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HARMONICS AND VOLTAGE QUALITY IN POST-FAULT RECONFIGURED 7-LEVEL DIODE CLAMPED MULTI-LEVEL INVERTERS

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ABSTRACT: In this paper the investigation of the post-fault reconfiguration on the inverter voltage total harmonic distortion in Multilevel Inverters (MLI) is done. To utilize the inverter redundancy three different operating conditions are introduced they are healthy, faulty and reconfigured methods. Hence to analyze the harmonic content of line-to- neutral voltage, accurate analytical model is introduced. For verification, two fault conditions are used. To analyze the harmonic content and RMS value of the achieved line to-Neutral voltages, reconfiguration method is applied. This method will mitigate the faults in effective way. From simulation results it can observe that proposed model gives accurate values. In the proposed project the 5-level multilevel inverter has been discussed. And the THD is 34.6% in extension paper the 7-level multilevel inverter will be analyzed with the same conditions as described in proposed paper, and THD response will be (20-22) %.

KEY WORDS: Multilevel Inverters (MLI), THD (Total Harmonic Distortion), RMS (Root Mean Square) Value, SPWM (Space Pulse width modulation), Space vector modulation (SVM).

I. INTRODUCTION

Multilevel inverters (MLIs) have been broadly utilized in the business for a few points of interest contrasted with two-and three level inverters. These points of interest incorporate the capacity to support higher voltage worry due to their fell per-stage structure, lower regular mode voltage, activity under both high recurrence exchanging and lower recurrence exchanging, and lower all total harmonic distortion (THD).

Weaknesses additionally exist including more mind boggling control systems and more semiconductor gadgets. The expanded number of semiconductor gadgets builds the danger of disappointment since the disappointment of a solitary gadget could make the entire inverter come up short. Nonetheless, the expanded number of semiconductor gadgets gives a chance to repetition to recuperate the inverter from flaws. In this manner, analysts have created numerous viable Methods to reconfigure MLIs to recoup from shortcomings. Excess exchanging plans have been created to endure an issue by working the staying solid gadgets, with center around stage moved and stage mien techniques. Space vector modulation (SVM) is additionally a well known tweak strategy, where've-control-based shortcoming cell or gadget bypassing techniques have been created.

Other than control-based reconfiguration, geography change is additionally viable to endure a flaw, or to sidestep the bombed cell or gadget with adjusted control conspire. For three-stage frameworks, the regular issue when one gadget comes up short is that the comparing leg additionally bombs which can cause uneven voltages and flows among stages; an impartial moved strategy was created to deal with lopsided conditions. These reconfiguration techniques are successful and full grown since they balance the three stages at wanted RMS values.

To break down the consonant substance of yield voltage waveforms in a staggered inverter, it is common for scientists to utilize programming devices or spotlight on the low-recurrence flight of stairs capacity to estimated the low frequency content of SPWM in staggered inverters. In any case, a model that incorporates high-recurrence impacts is required for precise numerical investigation of MLIs.

For the long power transmission and distribution using the lots of load centers and generating stations are interconnected, it became more complex in a modern systems. Reliability and quality of power supply is mainly concerning by the consumers where they are located. In the developed countries the power generation is fairly reliable, but power supply quality is not reliable. These systems are providing the uninterrupted energy flow at

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smooth sinusoidal voltage to the customers. In practice these distribution systems are having the nonlinear loads, which are affect the power supply quality.
The reliability of power is increasingly concerned with power suppliers and end-users. Since the late 1980s, the word "power quality" has become the most popular term in power industry. In the late 1980s, power electronic devices, generating the new loading equipments and microprocessor based controls achieved some premises for improving power quality. Further focus on the performance of power generation systems has been given to the continuing increase in the devices, such as high efficiency, variable speed motors and shunt capacitors, as a result of increasing power factor in order to reduce power loss. As a result, harmonic levels of the power systems are increasing and many people worry about future impacts on the capability of the system.

