MODEL PREDICTIVE CURRENT CONTROL OF REDUCED SWITCH MULTILEVEL INVERTER

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Abstract:

This project proposes a model predictive current control (MPCC) strategy for a reduced switch multilevel inverter (RSMI) topology. The RSMI offers advantages such as reduced component count and improved efficiency compared to traditional multilevel inverters. The Model Predictive Current Control (MPCC) algorithm utilizes a finite control set approach to predict future current errors and selects the optimal switching states to minimize these errors while considering constraints such as voltage limits and switching frequency. Simulation results demonstrate the effectiveness of the proposed MPCC strategy in achieving accurate current tracking and maintaining voltage balance across the inverter's output phases. Experimental validation on a hardware prototype further verifies the feasibility and performance of the proposed control technique, highlighting its potential for applications in renewable energy systems, motor drives, and grid-connected power converters.

KEYWORD: MPCC

INTRODUCTION:

One critical aspect of operating multilevel inverters is the implementation of robust current control strategies to regulate the output currents accurately. Model Predictive Control (MPC) has gained popularity in recent years as an effective control technique due to its ability to handle multivariable systems with constraints and uncertainties. By predicting future system behavior and optimizing control actions accordingly, MPC can achieve precise control while minimizing performance degradation caused by disturbances.

In this context, this paper presents a comprehensive investigation into the application of Model Predictive Current Control (MPCC) for RSMIs. The objective is to develop a robust control strategy that can effectively regulate the output currents of the RSMI while addressing the challenges posed by the reduced number of switching devices. By leveraging the predictive capabilities of MPC, the proposed control scheme aims to achieve accurate current tracking, minimize harmonic distortion, and enhance overall system performance.

LITERACY SURVEY:

Jawahar, S., & Ramamoorthy, P at [1] Explored the different multilevel inverter topologies that use multiple switching devices, energy storage devices, or unidirectional devices. The add-on driver circuit is required for each switching unit for proper operation. For the switching devices in the positive and negative arms of the bridge, the cascaded H-Bridge Multilevel Inverter requires overlapping switching pulses, which could result in a short circuit in the event of a device failure. This research uses fewer switching, energy storage, and driver circuits to overcome issues with various multilevel inverter topologies. In the current method, a single H-Bridge is used for phase reversal and a single switch is used for each stair case's positive output. Utilise theMOSFET's body diode property, driver circuits are minimised.

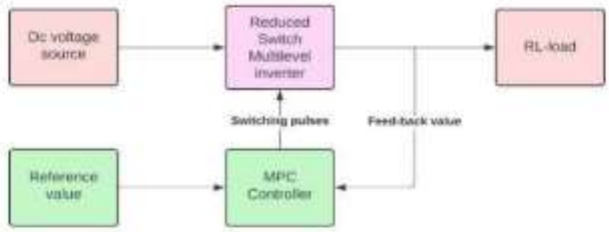
Holkar, K. S., & Waghmare, L. M. at [2]. Presented a review of the most popular techniques integrated into an industrial model predictive control. The history, fundamental concept, characteristics, and controller formulation of the most popular strategies, including Dynamic matrix control (DMC), Model algorithmic control (MAC), Predictive functional control (PFC), Extended prediction self-adaptive control (EPSAC), Extended horizon adaptive control (EHAC), and generalized predictive control (GPC), have been detailed.

Siddique, M. D., Iqbal, A., Memon, M. A., & Mekhilef, Sat [3]. Proposed a new MLI topology based on switched dc voltage source with reduced switch count for single-phase applications. With fewer components and a higher number of levels at the output, the topology that is being described was created with the restriction of having a lower blocking voltage of the switches. Additionally, both symmetrical and asymmetrical configurations can function with the suggested architecture. By computing angles for switching operations optimally, the staircase output voltages are synthesized using the Selective Harmonic Elimination (SHE) technique, which eliminates lower order harmonics.

Rodriguez, J at[4]. proposed a novel approach to improve such problems: model-free predictive control (MFPC). The method for determining the parameters of an autoregressive with exogenous input (ARX) model that is being given is based on a recursive least squares algorithm. The suggested approach eliminates the need for in-depth understanding of the physical system and offers an accurate prediction of the controllable variables. By incorporating a cutting-edge state space identification algorithm into the predictive control structure, this innovative strategy is made possible.

