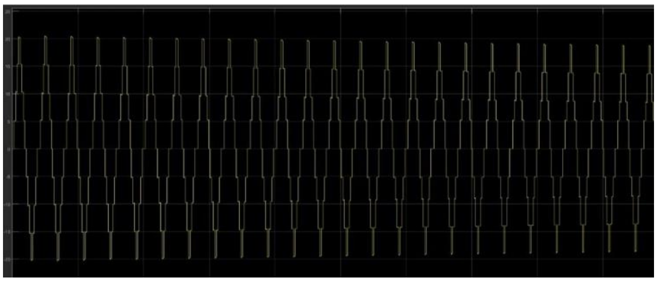

Fig 11: 9 level Output

A solar photovoltaic system is used because the input source. A sun photovoltaic gadget collects strength from the sun within the shape of heat or mild and converts it into electrical energy. Two solar panels are used. Each mobile produces zero.6V of electricity. One board will provide 100V DC strength as enter, while the opposite board will produce 300V DC electricity as input. Figure 5.12 suggests the Simulink version.

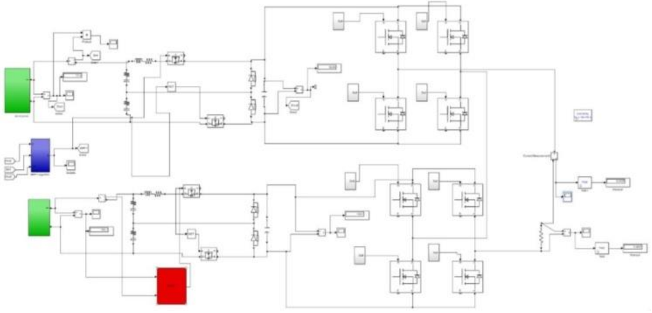

Fig 12: Simulink model

Since solar PV machine is a risky supply of energy, MPPT is used to music the most power point. For solar photovoltaic machine, it is the most common design. This MPPT approach uses the Perturb and Observe (P&O) technique. P&O is one of the maximum popular techniques to monitor MPP usage. This method changes the voltage or modern-day ratio of the photovoltaic machine. The MPPT simulink model is shown in Figure 13.

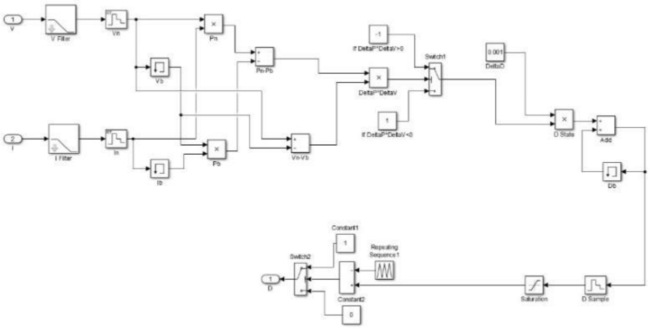

Fig 13: Simulink Model of MPPT

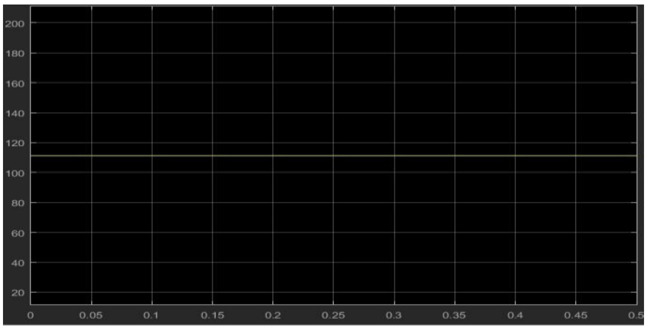

Fig 14: Tracked MPP of 112V

A DC-DC converter used on this software is a step-down converter. It typically increases the input voltage to the extent required with the aid of the weight. The step conversion is proven in Figure 15.

