SOFT SWITCHING CONTROLLER USING DYNAMIC RULE SUBSETSFOR MULTIPHASE - MULTILEVEL INVERTER APPLICATIONS

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Abstract: *This work presents a Dynamic rule-based soft switching controller for multiphase multilevel inverter drives applications. The complete control scheme including dynamic rule based soft switching is simulated using Matlab/ Simulink package. Proposed Control activity is accomplished by starting measuring the significant parameters in a rule-based system and afterward deciding their membership grades in the proper subsets. Then the intersection point of the dynamic rule subsets associated with a given rule is found with the value of that intersection point. In this manner, the intersection point of every rule is determined. Finally, the net control action is found by consolidating the action indicated by each rule in extent to the related rule's intersection point. This procedure is delineated in the accompanying areas of this work. This is done to achieve high dynamic performance with low Total Harmonic Distortion (THD). The simulation results validate the proposed approaches.*

Keywords: *Soft switching controller, Multiphase multilevel inverter, Cascaded H-bridge multilevel inverter.*

1.Introduction

In recent years, multiphase machine drives have pulled in noteworthy consideration among examiners because of its particular highlights. First purposes of enthusiasm of a multiphase gadget are: better consistent quality, expanded adaptation to non-critical failure, higher productivity, and higher torque thickness, lessened torque throbs, lesser per stage power taking care of prerequisites, upgraded measured quality and enhanced commotion attributes. Multiphase Multilevel Inverters (MMI) are right choice to show multiphase variable voltage and variable frequency supply. Multi-Level Inverter (MLI) has some specific features: low harmonic distortion diminished switching misfortunes, high-voltage capability by energy checked devices, good electromagnetic compatibility, and increased efficiency. In this section, various MLI structures are analyzed equally, and its measured wildlife modulation, powerand security necessities of every full bridge inverter. As compared with all MLI. The Cascaded Multi-Level Inverter (CMLI) is found to give the better result.

Numerous new adjustment strategies have been created to consider the developing number of MLI topologies. They are away to furnish a switched waveform with portable amplitude, frequency, and phase angle that is a sinusoid at a steady state. Compared to high voltage converters, the central facts of importance tracked are high-power excellence and smallest switching frequency. These two necessities contend, and subsequently, it is viewed as a standout amongst the enormous difficulties in MLI.

Based on the carrier frequency and modulation techniques to generate the significant result of Multilevel Inverter. Versatile phase opposition disposition (VPOD), vertical modifications PD, and phase shift signal are the commonly used carrier signals. The multi-level inverter gives significant response based on Space Vector Modulation (SVM) method. Because the SVM modulation technique create high frequency clock pulses and obtained minimum harmonics distortion. Be that as it may, this is also the purpose behind high switching losses. Subsequently, Key Pulse Width Modulation (KPWM) strategies are favored. Selective harmonic disposal has the upside of having few changes for each cycle, and furthermore, it accomplishes better effectiveness. All things considered, disconnected figurings are essential for doing helpful work.

In this work proposed the method for dynamic rule-based switching PWM algorithm. This algorithm gives a significant result of voltage balancing and generate very low harmonics distortion. The Complex programmable Logic Devices is used to execute the logic element is adopting proposed PWM technique.

2. PREVIOUS RESEARCH WORKS

Numerous contemporary bits of research have been utilized for new machine learning procedure to beat the inconveniences of counterfeit consciousness. A standout amongst the most critical of these strategies is the Artificial Neural Network (ANN) strategy, which has been utilized to build the genuine control and to enhance the ideal positions, prompting strong and correct outcomes.

Creator report a brought together SVPWM strategy for a multilevel inverter which require complex nonlinear computation including suggested modulation elements of SVPWM in [1, 2]. In like manner, the greater part of the SVPWM requires complex online calculation which prompts trouble progressively execution. In this manner just reproduction comes about are introduced. In this way, the traditional SVPWM requires extra memory which restrains the decisions of switching frequency and in this manner diminishing the precision of SVPWM [3], [4], [5]. To tackle this issue Genetic Algorithm (GA) - based SVPWM is use [6], however the GAs require a significantly cycle to locate the best outcomes, which is tedious. An ANN is likewise utilized as a part of SVPWM [4], [5] for productive inverter operation. The Adaptive Neural Fuzzy Inference System (ANFIS) based SVPWM is utilized for two-level inverters. Nonetheless, the methodology indicate above have issues in perspective of their extensive information prerequisite, long planning and learning times of direct and nonlinear limits that use gigantic memory for constant execution.