End users are more aware of problems with quality of the power. Utilities customers are better aware of issues such as sags, interruptions and challenges and transient switches to improve the power supply. So all computers in the network are interconnected. Integrated processes mean that loading equipment has far more important implications for failure of each component. Interestingly, the devices that are installed for increased productivity also often cause additional power quality problems to the device that is the most affected by the devices and common power disruptions. The efficient operation and control of the machines is increasingly dependent upon the quality of the energy when all processes are automated. Power quality can be described as a power supply that allows a proper functioning of the electric device. In reality customer-driven problem and the end user reference point is preferred for the quality of power. Thus any power problems that manifest in current or frequency, malfunction of customer equipment or voltage deviations that result in failure can be classified into the quality of the power supply issues.

These are producing the lots of problems in the end up of the distribution of power supply. Motor starting, unusual faults and capacitor switching evens are inflicting the problems of power supply quality in some nonlinear load systems. The problem with current / voltage which causes differences in frequency leading to customer system miss-operation or failure is known as the problem of power quality. The temporary voltage swell or power or temporary voltage sag can be caused at different nodes in the system depending on electric distance, type of connection for transformers and grounding between the nodes and faulty / load location.

The point of this undertaking is along these lines to determine a precise numerical model of MLI yield voltage to consider the effect of various post-issue reconfiguration techniques on the line-to nonpartisan voltage and investigate its consonant substance and RMS esteem. The task underscores that voltage quality improvement ought to go past simply keeping up the ideal line-to-line voltage shape. This venture gives investigation and correlation of consonant substance connected loads, Faulty and Reconfigured conditions. Three well known reconfiguration strategies: Two control-conspire adjustment techniques and unbiased point move strategy are applied for a 7-level NPC inverter for top side gadget disappointment for instance.

In the proposed paper the 5-level staggered inverter has been examined. Also, the THD is 34.6%In augmentation paper the 7-level staggered inverter will be investigated with indistinguishable conditions from depicted in proposed paper, and THD reaction will be (20-22) %.

II. LITERATURE SURVEY

Post-fault reconfiguration for a versatile and hybrid 4 Leg NPC-flying capacitor topology
This task presents a control system for an islanded medium voltage micro grid to organize hybrid power source (HPS) units and to control interfaced staggered inverters under unequal and nonlinear burden conditions. The proposed HPS frameworks are associated with the heaps through a cascaded H-bridge(CHB) staggered inverter. The CHB staggered inverters increment the yield voltage level and improve power quality.

The HPS utilizes fuel cell (FC) and photovoltaic sources as the principle and super capacitors as the integral force sources. Quick transient reaction, superior, high force thickness, and low FC fuel utilization are the fundamental favorable circumstances of the proposed HPS framework. The proposed control methodology comprises of a force the board unit for the HPS framework and a voltage regulator for the CHB staggered inverter. Each dispersed age unit utilizes a multi relative full regulator to control the transports voltages in any event, when the heaps are uneven or potentially nonlinear. Advanced time-area recreation examines are done in the PSCAD/EMTDC condition to check the exhibition of the general proposed control framework.

The effect of the voltage exchange is generally seen as transient operation. This kind of transient can happen in a huge single-stage stack as an impact of exchange. Different mechanical systems can be protected by electrically confining them to the controlling instrument against these transient exchanges.

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Five level Diode Clamped Inverter to Eliminate Common Mode Voltage and reduce dv/dt in Medium Voltage Rating Induction Motor Drives

The High force enlistment machines are planned at medium voltage (MV) rating for better execution. The Multi Level inverters (MLI) can furnish medium voltage with great yield at low changing recurrence when contrasted with traditional two-level inverter. What's more, MLI lessens, exchanging misfortunes and spillage current. In this undertaking, ways to deal with decrease and take out the common mode voltage (CMV) utilizing five level diode clamped multilevel inverter (DCMLI) are introduced. The CMV spikes are additionally disposed of by moving dead-time over the stage shaft. A tale procedure for the determination of changing states to integrate the longing vector is proposed. This venture understands the usage of five-level diode cinched MLI for three stage enlistment engine. Test results exhibit the achievability of the proposed arrangement.