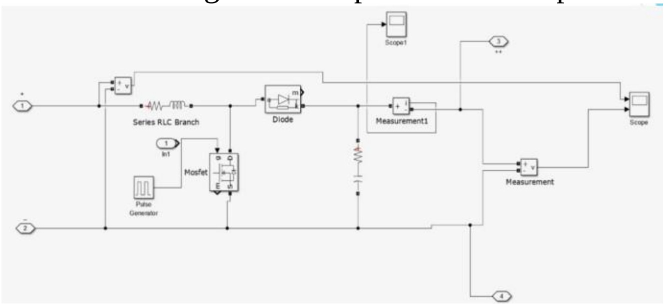

Fig 15: Boost Converter

Artificial Intelligence (AI) is a neural-fuzzy controller era. A neuro-fuzzy gadget can be used to generate more beneficial guidelines for humans. With the assist of this gadget, the records flowing from the enter to the output could be stored in a regular nation. In this device, you first have to initialize the facts, then input the regulations and take a look at the popularity of the controls. This machine, the use of an artificial intelligence-driven set of rules, become used to set the mute position and the right parameters for the rule machine.

A traditional controller is used to control the voltage on the load facet, at the same time as a neuro-fuzzy controller does the same activity speedy and appropriately. Figure 16 suggests a neuro-fuzzy controller with a closed-loop level.

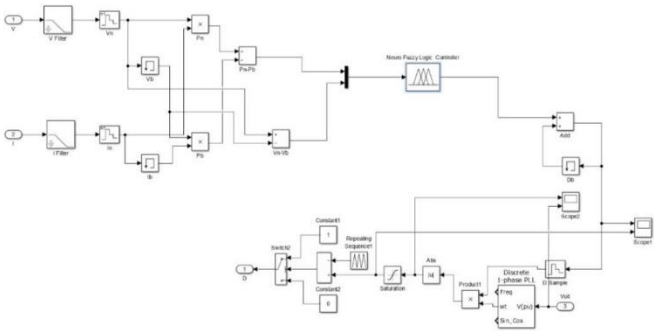

Fig 16: Neuro Fuzzy with Phase Locked Loop

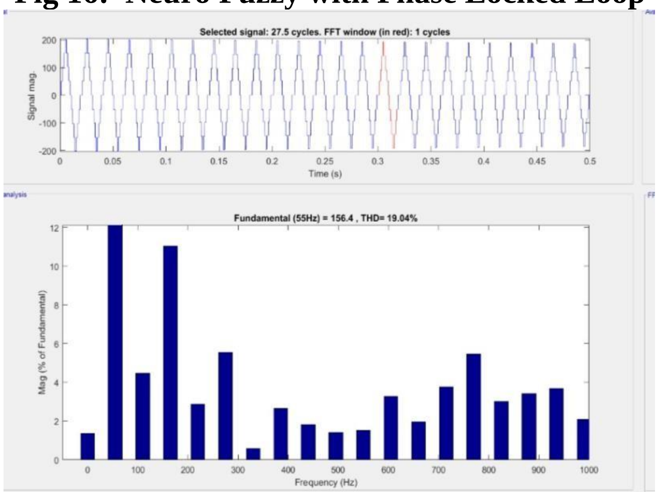

Fig 17: THD of Proposed System with Neuro Fuzzy Controller

THD=19.04%

COMPARISON OF EXISTING AND PROPOSED SYSTEM RESULTS

	9 level	7 level
switch count	8	9
DC source count	2	3
Efficiency	64	50
THD	23.52	24.92

Table 5: Comparison of 9 level & 7 level

COMPONENTS COMPARISON WITH DIFFERENT STRUCTURES OF MLI

MLI Structure	Diode Clamped	Cascaded H Bridge	Flying Capacitor	Asymmetric CHB
DC Sources	1	4	1	2
Clamping Capacitors	-	-	6	-
DC Split Capacitors	4	-	4	-
Clamping Diodes	12	-	-	-
Main Switches	16	16	16	8
Total Components Count	33	27	27	10

Table 6: Comparison of proposed topology with Neuro-Fuzzy connected proposed topology

9 Level	
With Neuro Fuzzy	Without Neuro Fuzzy
THD = 19.04%	THD = 23.52%

BLOCK DIAGRAM

Fig 18: Block diagram of proposed system

CONTROLLER UNIT

Arduino UNO

Arduino UNO Pulse Generator is used to generate pulses from a 5V electricity deliver. It is an open source microcontroller based at the ATmega328 chip. The pulse generator from the controller unit may be round 5V, however electrical machines will operate as a minimum 9V, up to 15V. Therefore, the pulses from the controller unit are converted, amplified and separated to 12V or 15V with the same frequency and responsibility cycle. The transistor acts as an amplifier. For this conversion, separation and amplification, the pulses from the controller module are related to the enter of the driving force circuit. The Arduino UNO board is shown in Figure 19.