Walsh limits is proposed to ideal switching edges in [6]. Fourier-Walsh change grid is used to change supernatural condition set to straight conditions. By then, it enhances the switching aspects [7]. PSO methodology as a developmental algorithm has been proposed in [8]. The nonlinear issues with numerous ideal are dependably explained by utilizing PSO [1, 7]. Additionally, GA is a standout amongst the most by and large used systems for developmental algorithms. GA and PSO can precisely discard all low-arrange harmonics since they can decide the ideal switching edges with high exactness.

GA has focal points, for example, better THD (Total Harmonic Distortion) minimization, clearer algorithm, with a lessening of computational time differentiated and PSO [8]. GA is more suitable and its execution in MATLAB programming is simple [9]. Hybrid Genetic Algorithms (HGA) have been produced to dispense with the tweaking issue of a nearby pursuit in GA. It is a curve of resident examination and GA [10]. In the second step, the believed switching controls are recorded in a look-into table to use for the genuine applications. Be that as it may, when the quantity of switching points is expanded, a critical investigate table would be required. Moreover, it isn't doable to perform with a long look-into table in a computerized signal processor, and the arrangements may miss for some working focuses [11].

This paper proposes a particular consonant end control system on a three phase four leg inverter. Four-leg control signal three-phase control signal using experimental Fourier-based conditions, which takes triple harmonics out at the lower position by any other method and additionally passed by passing on, in which the fourth leg is proportional to harmonics To give less triple harmonics made by alternative legs [12].The undesired torque harmonics can be eliminated at low switching frequency by controlling the pulse through rotor flux of the drive machine [13],[14]. This paper discusses the low harmonic losses can be achieved through low switching frequency and optimum output voltage vector [15],[16],[17].

A SVPWM technique is created for three-phase 4 wire inverter control of current control. Also, many circle system computerized controls are viewed from the viewpoint of the killjoy control method [18].This paper presents another control, with the purpose of production control of the best three-stage output voltages in a wide range of straight / nonlinear and balanced / stable loads. Planned control uses a circuit equatorial decryption strategy and is implemented by a controller center and a combination of reasoning hardware with a review signal informatics [19-20].

3. MATERIALS AND METHODS

The Power circuit topology of a proposed multiphase multilevel inverter model appears in Figure 1. The inverter input DC voltage is viewed as being consistent. The load is taken as star-associated, and the multilevel inverter output stage voltages are with the symbol (a,b,c,d,e). The topology of the proposed dynamic rule-based multilevel inverter comprises of arrangement H-Bridge inverter cells, impedance systems, DC sources, motor and vibrant rule-based controller. Since MLIs are incredibly suited for multiphase load models, the few DC sources in the multiphase multilevel structure can be accessed from renewable sources and batteries or ultra-capacitors. An isolated voltage source Vdc1, Vdc2, Vdc3…Vdc is associated with different sources using an uncommon consolidated H-bridge circuit. Every H-Bridge circuit comprises of four dynamic switching components that can make the output voltage either positive or negative extremity.

In optimum Selective Harmonic Elimination (SHE), each dynamic gadget can be switched as twice per cycle, and many parts can be disposed of. In nonlinear conditions, the main problem related to the

SHE system is the inconvenience to get the switching points. In this work, a novel dynamic oversee exhibit is created to deal with the SHE issue. Reproduction and exploratory outcomes are gotten for a 5-level multiphase-MLI to approve the proficiency and exactness of the proposed strategy.