In the present years, an Switch Mode Power Supply (SMPS) comprise the IT equipments power arrangements and reason of behind that the increasing of the distortion of harmonic voltages are indicates in third, fifth and seventh level. The third harmonic is a "tripelen" harmonic and thus includes a neutral three-stage system, which can be adjusted in a zero request phase arrangement. The growth of IT-hardware usage has led to concern that neutral conductors can be overloaded and transformers are overheated. The equipment manufacturers often arrange and manufacture muddled hardware which slowly defenses itself against power quality varieties. There are several issues about the hardware affectability and the effect on identifying equipment of power quality events

Distributed Control of a Fault Tolerant Modular Multilevel Inverter for Direct-Drive Wind Turbine Grid Interfacing

Secluded generator and converter geographies are being sought after for huge seaward wind turbines to accomplish adaptation to non-critical failure and high dependability. A brought together regulator presents a solitary basic purpose of disappointment which has forestalled a really particular and issue open minded framework from being gotten. This examination investigations the inverter circuit control necessities during typical activity and lattice issue ride-through, and proposes a circulated regulator configuration to permit inverter modules to work autonomously of one another. All the modules freely gauge the network voltage size and position, and the modules are synchronized together over a CAN transport. The CAN transport is additionally used to interleave the PWM exchanging of the modules and synchronies the ADC inspecting. The regulator structure and calculations are tried by research facility explores different avenues regarding appreciation to typical activity, starting synchronization to the network, module adaptation to non-critical failure and lattice shortcoming ride-through.

On the whole type of electric arcing gadgets, electric circular furnaces and electric discharge lighters are available. These gadgets are very non-direct charges. The effects of bend furnaces are difficult to moderate; usually it will not be possible to adjust the stages with different furnaces as circular segment furnaces are worked in different modes leading to stage unevenness. Due to the irregular interchange of the curve welders, the transients in the near-by system are frequently triggered and some electronic gears may require protection against indiscreet spikes

For the improvement of nature of the heap voltage utilizing DVR in view of a versatile hysteresis voltage control system was expounded by H. Ezoji et al. As indicated by them Hysteresis Bandwidth (HB) can be progressively balanced by versatile hysteresis band number cruncher with the target of consistent gadget exchanging recurrence.

Particular of the vigor and mistake following execution considered for appropriate determination of weighting capacities. It is noteworthy that the blending of the $H\infty$ controller increases with positive and negative line frequencies. The positive and negative segments of the arrangement would therefore be managed adequately. Yun Wei Li composes and installs a $H\infty$ voltage circle and inward current circle.

Viz. for the payment of energy quality problems. Pedro Roncero-Sanchez provided voltage lists, voltage sounds and voltage uneven characters with monotonous controller. They observed that monotonous controller claiming fame is a rapid transient reaction and it guarantees zero faults in enduring state condition for any sinusoidal unsettling influence and any sinusoidal information. They used either stationery reference outline or turning reference outline for controller execution.

Eng Kian Kenneth Sng portrayed an arrangement repaying gadget that is transformer-free self-charging DVR to alleviate the voltage hangs and manage the DC Link voltage. The price and volume of the machine could be minimized due to the lack of the transformer is observed by them. The DC Link voltage control device is smooth with the inductor energy of the channel. The transformer supplies pay energy where the payload period is affected as a DC capacitor. For smoothing voltage and not for storing energy the Standard DC Link capacitor can be used. Takushi Jimichi displays three stage voltages of repayment superimposed by zero parts of the control system.

III. MATHEMATICAL MODEL BASIS

In the proposed mathematical model, level shifted based PWM is implemented. In this the top switches of inverted signal will accept the phase leg which is coming from lower side and the switches functions which are coming from right side will construct the inverter output. From figure (1) the five level multi level inverter is shown. This inverter will accept the *S1* and *S1'*, *S2* and *S2'*, *S3*and *S3'*, *S4* and *S4'* signals which are inverted. From equation (1) it can observe that instantaneous output voltage Vout(t). Here the input DC voltage is represented as Vin and switching function is represented as qi(t).