Azab, M. at [5]. A finite control set model predictive control scheme for single-phase grid-connected inverters. Renewable and Sustainable Energy Reviews, 135, 110131. This paper examines a finite control set model predictive control (FCS-MPC) based control method for a single-phase grid-connected inverter. The suggested grid integration method allows for direct control over the amount of reactive and active power (PQ) that is added to the grid from distributed energy resources (DERs). These resources are made up of battery banks that store energy and photovoltaic (PV) arrays that function as renewable resources. Low voltage ride through (LVRT) capacity of the inverter during voltage sag is also included in the direct PQ control system.

BLOCK DIAGRAM:



DC Voltage Source:

A *DC voltage source* is an electrical gadget that provisions a consistent Direct Flow (DC) voltage to a circuit. In contrast to Rotating Current (AC) which heads in a different path occasionally, DC voltage keeps a proper extremity, causing it ideal for applications that to require a consistent and unvarying power supply. **Reduced Switch Multilevel Inverter:**

A single-phase hexagonal inverter with 8 switches and 3 voltage sources is a sort of staggered inverter that is intended to expand the power result and productivity of electrical frameworks. This inverter design is especially valuable in applications that require a top-notch power supply with negligible symphonious twisting.

MPC (Model Predictive Current) Controller:

Model Predictive Current Control (MPCC) is a complex control system that can be applied to single-stage staggered inverters to direct the result flows with high accuracy and proficiency

MPCC means to control the result flows of single-stage staggered inverters to accomplish explicit execution targets, like precise following of reference flows, limiting current music, and guaranteeing strong activity under fluctuating burden conditions. MPCC uses a prescient control approach where future framework conduct is anticipated in light of a unique model of the inverter and the heap. By taking into account future states and imperatives, MPCC enhances the control activities over a limited forecast skyline to accomplish the ideal current reaction.

Reference value:

In Model Predictive Current Control (MPCC), the reference signal assumes an essential part in accomplishing the ideal current reaction in the control circle. Here is a concise note on the reference signal in MPCC:

The reference signal in MPCC addresses the ideal current that the control framework expects to follow. It fills in as the setpoint for the ongoing control circle, directing the regulator to create control flags that drive the genuine current towards the ideal worth.

The reference signal characterizes the objective current level that the control framework tries to accomplish. It is regularly determined in light of the prerequisites of the application or the ideal exhibition of the framework.

RL load:

A RL (resistor-inductor) load is a typical kind of burden experienced in electrical frameworks. With regards to staggered inverters, a RL load comprises of both opposition (R) and inductance (L) parts. The obstruction addresses the dissipative component, while the inductance represents the energy stockpiling and time defer in the heap.

Feedback Signal:

In MPCC of staggered inverters, the input signal assumes a vital part in guaranteeing precise current guideline. It gives data about the genuine current coursing through the inverter's result stage, empowering the control framework to contrast it and the ideal reference current and create suitable control activities. The criticism signal structures a piece of the criticism circle in the MPCC control framework. By contrasting the genuine current and the reference current, the regulator creates control flags that change the exchanging examples of the inverter's power changes to precisely limit any deviation and track the ideal current waveform.

Pulse Signal:

Pulse signals assume a crucial part in MPCC by deciding the exchanging examples of the staggered inverter's power switches. These heartbeat signals control the age of voltage levels to direct the result current waveform as indicated by the ideal reference current.In MPCC, pulse signals direct the timing and span of the exchanging occasions for each power switch in the staggered inverter. By controlling the actuation and deactivation of switches, beat signals decide the voltage applied to the heap and subsequently manage the result current.

MODEL PREDICTIVE CURRENT CONTROL:

Model Prescient Current Control (MPCC) is a complex control technique utilized in staggered inverters to direct the result flows to wanted reference values. In a staggered inverter, various DC voltage sources are utilized to blend a ventured AC waveform, giving better symphonious execution and lower voltage weight on the exchanging gadgets contrasted with customary two-level inverters.

1.Predictive Control Approach:

MPCC utilizes a perceptive control approach, where the control estimation predicts future structure direct considering the current status and a model of the system components. This insightful limit considers smoothing out control exercises over a restricted assumption horizon.

2.Model of the Inverter:

To predict the future approach to acting of the structure, MPCC requires an exact model of the stunned inverter. This model consolidates the components of the structure, similar to the voltage and current components, trading behavior of the power devices, and the effects of the pile.

