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"Model Predictive Control for a Seven-Level Packed U-Cell Inverter Is Implemented In The Real Time"

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Abstract -
As we know that now days multilevel inverters which are used for the renewable energy resources are using in tremendous level so for that it is necessary to increase the performance of the multilevel inverter so for that model predictive controller have been proposed here. This paper of model predictive controller (MPC) which is design and implemented on the seven level packed u cell inverter. Packed u cell inverter has an auxiliary dc source and capacitor which has one isolated dc source. Packed u cell multilevel inverter is used here because of it has more advantages than the other multilevel inverter topology (mli). The main function of the model prescient controller (MPC) is that it gives the seven level voltage at the output of the inverter by controlling the magnitude of the capacitor. Since it can be used for power grid application. Subsequently taking the result on MATLAB /simulation it is observe that it reduces the third harmonic distortions (THD) in the output of the inverter.

Keywords: *PUC inverter, multilevel inverter, model predictive controller, power quality, grid connected PV etc.*

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I. Introduction

These days, multilevel inverter (MLI) are in fast turn of events and have become an exceptionally helpful answer for environmentally friendly power assets application because of its capacity to manage distinctive force rating exchanging semiconductors, working recurrence and applied voltage and current (MLI) Geographic's like cascade h bridge (CHB), flying capacitor (FC), neutral point clamped (NPC) and packed u cell inverter (PUC). PUC inverter has a great deal of focal points contrasted and other MLI topology A model prescient controller (MPC) has been planned and executed on the packed u cell inverter which has one isolated dc source and one capacitor as an assistant DC connect . The MPC is objected to direct the capacitor voltage at the ideal extent to have seven voltage levels at the output of the inverter .since power grid connected application is targeted here. the inverter ought to be fit for providing mentioned measure of dynamic and receptive force at the purpose of regular coupling (PCC) too contrasted and run of the the mill two level converters, development converter will offers partner degree prudent option in contrast to high power application giving a prime quality yield voltage ,expanding the strength and heart lines and lessening the attraction impedance .energy strength, reliablness, power thickness ,straightforwardness ,value adequacy for development converter. Specialists wherever the globe are payment pleasant endeavours to present new geographies for staggered converter. As of late ,a part of development converters is risen, during which their decrease structure geographies use lower scope of gadgets contrasted with the available geographies'. To encourage a worth effective converter, lower scope of a part moreover as prime quality waveform, development converter with the 'diminished structure' (MCRS) are fitting for top or medium force framework. Multilevel inverter (MLI) have been widely use Interruptible power supply, renewable energy integration, and motor drive application duty their high power quality, reduce switch9ing losses, higher number of level (better voltage waveform) and possible operation in high Lower application various MLI topology have bee reported in the literature for different application recently, the packed u- cell (PUC) inverter has been consider as one of the most interesting single dc source (MLI) TOPOLOGYS due to its high reliability (reduce number of active and passive element),high power

quality, enlarge multilevel inverter multilevel voltage synthesise versatility however, the effective operation of the PUC inverter depends mainly on the appropriate selection of the switching pattern to guarantee high tracking accuracy of the system variable and minimization of the switching losses. When a proportional integral (PI controller) is use the inclusion of the system non linearity became a measure problem. Model predictive control (MPC) has been considered as promising alternative to standard controllers especially on the presence of the system nonlinearity

Thus, MPC is one the most effective control method for MLIs as it combine discrete characteristics of the converter a finite control set MPC (FCS-MPC) was propose as an optimise control solution to achieve good dynamic performance using an optimise performance however one of the greatest technical challenges in the design of the MPC algorithm is the determination of appropriate weighing

Factor to obtain the desire control objective the best selection of the cost function is a challenging task where a bad design code lead to system instability. In this contest, trial and error technique have been mostly use for selection of the most suitable weighting factor that can lead to the aim control performance however, this technic are time-consuming an non effective when applied at different operational condition on in which the selected weighting factor code optimise locally.in order to decrease the computation time, a branch –and- bound method was investigate in, where the weighting factor is selected empirically. The study in proposed a recursive multicarrier optimisation algorithm for the tuning of the weighting factor. The authors in proposed a waiting factor optimization technic based on estimation of the obsolete error of the state variable tracking. In, an adaptation strategy of online waiting factor was present using an analytical variant. However, the proposed method no constrain on the average switching frequency.

II. Literature review

1) Julie I. Metri Hani Vahedi Hadi Y. Kanaan ; Kamal Al-Haddad evaluated and analyzed in "Real-Time Implementation of Model-Predictive Control on Seven-Level Packed U-Cell Inverter," IEEE Transactions on Industrial Electronics (Volume: 63 , Issue: 7 , July 2019). a model-predictive control (MPC) has been designed and implemented on the packed U-cell (PUC) inverter, which has one isolated dc source and one capacitor as an auxiliary dc link. The MPC is designed to regulate the capacitor voltage at the desired magnitude to have seven voltage levels at the output of the inverter. Since grid-connected application is targeted by this application, the inverter should be capable of supplying requested amount of active and reactive power at the point of common coupling (PCC) as well. Therefore, MPC should also consider the line-current control to monitor the exchange of reactive power with the grid while injecting appropriate active power at low total harmonic distortion (THD). Various experimental tests including change in dc-source voltage, active power variation, and operation at different power factor (PF) have been performed on a laboratory prototype to validate the good performance obtained by the proposed MPC. The dynamic performance of the controller during sudden changes in dc capacitor voltage, supply current, and PF demonstrates the fast and accurate response and the superior operation of the proposed controller.