3.1. Harmonic Elimination Technique for Multiphase-MLI Fed Model

To dissect the multiphase MLIs output waveform Fourier arrangement extension is connected. As per the Fourier development of the stage, voltage can be communicated in (1)

Where

= DC Amplitude

= Switching angle

The switching angles of the cell that are obliged in the vicinity of 0 and 90°.In this way, this limitation can be composed as follows

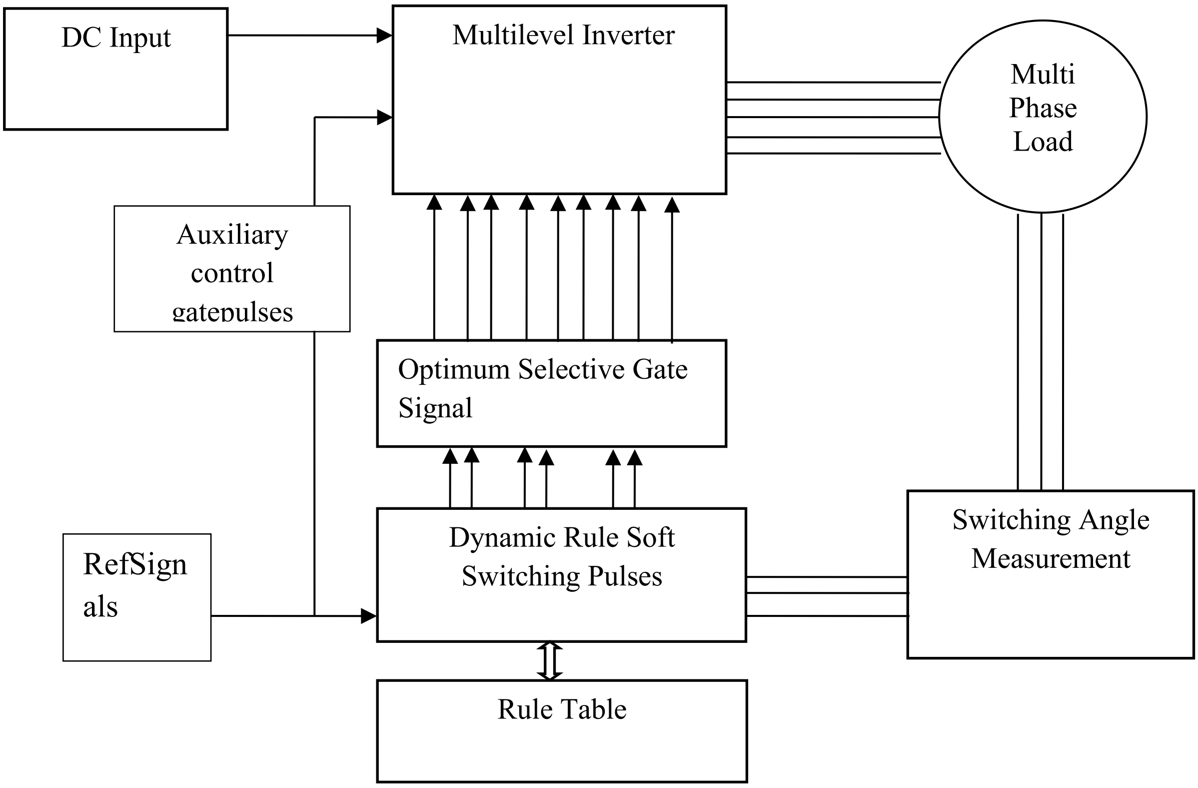
V=Desired value of the fundamental component

S= quantity of partitioned DC sources

α_1,α_2 and α_3 = Switching angles

Moreover, the outcomes ought to fulfill the imperatives to comprehend the non-linear equations utilizing the proposed technique are explained below.

Figure. 1. Block diagram of proposed controller



Selective harmonic elimination procedure manage condition (1) not exclusively to decrease or evacuate the most minimal voltage harmonics distortion yet in addition to fulfill the basic segment necessity. A fifth and seventh harmonics of the five level inverter is disposed from voltage waveforms. Triple harmonics should banish since line voltage on account of its symmetric attributes. In this manner, for the proposed multiphase MLI the arrangement of conditions are shaped as takes after.