3.Finite Control set:

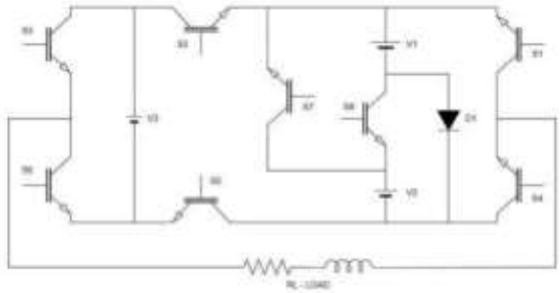
MPCC works by picking control exercises from a restricted game plan of possible voltage vectors. Each voltage vector connects with a specific mix of trading states for the power devices in the inverter. By picking the reasonable voltage vector at each examining second, MPCC have some control over the outcome streams to follow the reference values while satisfying limits on the trading repeat and voltage stresses.

4.Performance and Robustness:

MPCC offers a couple of advantages over customary control frameworks, including dealt with transient response, lessened consonant twisting, and better goodness to limit assortments and disrupting impacts. By explicitly considering the future progression of the system and upgrading control exercises as required, MPCC can achieve preferable execution contemplated over standard control techniques. In overview, Model Predictive Current Control (MPCC) is areas of strength for a technique for staggered inverters that utilizes control principles to coordinate outcome streams with high precision and capability. By further developing control exercises over a restricted figure horizon, MPCC can achieve brilliant execution and strength in various applications, including harmless to the ecosystem power structures, motor drives, and power grid applications.

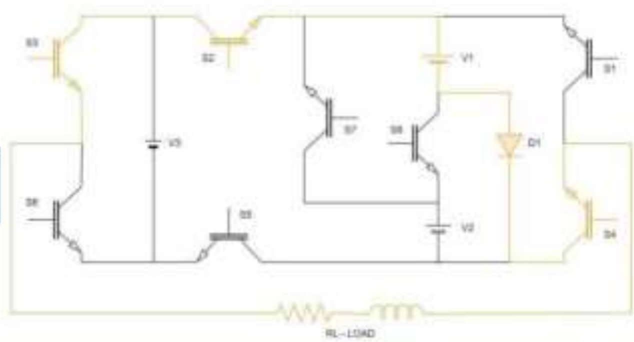
REDUCED SWITCH MULTILEVEL INVERTER:

The multilevel inverter can generate fifteen-level output using eight switching devices, one diode, and three dc-link voltages. The operating principle, grid-connected configuration, and the calculation of blocking voltage have been discussed briefly in this section. The inverter contains of eight controlled switches and one diode connected in a hexagonal configuration. There are three voltage Sources connected to the inverters with a voltage ratio of 1:2:3. Ie; if the Voltage Sou rce V1 is 50v, then the value of V2 will be double the value of V1 (100v) and the value of V3 will be double the value of V2 (200v). The load connected to the inverter is RL (Resistive - Inductive) load. The gate pulses to the inverter are generated by MPCC controller.



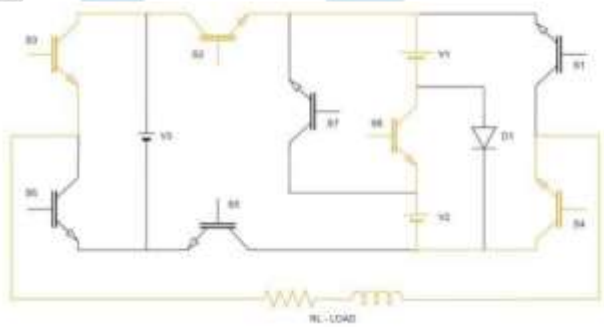
SWITCHING SEQUENCE:

The proposed topology has fifteen modes: a single zero mode, seven positive modes, and seven negative modes. To generate these fifteen modes, the proposed topology uses only eight switching devices along with three voltage sources. The values of the voltag e sources are selected so that the value of V2 must be twice the times of V1, and the value of V3 will be four times that of the supply voltage V1. The switches (S1, S2) and (S3, S6) are turned on simultaneously to avoid the short circuit of dc sources.



In this State, Switches S4, S3 & S2 are turned ON and Diode ‘D’ is naturally forward biased. The current flows from the DC Voltage Source ‘V1’ to load through Diode – S4 and returns to the source through S3 – S2 and DC Voltage Source. The Output Voltage is V1.