Fig 19: Arduino UNO

Driver Unit

The driver module is used to isolate and increase the pulses generated via the controller, and these using pulses are supplied to electricity devices like MOSFET, IGBT, and so forth. The pulses from the controller could be three.3V or 5V, this voltage degree is elevated to 12V or 15V with the equal frequency and obligation cycle. It have to additionally have its own sort of safety. The TLP250 driving force circuit is shown in Figure 20. A TLP250 motive force IC is used. This driver circuit uses 12V AC step-down transformers to offer 12V AC energy. The 12V AC is rectified and filtered, and clean DC is supplied to the driving force circuit. The 18v Zener diode acts as a gate protector, which prevents reverse voltage. There are four pins in the two motive force circuits, a complete of 8 pins are used in the driving force module. Each of the 4 pins will provide a pulse in an inverted circuit.

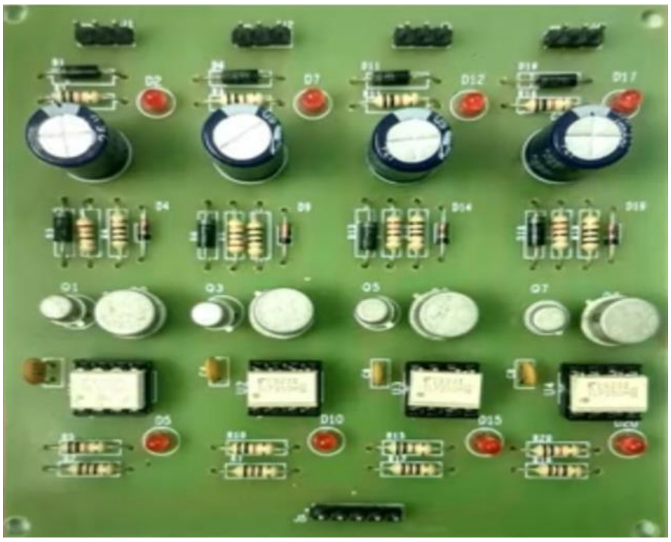

Fig 20: TLP250 Driver Circuit

CONCLUSION

The electronic devices may be provided with person and amplified pulses at the output of the motive force module. For the two DC resources, single-level step-down transformers of 15V 1A and 6V 500mA are used. This alternating voltage is converted to an immediate voltage using a rectifier bridge. Now the enter sources are 21V and 8V, a total of 29V is furnished to the inverted circuit. There are 8 IRF840 MOSFET switches within the inverted circuit. A 5W resistive load is used. The output voltage at load R is 58V, and the output waveforms may be regarded on a DSO or CRO.

This have a look at investigated the reasons of the foundation-induced output cutting-edge and voltage variations in stacked MLCs inside the presence of partial branching inside the power mobile. For this cause, an MLC stack is proposed in which individual cells are capable of providing a voltage lower than the total cell voltage, which lets in the cell responsibility cycle to go back to harmony after being reduced because of partial shading. Compared to competitors, the design turned into fee-effective, lightweight, and small in standard size as it did now not require other passive additives. The upgrade involved only some active parts. The proposed converter, as proven by simulation and experiments, substantially improves the first-class of voltage and modern-day evolution underneath partial colour, lowering the THD consistent with the 50th harmonic order described by way of EN50160.

From 15.23 percent to 10.75 percentage depending on voltage and present day. Generally, an n-degree inverted H-bridge cascaded can be furnished with 2(n-1) switches and n-half regular current assets, so sixteen switches and 4 steady contemporary assets are required to produce a nine-degree output. But we can greatly lessen the wide variety of uneven rods on this H-bridge. We also find that as the scale will increase, the sine waveform improves. The proposed uneven cascaded H-bridge inverter is used to reduce the variety of switches and enhance the advantage. Multi-level inversion is used to synthesize intently-coupled voltage waveforms from distinctive DC voltage degrees. Compared to diode clamp, floating capacitor and multi-degree cascade inverters, the proposed nine-degree multi-stage inverter calls for fewer components to achieve the same quantity of voltage tiers. Finally, by way of including a neuro-fuzzy controller to the proposed topology, we have further decreased the full harmonic distortion.