Where M is the modulation index that can be considered as follows

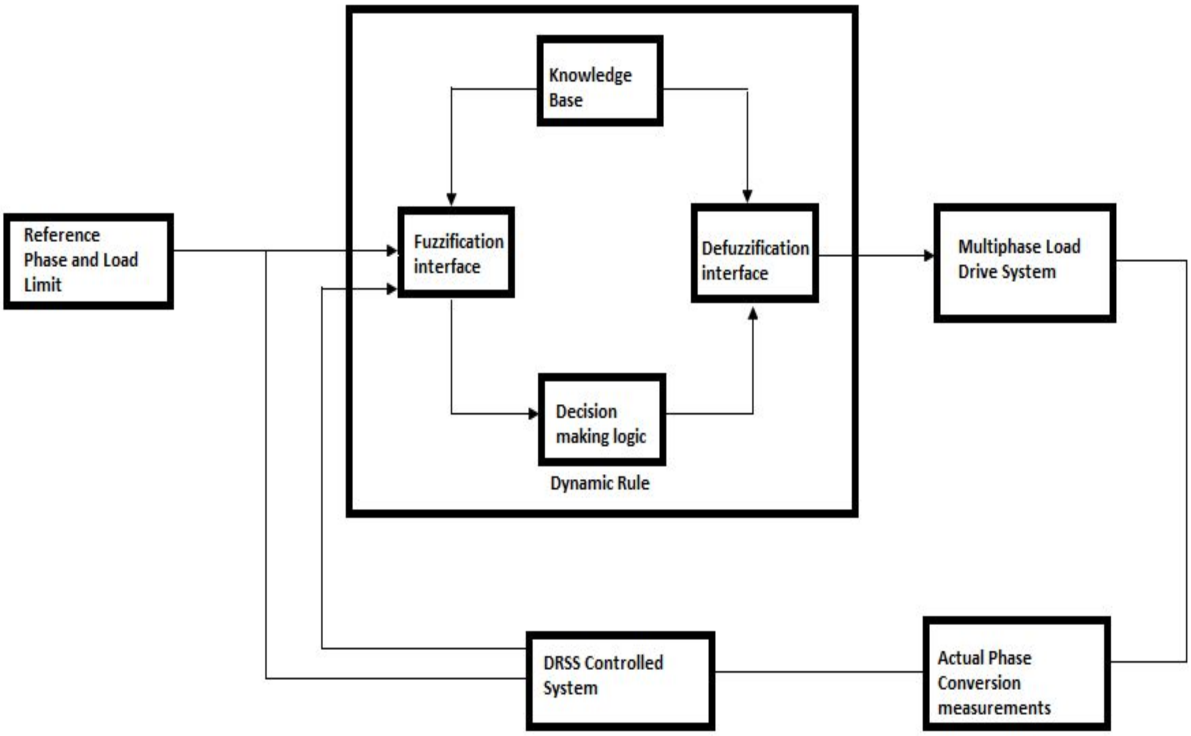
The Modulation index M as expressed as follows

4. SOFT SWITCHING CONTROLLER USING DYNAMIC RULE SUBSETSFED MULTIPHASEMULTILEVEL INVERTER

The traditional controller does not have output saturation limiters and conceivable conditions for the multilevel inverter harmonics still exist. To overcome this inconvenience, an extra ordinary integrator output will be kept at maximum, which is known as against windup phenomenon. The primary target of the proposed control design is to avoid the over motivating force in the integrator and along these lines the output will be kept inside a restricted range. It is normal that there will be an expansive change in the controller execution under each working state of the brushless dc drive.

4.1. Soft switching control pulse generation using Dynamic rule Subset

The multilevel inverter load can be controlled by controlling the multiphase MLI inverter switching pulses utilizing the proposed technique. The control unit gives the data about required switching pulse values during an error condition.