Switching State 2:

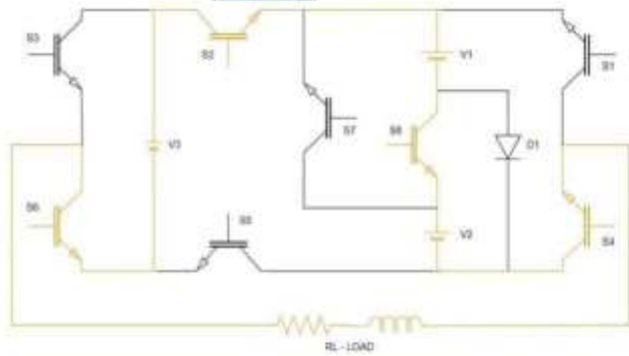


Switching State 1:

In this State, Switches S8, S4, S3 & S2 are turned ON. The load is supplied from two sources (V1, V2). The current flows from the DC Voltage Source 'V1' to load through S8 – V2 – S4 and returns to the source through S3 – S2 and DC Voltage Source. The Output Voltage is V1+V2.

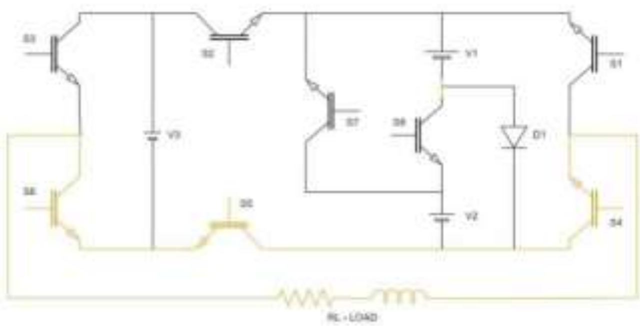
VOLTAGE SEQUENCE	ACTIVE SWITCH	CURRENT PATH
V1	S4,S3,S2	V1-D1-S4-Load-S3-S2-V1
V2	S4,S3,S2,S7	V2-S4-Load-S3-S2-S7-V2
V1+V2	S8,S4,S3,S2	V1-S8-V2-S4-Load-S3-S2-V1
V3	S2,S1,S6	V3-S2-S1-Load-S6-V3
V1+V3	S2,S4,S6	V3-S2-V1-D1-S4-Load-S6-V3
V2+V3	S2,S7,S4,S6	V3-S2-S7-V2-S4-Load-S6-V3
V1+V2+V3	S2,S8,S4,S6	V3-S2-V1-S8-V2-S4-Load-S6-V3
0	S4,S5,S6	S4-Load-S6-S5-S4
-V1	S5,S6,S1	V1-D1-S5-S6-Load-S1-V1
-V2	S7,S5,S6,S1	V2-S5-S6-Load-S1-S7-V2
-(V1+V2)	S5,S6,S1,S8	V1-S8-V2-S5-S6-Load-S1-V1
-V3	S3,S4,S5	V3-S3-Load-S4-S5-V3
-(V1+V3)	S5,S3,S1	V1-D1-S5-V3-S3-Load-S1-V1
-(V2+V3)	S5,S3,S1,S7	V2-S5-V3-S3-Load-S1-S7-V2
-(V1+V2+V3)	S5,S3,S1,S8	V1-S8-V2-S5-V3-S3-Load-S1-V1

Switching State 3:



LEVEL GENERATION PROCEDURE (DIAGRAM REPRESENTATION):

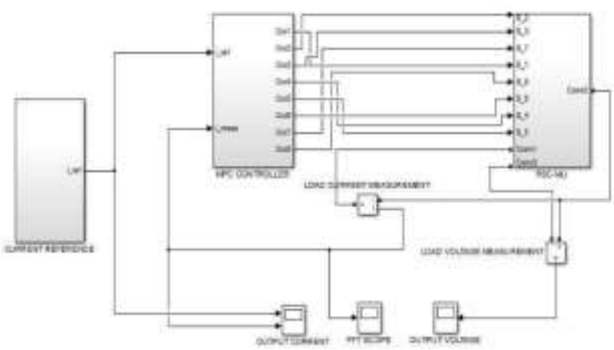
In this State, Switches S8, S4, S6 & S2 are turned ON. The load is supplied from all three sources (V1, V2, V3). The current flows from the DC Voltage Source 'V1' to load through S8 – V2 – S4 and returns to the source through S6 – V3 – S2 and DC Voltage Source. The Output Voltage is V1+V2+V3.