$$V_{out}(t)=\sum_{i=1}^{S} q_i(t)\times\frac{1}{S}V_{in} \qquad \text{……………(1)}$$

$$q_i(t)=d_i(t)+\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{\sin(n\pi d_i(t))}{n}\cos(n\omega_{switch}t), i=1,2,3,\cdots,S \qquad \text{…………(2)}$$

$$V_{out}(t)=\frac{1}{S}V_{in}\sum_{i=1}^{S}d_i(t)+\frac{2V_{in}}{S\pi}\sum_{i=1}^{S}\sum_{n=1}^{\infty}\frac{\sin(n\pi d_i(t))}{n}\cos(n\omega_{switch}t) \qquad \text{………..(3)}$$

The switching frequency is represented as ω and the function of duty cycle is given as di(t). this duty cycle function has an offset *d* (*t*) 1 *k t*. Here modulation index is represented as k.

$$M_i(t)=\begin{cases}\frac{Sk\sin(\omega_{out}t)}{2}+\frac{S}{2}, R_i\\ i, R_{i+1,i+2,...,S}\\ i-1, R_{i-1,i-2,...,1}\end{cases} \qquad \text{……………..(4)}$$

$$d_i(t)=M_i(t)-i+1=\begin{cases}\frac{Sk\sin(\omega_{out}t)}{2}+\frac{S}{2}-i+1, R_i\\ 1, R_{i+1,i+2,...,S}\\ 0, R_{i-1,i-2,...,1}\end{cases} \qquad \text{………………(5)}$$

$$V_{out}=(\frac{V_{in}k\sin(\omega_{out}t)}{2}+\frac{V_{in}}{2})+\frac{2V_{in}}{S\pi}\sum_{n=1}^{\infty}\frac{\sin[\frac{n\pi Sk\sin(\omega_{out}t)}{2}+n\pi(\frac{S}{2}-i+1)]}{n}\cos(n\omega_{switch}t), R_i \qquad \text{.(6)}$$

$$\sin\left[\frac{n\pi Sk\sin(\omega_{out}t)}{2}+n\pi(\frac{S}{2}-i+1)\right]=(2J_1(x)\sin(\theta)+2J_3(x)\sin(3\theta)+2J_5(x)\sin(5\theta)+\cdots)$$

In this five-level neural point clamped (NPC) inverter is used and this is shown in figure (2). The simulation result of this circuit waveform is centered on 100v by having the negative DC bus rail. From table 1 it is indicated that parameters of proposed model. From figure (3), the generated waveform is shown. This generated waveform represents the similarity of simulation and experimental waveform. Both RMS and THD values are represented in table II.

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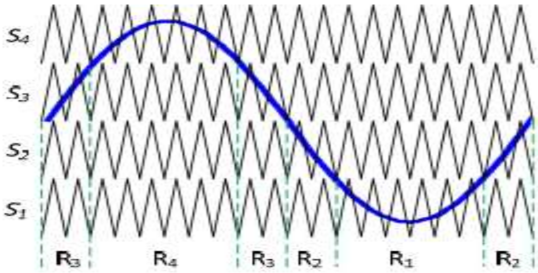