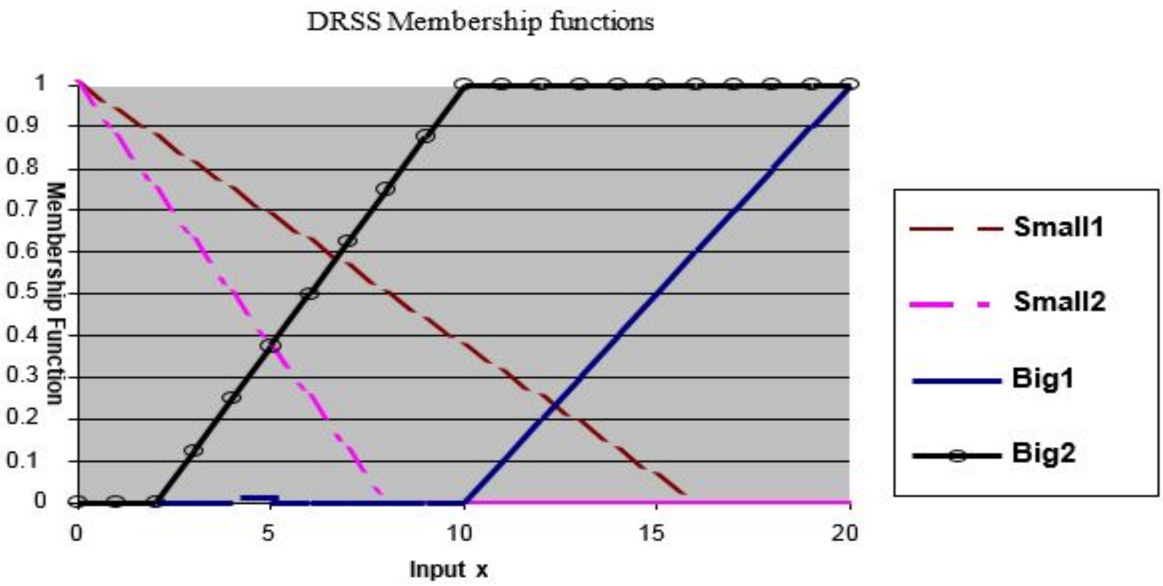


Figure.2.Configuration of Proposed Controller

Figure 3.Sample Membership Function of DRSS

The overall control action was found by joining the development demonstrated by each control in the degree to the related control's DOF. In This strategy is shown in the following areas of this work. Dynamic Rule Soft Switching controller(DRSS) comprises of three main components namely Fuzzification, defuzzification and dynamic rule decision logic interface which converts input data into suitable linguistic variables.

Arguments related to the membership functions of the union and intersection of dynamic rule-based soft switching sets have been recalled. The intersection of sets error *(A)* and change in error *B* are given as, $\mu_{A\c{C}B}$ = min (μ_A, μ_B). A dynamic rule-based soft switching control system encompasses some rules; for example, in multivariable control (**Multiple Input Single Output**), the relevant rules for what they imply should be tested. Consider a system with *n* implications (rules); the variable of consequence, *y*, will have to be written for each of these effects, leading to y_i variables of the outcome. There are three stages of calculations in Takagi-Sugeno controllers**:**

i. **FUZZIFICATION**: Fuzzify the input. For all input variables compute the implication for each of the rules;

ii. **INFERENCE or CONSEQUENCES**: For each connection compute the consequence for a rule to be fired. Then calculate the output *y* for the rule by using the linear relationship between the inputs and the output ($y = p_0 + p_1x_1 + \ldots + p_kx_k$.).

iii. **AGGREGATE:** The last output y is surmised from n-suggestions and given as a normal of all individual implications y^i with weights $|y= y^i|$:

Where |y= yi | remains for the true value of a given proposition. Consider the following fuzzy implications (or rules) R_1, $R2$, R_3 used in the design of a Takagi-Sugeno controller:

Where y (i) refers to the following variable for each rule categorized Ri and x1 and x2 refer to the input variables that look in the premise of the rules. The membership function for *small*$_1$, *small*$_2$, *big*$_1$, and *big*$_2$ are specified in Table 1 and Figure 3.

The output *y* for the values such as x_1 = 12 &x_2 = 5 using Takagi and Sugeno's formula:

Table 1.Sample System Membership Functions Values

X	Small1	Small2	Big1
0	1	1	0
1	0.938	0.875	0
2	0.875	0.75	0
3	0.813	0.625	0
4	0.75	0.5	0
5	0.688	0.375	0
6	0.625	0.25	0
7	0.563	0.125	0
8	0.5	0	0
9	0.438	0	0
10	0.375	0	0
11	0.313	0	0.1
12	0.25	0	0.2
13	0.188	0	0.3
14	0.125	0	0.4
15	0.063	0	0.5
16	0	0	0.6
17	0	0	0.7
18	0	0	0.8
19	0	0	0.9
20	0	0	1