REFERENCES

1. Amaral .F.V, Parreiras, Lobato, Machado, Pires and B. de Jesus Cardoso Filho, "Operation of a Grid-Tied Cascaded Multilevel Converter Based on a Forward Solid-State Transformer Under Unbalanced PV Power Generation," IEEE Trans. Ind. App., vol. 54, no. 5, pp. 5493-5503, Sept.-Oct.2018.
2. Farivar .G, Hredzak .B and Agelidis, "A DC-Side Sensorless Cascaded H-Bridge Multilevel Converter-Based Photovoltaic System," in IEEE Trans. Indus. Electron., vol. 63, no. 7, pp. 4233-4241, July2016.
3. Honbu .M, Y. Matsuda, Miyazaki and Jifuku, "Parallel Operation Techniques of GTO Inverter Sets for Large AC Motor Drives," IEEE Trans. Ind. App., vol. IA-19, no. 2, pp. 198-205, March1983.
4. Konstantinou .Y .Yu .G, Hredzak and Agelidis, "Power Balance of Cascaded H- Bridge Multilevel Converters for Large-Scale Photovoltaic Integration," IEEE Trans. Power Electron., vol. 31, no. 1, pp. 292-303, Jan.2016.
5. Konstantinou .Y .Yu .G, Hredzak and Agelidis, "Operation of Cascaded H-Bridge Multilevel Converters for Large-Scale Photovoltaic Power Plants Under Bridge Failures," IEEE Trans. Ind. Electron., vol. 62, no. 11, pp. 7228-7236, Nov.2015.
6. Lashab .A, D. Sera, J. Martins and Guerrero, "Multilevel DC-Link Converter-Based Photovoltaic System with Integrated Energy Storage," 2018 5th International Symposium on Environment-Friendly Energies and Applications (EFEA), Rome, 2018, pp.1-6.
7. Lashab .A, Sera .D and Guerrero, "Harmonics Mitigation in Cascaded Multilevel PV Inverters During Power Imbalance Between Cells," 2019 IEEE Int. Conf. Environ. Electr. Eng.2019.
8. Leon .J .I, Kouro, Franquelo, Rodriguez, and B. Wu, “The essential role and the continuous evolution of modulation techniques for voltage-source inverters in the past, present, and future power electronics,” IEEE Trans. Ind. Electron., vol. 63, no. 5, pp. 2688–2701, May2016.
9. Marquez .A, Leon .J .I, Vazquez, Portillo, Franquelo, Freire, and Kouro, “Variable- angle phase-shifted pwm for multilevel three cell cascaded h-bridge converters,” IEEE Trans. Ind. Electron., vol. 64, no. 5, pp. 3619–3628, May2017.

10. Marquez .A, Leon, Vazquez, Franquelo, and Kouro, “Operation of an hybrid PV- battery system with improved harmonic performance,” IECON 2017 - 43rd Annu. Conf. IEEE Ind. Electron. Soc., pp. 4272–4277,2017.
11. Rong .F, Gong and Huang, "A Novel Grid-Connected PV System Based on MMC to Get the Maximum Power Under Partial Shading Conditions," IEEE Trans. Power Electron., vol. 32, no. 6, pp. 4320-4333, June2017.
12. Tafti .H .D, Maswood, Konstantinos, Townsend, Acuna, and Pou, Flexible Control of Photovoltaic Grid-Connected Cascaded H-Bridge Converters during Unbalanced Voltage Sags,” IEEE Trans. Ind. Electron., vol. 65, no. 8, pp. 6229– 6238, 2018.
13. Villanueva .E, Correa .J, Rodriguez and Pacas, "Control of a SinglePhase Cascaded H-Bridge Multilevel Inverter for Grid-Connected Photovoltaic Systems," in IEEE Trans. Ind. Electron., vol. 56, no. 11, pp. 4399-4406, Nov.2009
14. Wang .C, Zhang .K, Xiong, Xue, and W. Liu, “An Efficient Modulation Strategy for Cascaded Photovoltaic Systems Suffering from Module Mismatch,” IEEE J. Emerg. Sel. Top. Power Electron., vol. 6, no. 2, pp. 941–954, 2018.
15. Wang .C, Zhang, L. Liu and W. Liu, "A novel modulation method applied in quasi- Z-source based cascaded pv system suffering module mismatch," IECON 2015 - 41st Annu. Conf. IEEE Ind. Electron. Society, Yokohama, 2015, pp.004911- 004916.
16. Xiao .B, Hang .L, Mei .J, Riley .C, Tolbert and Ozpineci, "Modular Cascaded H- Bridge Multilevel PV Inverter With Distributed MPPT for Grid-Connected Applications,"IEEETrans.Ind.App.,vol.51,no.2,pp.1722-1731,March-April2015.