Fig.1. Phase-shifted PWM of 5-level inverter

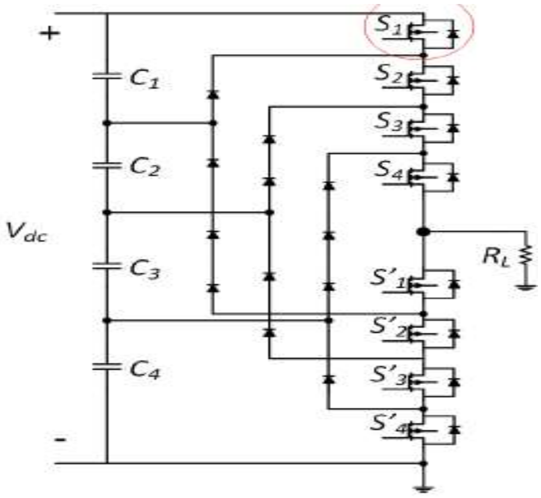

Fig. 2. Single phase of five level NPC inverter

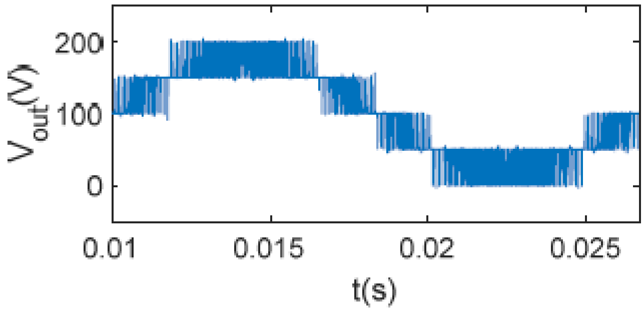

Fig. 3. Waveform generated by mathematical model

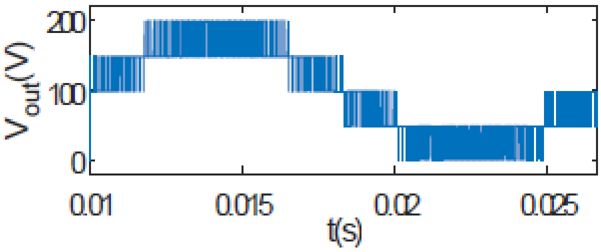

Fig.4. Dynamic simulation of healthy condition

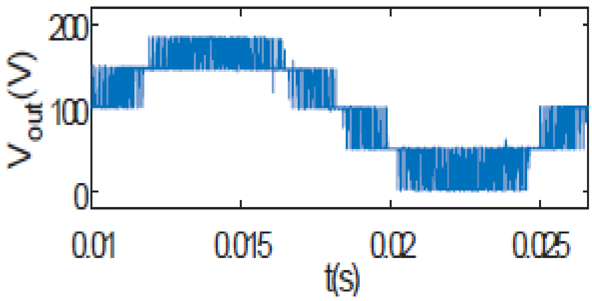

Fig. 5. Experimental result for healthy condition

TABLE I. SYSTEM OPERATING CONDITION

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Parameter	Value
DC link voltage	200V
Fundamental frequency	60Hz
Switching frequency	10kHz
Modulation index	0.8

TABLE II. COMPARISON BETWEEN FFT TOOLBOX AND MATHEMATICAL MODEL

	RMS	THD
Mathematical Model	116.55V	39.11%
Dynamic Simulation	114.95V	38.41%
Experimental Result	113.25V	37.22%