Using a centre of area computation for *y* we get:
(4)

$$y = \frac{0.25*17+0.2*24+0.375*15}{0.25+0.2+0.375} = 17.8$$

Table 2.Sample System Rules

Rule	Rule 1	Rule 2	Significance	Truth Value (Rule 1 &Rule2)
R_1	*Small*$_1$ $(x_1) = 0.26$	*Small*$_2$ $(x_2) = 0.381$	$y^{(1)}= x_1 + x_2 =12+5$	Min(0.26 0.381)=0.26
R_2	*Big*$_1$ $(x_1)= 0.3$		$y^{(2)}= 2x_1= 24$	0.3
R_3	*Big*$_2$ $(x_2)= 0.381$		$y^{(3)}= 3x_2$ *15*	0.381

4.2. Dynamic rule-based decision making

Selection data of dynamic rule process is researched by Mamdani method. The data and output relationship are viably got by Mamdani deduction system. The proposed arrangement of benchmarks is given in table 3. The administrator has utilized to obtain the DRSS result from the course of action of return of Min head. The results made by the proposed sets and proposed basis operation by assessing every one of the Rules. The error is e and error rate (change of error) Ce, the error and error rate is computed as

$$\text{error} = V_{ref} - V_s$$

$$\text{error rate} = \text{error(n)} - \text{error(n-1)} \qquad (5)$$

In the proposed DRSS plan, the speediness error and the rate of speediness error are measured as the semantic information components and the torque portion is regarded as the output variable. They are also represented in triangular enrollment work with the extent of - 70 to 70. DRSS Inference System of the proposed structure is utilized to switch the speed of output. Defuzzification is completed by using centroid system.

Aggregation of standards is done by the conjunctive arrangement of standards and the rules are related by "and" connectives. Collected output is given by

Using a centre of area calculation for *y* we get

Table 3: Proposed logic rule table

Δe \ e	NL	N	NM	NS	Z	PS	PM	P	PL
NL	NL	NL	NL	NL	NL	NL	N	N	NM
N	NL	NL	NL	NL	N	N	NM	NS	NS
NM	NL	NL	NL	N	N	N	NM	NS	NS
NS	NL	N	NM	NM	NM	NM	NS	NS	NS
Z	N	NM	NS	NS	Z	PS	PS	PM	P
PS	PS	PS	PS	PM	PM	PM	PM	P	PL
PM	PS	PS	PM	P	P	P	PL	PL	PL
P	PS	PS	PM	P	P	PL	PL	PL	PL
PL	PM	P	P	PL	PL	PL	PL	PL	PL

4.3. Algorithm for Proposed DRSS

Step 1: Reset feedbacks

a)error b)error rate(change of error)

Step 2: lead subsets improvement

Step 3: Input estimation of the level of enrollment of inputs of every fuzzy membership.

Step 4: Development of instructions (utilizing function table)

If e == Y && Ce == Y

Output=Y

End If

Step 5: Control Degree Of Freedom (DOF) of every instruction (imperative quality)

(6)

The inference of DRSS control rules for the picked inverter is heuristic in nature and depends on the accompanying criteria:

- When the output of the inverter digresses a long way from the reference, the repaying signal/change of tweaking sign must be extended to convey the return to the text rapidly.
- When the output of the inverter is moving towards the reference, a little change of balancing sign is vital.

When the output of the inverter is close to the reference and is moving towards it quickly, the tweaking signal must be kept steady to expect to promote deviation.
When the reference has come to and the yield is so far changing, the adjusting signal must be improved a little piece to shield the arrival from moving perpetually.
When the reference has come to and the output is enduring, the balancing signal stays unaltered.
When the output is bigger than the reference, the adequacy of balancing sign must be diminished and the other way around.

Step 6: Framing the yield set: yield sets for shaped standards e.g. yield set is Y.

Step 7: Computation of centroid for every output conventional: centroid for fuzzy set Y=0

Step 8: Defuzzification

(7)

The output of the proposed procedure is a control flag that is utilized as a part of the switching signals. The carrier flag is contrasted and the generation of switching flag. A strategy for working as FIS can be compacted as

- Pick a Mamdani (or) Sugeno
- Picked vital input - output inconstant
- Regulate the participation work for each intelligent term.
- Design and gathering of fuzzy if-then standards.
- Select the defuzzification technique in this projected strategy 49 proposed procedures are utilized.