In this State, Switches S4, S5 & S6 are turned ON. The load is supplied no Sources, all three Sources(V1,V2,V3) are in off state. The current flows from to load through S4 and returns to the source through S6 – S5. The Output Voltage is 0 volts.

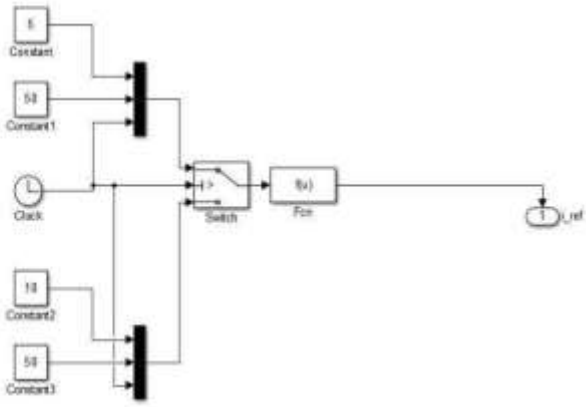
Switching State 4:

CIRCUIT SIMULATION:

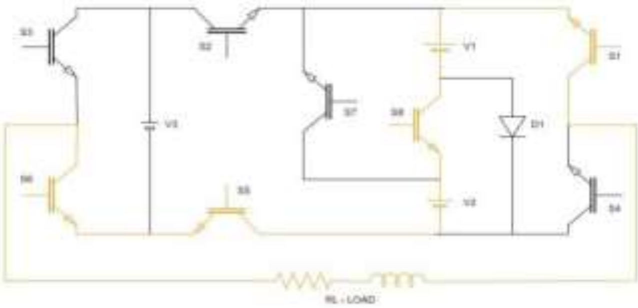


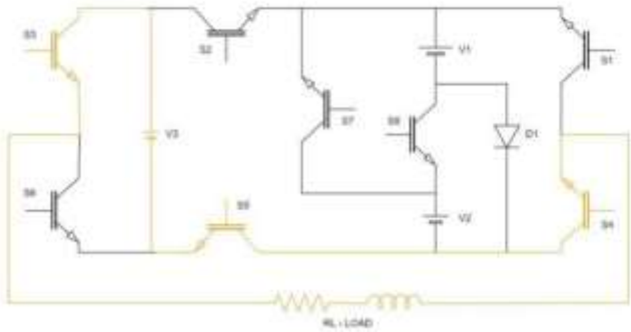
Switching State 5:

In this State, Switches S4, S3 & S5 are turned ON. The load is supplied fromonly one Source (V1). The current flows from the DC Voltage Source ‘V3’ to load through S3 and returns to the source through S4 – S5 and DC Voltage Source. The Output Voltage is - V3.



Switching State 6:





In this State, Switches S8, S5, S6 & S4 are turned ON. The load is supplied from two sources (V1, V2). The current flows from the DC Voltage Source ‘V1’ to load through S8 – V2 – S5 – S6 and returns to the source through S1 and DC Voltage Source. The Output Voltage is - (V1+V2).

The simulated circuit of the inverter contains of three major divisions. They are, Reference Block, MPC Controller Block & Reduced Switch Multilevel Inverter Block. The functions of each block are explained below.

CURRENT REFERENCE BLOCK:

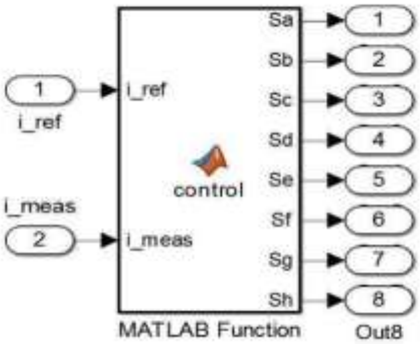
The Reference block contains of Constant values of Maximum current (A), Frequency (f) and Clock cycle for the Reduced Switch Multilevel Inverter. All three Values are Muxed and Sent to the Function Block through Fcn block.

A change over Switch is used to Change the Reference values for the inverter control circuit. After a preset time of delay, the reference is changed to the second reference circuit and the control circuit triggers the inverter according to the reference. The following figure shows the Simulated circuit for generating Reference Current Signal.