IV. RESULTS

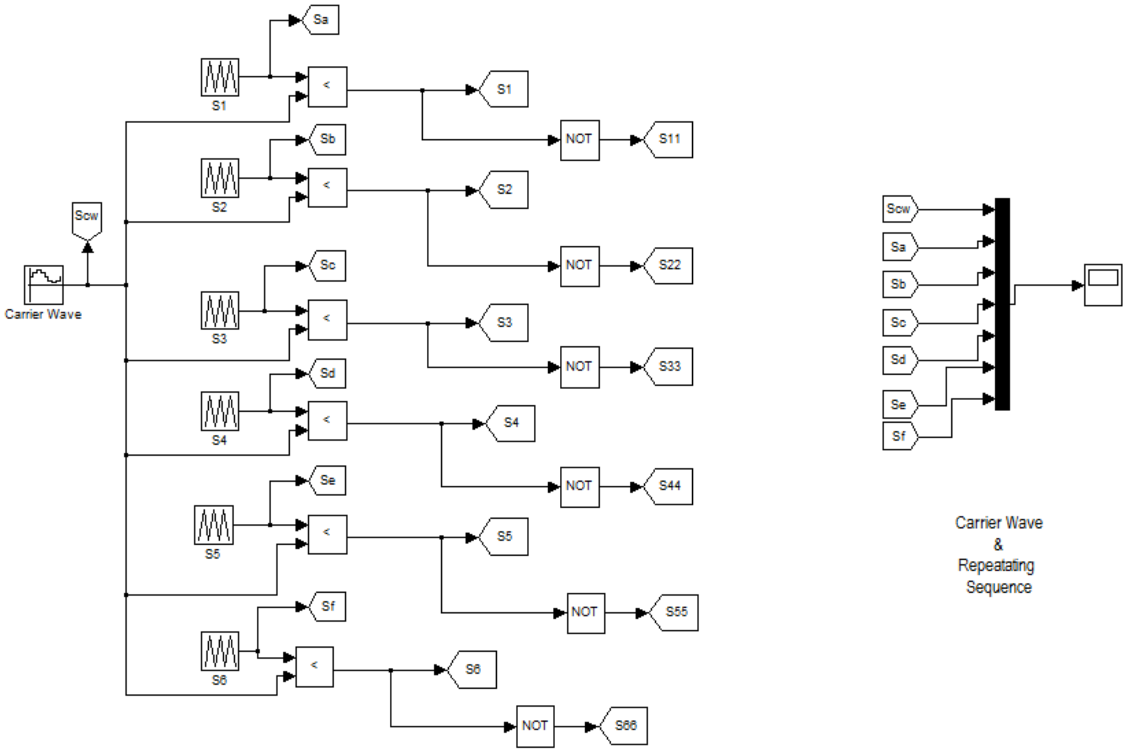

Fig: 6.simulation modeling of pwm generation for 7-level mli

Simulation results for 7-level mli is appear as shown in fig.7 and the total harmonic distortion is verified by fast Fourier theorem analysis.