The benefit of the proposed DRSS determination framework has been appeared in controlling nonlinear, complex, time-fluctuating segment shapes in main problems. It can be utilized as an online pick up tuner for the back-count controller.

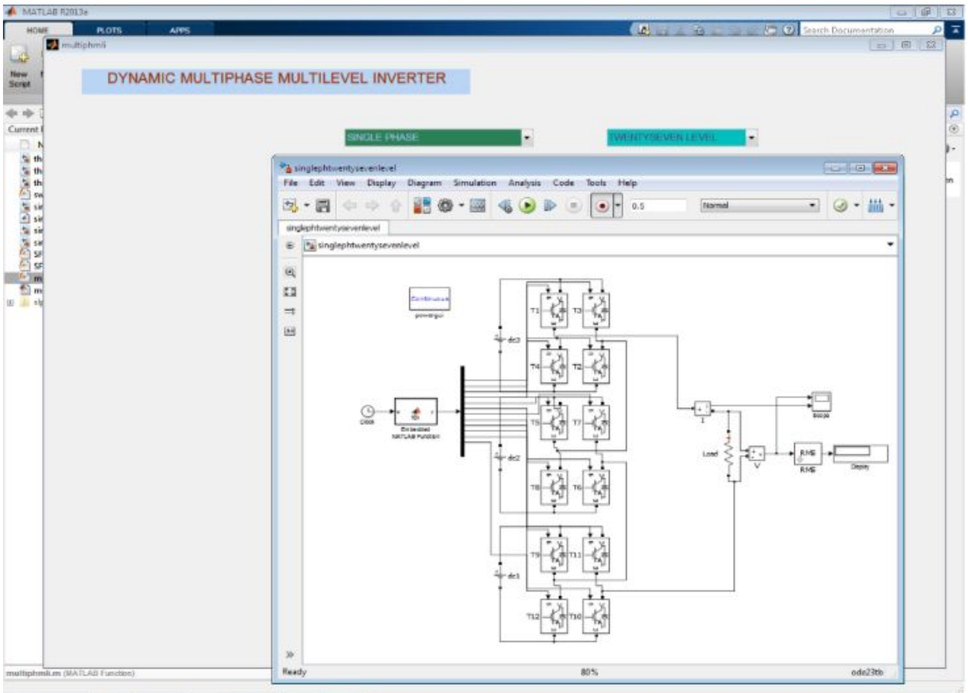


Figure 4 Simulation diagram of proposed multiphase multilevel inverter

The advanced control involves Mamdani DRSS inference system as a pickup tuning – mechanical assembly for the back-count controller. The proposed strategy is used for tuning the controller get in online mode under each and every single working condition.

5. MATHEMATICAL MODELLING OF MULTIPHASE-MULTILEVEL DRIVE SYSTEM

Proposed DRSS control is an effective instrument that depends on the practices of present nonlinear systems. The proposed control technique comprises of related neurons that impact by sending signals to each other along weighted associations. Association weights are changed by learning guideline in the preparation procedure. The yield Yj as takes after

(8)

where
f = initiation function
x_i = input signal
w_{ji} = association weight
The quantity of formed changes amongst the desired and real values of the output neurons E is given by

(9)

where
y_{dj} = desired value of output neuron
y_j = real output of that neuron

The perfect response for deciding points and making PWM signals have been delivered. Therefore, the ideal 11-switching edges are controlled by streamlining the target work fitted for switching points of a few adjustment records. The Root Mean Square Error (RMSE), coefficient of confirmation (R2) and Mean Absolute Error (MAE) have been used to evaluate the execution. These criteria are given by:

(10)

(11)

(12)

where
n = number of information test

$y_{pre,i}$ = measured value
y_i = estimation of an information sample

6. RESULTS AND DISCUSSIONS:

The Simulink model of the proposed multiphase-27 level Multilevel Inverter frameworks for dynamic administer based multiphase heartbeat width adjustment procedure appeared in Figure 4. This circuitinvolves a single stage, three stage and five stage spans associated in course with MOSFET as switching gadgets. Four separate voltage wellsprings of significant worth Vdc=90V are utilized to stimulate the power circuit. The heap on the inverter is resistive of substantial worth R= 50 Ω. The control unit which generates required switching signals is shown as the subsystem. The THD is measured using signal THD block for every switching angle.