In the above figure, 'Constant' are the preset reference values of current that the inverter must produce,

'Constant 1' are the preset values of frequency that the inverter will operate on. 'Clock' is used to generate Time pulses to operate according to the Sample Time. 'Switch' contains of a preset value of time that the circuit must change over the reference current from one circuit to other to give reference signal to the Multilevel Inverter. Here, the Inverter is connected to the first current reference for a particular time period of '0.1 ms' and changed to another current reference circuit after 0.1 ms of time. The Reference is changed from 5Amps, 50Hz to 10Amps, 50Hz circuit. The inverter will generate the preset values of current

MPC CONTROLLER BLOCK:



The MPC Controller Contains of Algorithms that is used to evaluate and compare the Feedback and Reference signals. The MPC Controller compares the reference and actual load current value and evaluates the overall difference between them. Pulses are generated according to the reference. If the value of frequency and current are pre fetched in the reference, the load current is not further exceeded the preset reference value. The Cost function 'g = (abs(real(i_ref – iK2))) is used to find the least value of Difference between Reference and the Feedback. Where, i_ref is the Reference current fed from the reference circuit and iK2 is the Current Prediction Value. iK2 = (1 – R*Ts/L)* i_meas + Ts/L*(v_o1). Where;

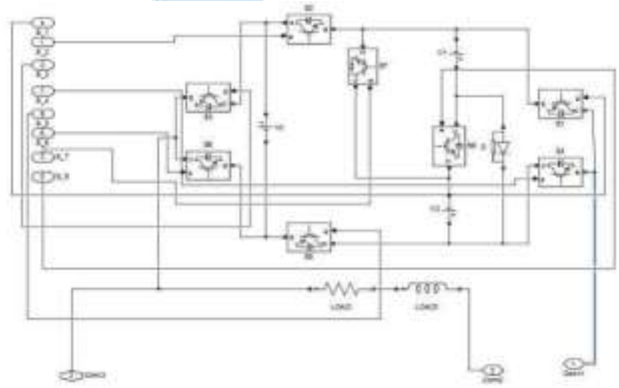
R = Resistor value,

L = Inductor value, Ts = Sample

Time value, i_meas = Feedback Current

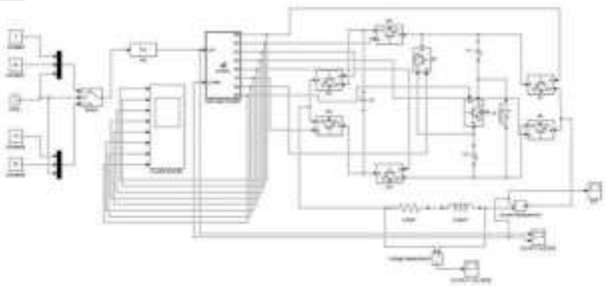
value, v_o1 = Voltage Vector value.

REDUCED SWITCH COUNT MULTILEVEL INVERTER (RSC-MLI) BLOCK:



The above figure (Fig 3.3.3) shows the simulated diagram present in the Reduced Switch Count Multilevel Inverter Block. A single-phase RSC-MLI with 8 switches and 3 voltage sources is a sort of staggered inverter that is intended to expand the power result and productivity of electrical frameworks. This inverter design is especially valuable in applications that require a top notch power supply with negligible symphonious twisting. The inverter that can generate fifteen-level output using eight switching devices, one diode, and three dc-link voltages.

SIMULATUION DIAGRAM:



WORKING:

REFERENCE BLOCK:

The Reference block contains of Constant values of Maximum current (A), Frequency (f) and Clock cycle for the Reduced Switch Multilevel Inverter. All three Values are Mixed and Sent to the Function Block through Fcn block.

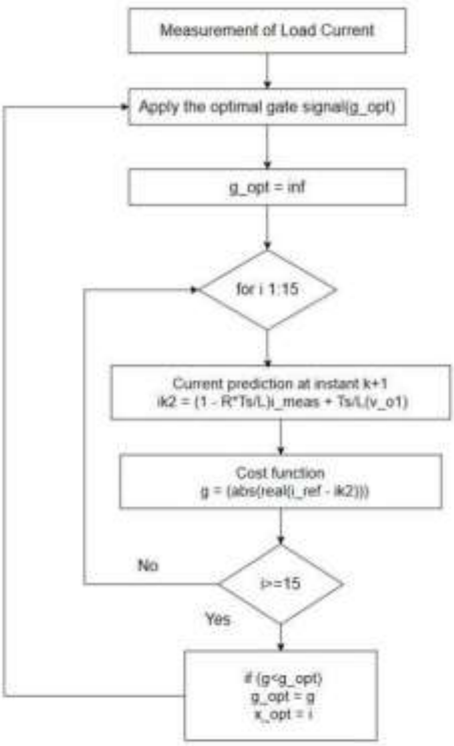
A change over Switch is used to Change the Reference values for the inverter control circuit. After a preset time of delay, the reference is changed to the second reference circuit and the control circuit triggers the inverter according to the reference.