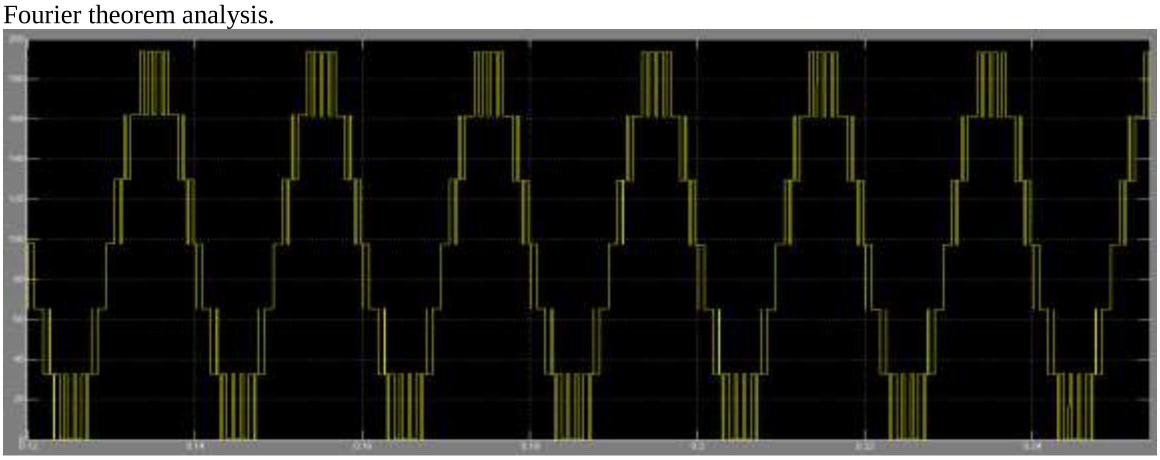

Fig: 7:Simulation results of 7-level mli

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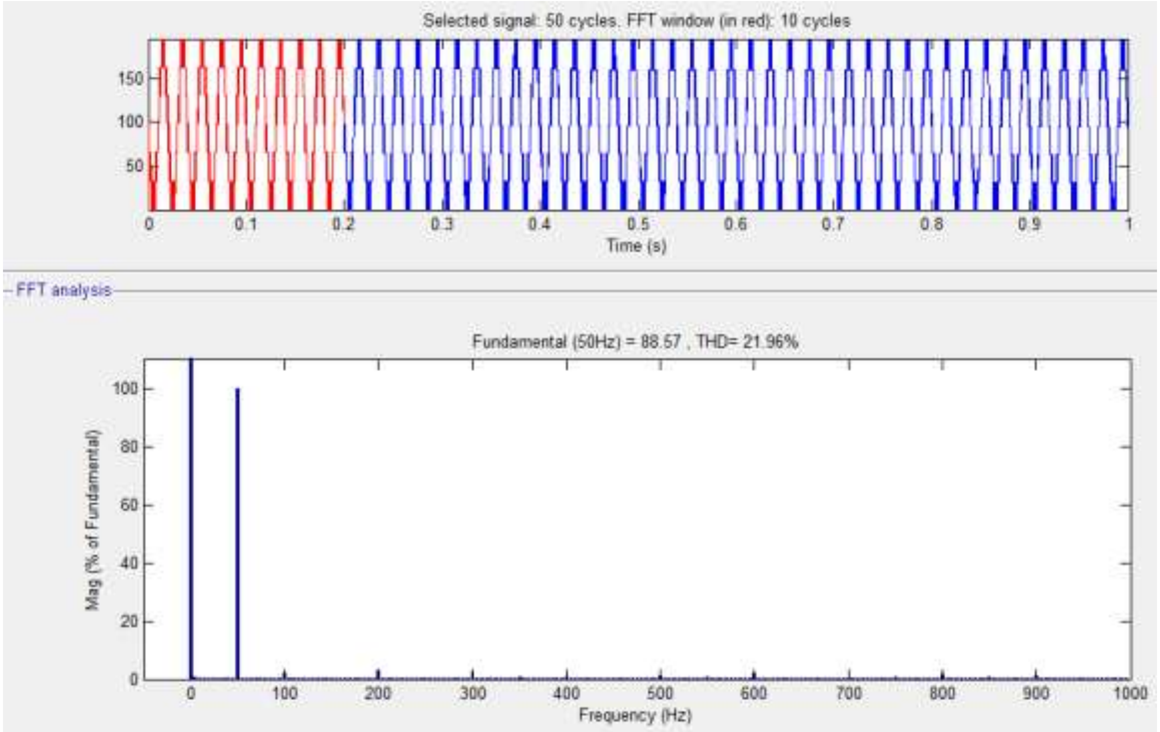

Fig: 8: FFT window for 7-level MLI with 21.96% THD.

TABLE III.
RMS COMPARISON BETWEEN MATHEMATICAL MODELS AND SIMULATION

Condition	Mathematical Model	Simulation	PE
Healthy	116.55V	114.95V	1.39%
NPS	107.24V	104.89V	2.24%
ALM	108.14V	106.18V	1.85%
120° DPWMMIN	89.37V	88.05V	1.50%

TABLE IV.
THD COMPARISON BETWEEN MATHEMATICAL MODELS AND SIMULATION

Condition	Mathematical Model	Simulation	PE
Healthy	39.11%	38.41%	1.82%
NPS	59.02%	57.30%	3.00%
ALM	39.59%	39.05%	1.38%
120° DPWMMIN	38.60%	38.24%	0.94%

TABLE V.
COMPARISON OF RMS BETWEEN RECONFIGURED AND HEALTHY CONDITIONS

Methods	Healthy	Reconfigured	PD
NPS	114.95V	104.89V	-8.75%
ALM	114.95V	106.18V	-7.63%
120° DPWMMIN	114.95V	88.05V	-23.40%

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TABLE VI.
COMPARISON OF THD BETWEEN RECONFIGURED AND HEALTHY CONDITIONS

Methods	Healthy	Reconfigured	PD
NPS	38.41%	57.30%	49.18%
ALM	38.41%	39.05%	1.67%
120° DPWMMIN	38.41%	38.24%	-0.44%

V. CONCLUSION

At last in this paper the investigation of the post-fault reconfiguration on the inverter voltage total harmonic distortion in multilevel inverters (MLI) was done. Hence to analyze the harmonic content of line-to- neutral voltage, accurate analytical model is introduced. For verification, two fault conditions are used. To analyze the harmonic content and RMS value of the achieved line to-Neutral voltages, reconfiguration method is applied. This method will mitigate the faults in effective way. From simulation results it can observe that proposed model gives accurate values. In the proposed project the 5-level multilevel inverter has been discussed. And the THD is 34.6% in extension paper the 7-level multilevel inverter will be analyzed with the same conditions as described in proposed paper and THD response will be (20-22) %.

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