By adding additional H-Bridge circuit in the multiphase 27-level single phase inverters are tested with the same modulation technique.

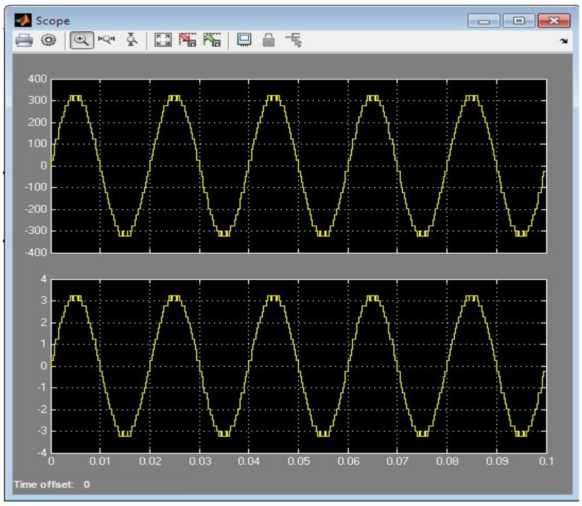


Figure 5 Simulation results for output voltage and output current for single phase 27-level inverter using DRSS

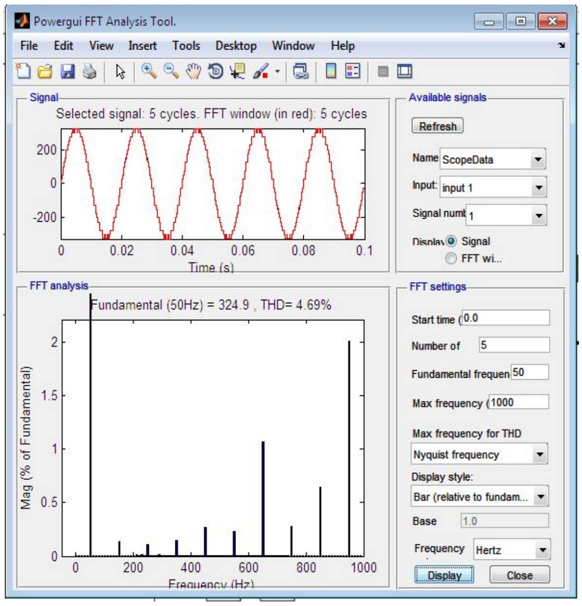


Figure 6 FFT Analysis for DRSS model

Table 4 Comparison Multiphase multilevel inverter parameter values under various switching techniques

Parameters	**SVPWM**	**MSVPWM**	**Proposed DRSS control**
THD	13.02%	9.92%	4.69%
Magnitude level	400V	400V	400V
Fundamental Frequency	50 Hz	50 Hz	50 Hz
Switching frequency	2-4 kHz	2-4 kHz	2-4 kHz

Table 5 THD comparison of proposed MLI under various phase and various switching conditions

Method	THD %		
	Single phase	**Three phase**	**Five phase**
SVPWM	13.02%	15.44%	19.34%
MSVPWM	9.92%	11.65%	17.77%
Proposed	4.69%	10.92%	15.09%

It can be seen that, based on the various level conditions, Proposed PWM based MLI recovers the different THD% than the other methods. For comparison purpose, the overall performance indices of varying level of MLI system associated with the switching frequency are given in Table 5.

7. CONCLUSION

This work proposes DRSS algorithm has been used to simulate the multiphase multilevel inverter and the performance of the output results is examined. By using different types of switching angles the simulation result keeping up supply voltage consistent and equivalent. From the simulation results, it is inferred that for all the arrangement changing angles, the Proposed DRSS techniques gives minimum THD. The reduced THD values for 5, 3, 1-phase of 27-level inverters are 4.69%, 10.92%, and 15.09%.Hence, it is concluded that the proposed DRSS techniques are useful in removing lower order harmonics than the conventional methods.

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