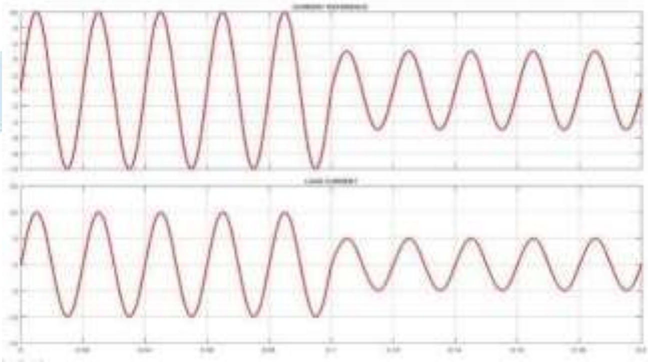
MPC CONTROLLER:

The MPC Controller Contains of Algorithms that is used to evaluate and compare the Feedback and Reference signals.

The MPC Controller compares the reference and actual load current value and evaluates the overall difference between them. Pulses are generated according to the reference. If the value of frequency and current are pre fetched in the refere nce, The load current is Not further exceeded the preset reference value.

Flow chart for MPCC algorithm

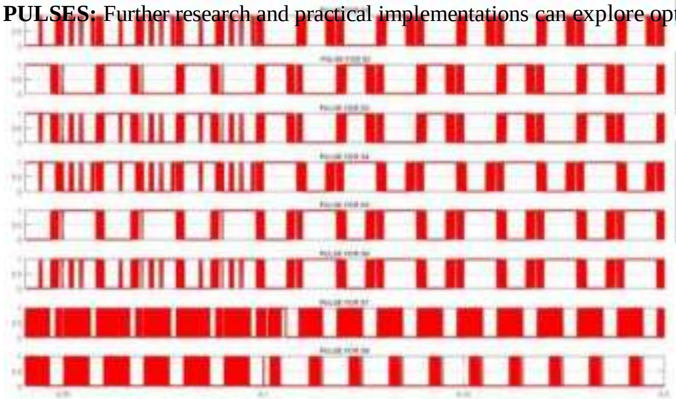




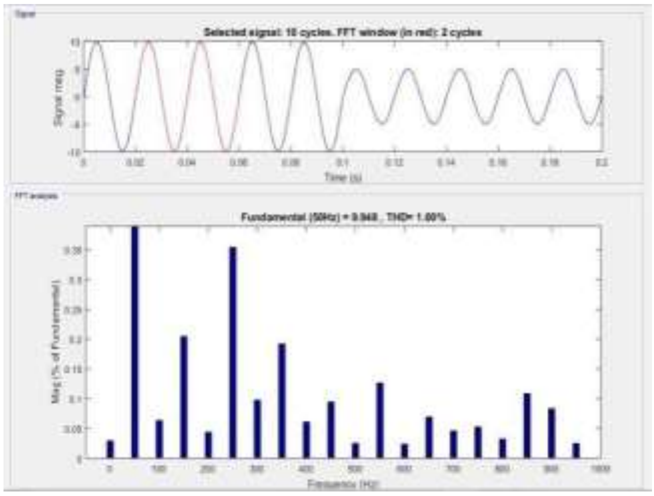
CONCLUSION:

In conclusion, Model Predictive Current Control (MPCC) offers significant advantages for Reduced Switch Multilevel Inverters (RSMIs). It provides precise current regulation, improved dynamic response, and reduced harmonic distortion. Additionally, MPCC enables efficient utilization of the available switching states, enhancing the overall performance and reliability of RSMIs in various applications, from renewable energy systems to motor drives and grid-connected systems.

PULSES: Further research and practical implementations can explore optimization techniques and hardware-in-the-loop simulations to fully harness the potential of MPCC in RSMIs.



FFT ANALYSIS:



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