2) W Seyed Mehdi Abedi Pahnehkolaei ; Hani Vahedi ; Alireza Alfi ; Kamal Al-Haddad in Comparative study of multi-objective finite set predictive control methods with new max–min strategy applied on a seven-level packed U-cell inverter IET Power Electronics (Volume: 12 , Issue: 9 , 8 7 2019). This article studies the design and implementation of multi-objective predictive control (MO-PC) of a grid-connected seven-level packed U-cell (PUC7) inverter for minimising the line current total harmonic distortion (THD) and capacitor voltage error simultaneously. The weighting factor method is usually used as a simple method for solving the control problem in the literature. However, there are some difficulties and shortcomings in the calculation of weighting factors. Here, max–min selection strategy with together priority is adopted to reduce these deficiencies and improves the system performance. The switch model of the PUC inverter is derived and then applied in designing the MO-PC for grid-connected applications, where a controlled active or reactive power is injected into the utility. A comparative study among three strategies of weighting factor, fuzzy decision-making and max–min selection is performed to distinguish the proposed method superiority. Experimental results are given to validate the practicality of the applied controller in regulating the line current and capacitor voltage of the grid-connected PUC7 inverter

3) Rajesh Vasu ; Sumit Chattopadhyay ; Chandan Chakraborty, " Seven-Level Packed U-Cell (PUC) Converter with Natural Balancing of Capacitor Voltages," IEEE Transactions on Industry Applications DOI: 10.1109/TIA.2020.3008397. A seven-level Packed U-Cell inverter is presented in this paper. The converter uses a single dc source and two floating capacitors, whose voltages are balanced in open-loop, to produce multilevel output voltage. Peak magnitude of the output phase voltage is same to that of the dc source. Voltage developed across floating capacitor add intermediate voltage-levels by establishing an asymmetric ratio (with respect to the available dc voltage in the circuit). The average energy exchange (when the network is in steady state) of the capacitors with the rest of the invertercircuit will be zero. This helps the capacitors to maintain desired voltages and thus create intermediate levels of steady dc voltages. Performance of the converter is validated in simulation by MATLAB/Simulink and testing of the converter is done for resistive as well as inductive loads. Experimental

verification of the converter is carried out on a laboratory prototype and the obtained results match well with the simulation.

4) Hani Vahedi ; Mohammad Sharifzadeh ; Kamal Al-Haddad discussed on Modified Seven-Level Pack U-Cell Inverter for Photovoltaic Applications IEEE Journal of Emerging and Selected Topics in Power Electronics (Volume: 6 , Issue: 3 , Sept. 2018). proposes a modified conation of single-phase pack U-cell (PUC) multilevel inverter in which the output voltage has higher amplitude than the maximum dc link value used in the topology as a boost operation. The introduced inverter generates seven-level ac voltage at the output using two dc links and six semiconductor switches. Comparing to cascaded H-bridge and neutral point clamp multilevel inverters, the introduced multilevel inverter produces more voltage levels using less components. The proposed inverter is used in photovoltaic (PV) system where the green power comes from two separate PV panels connected to the dc links through dc-dc converters to draw the maximum power. Due to boost operation of this inverter, two different PV panels can combine and send their powers to the grid. Simulations and experimental tests are conducted to investigate the good dynamic performance of the inverter in grid-connected PV system..

5) N. Rajanand Patnaik ; Y. Ravindranath Tagore ; S. Chaitanya Presented " Advanced seven level transformer-less multilevel inverter topology for PV application," IEEE Xplore: 11 July 2017 DOI: 10.1109/AEEICB.2017.7972393 on trend the Renewable Energy Sources (RES) are the main alternative concept to develop the power generation and it is cheap compared to other sources. The RES (Renewable Energy Sources) like solar energy, wind energy, geothermal energy, biomass, tidal power etc., and here among all these sources of energy solar module is developed with two individual boosts converters are utilized to step-up the voltage with Maximum Power Point P&O (Perturb & Observe) technique. The fundamental concentration of this paper is to present the advanced multilevel competitive inverter topology with reduction in device count is the main merit of this topology which is called Packed U Cell (PUC). The main issue of previously designed multilevel inverter topologies is bulk in complex structures; hence it affects the overall system in terms of cost. Due to the excellent characteristics of Packed U Cell topology there is no need of filter requirement, because of output voltage and current are nearer to sinusoidal. To highlight the merits and performance of this proposed concept was simulating in MATLAB/Simulink

6) Shunlong Xiao ; Morcos Metry ; Mohamed Trabelsi ; Robert S. Balog ; Haitham Abu

A Model Predictive Control technique for utility-scale grid connected battery systems using packed U cells multilevel inverter IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society Grid-connected energy storage systems have been implemented in ac power systems as uninterruptable power supplies (UPS). Batteries and bi-directional power converters provide electrical power when off-grid and recharge when grid-connected. In this paper, a packed U cells (PUC) seven-level inverter has been selected as the grid-interface due to the lower cost and fewer number of components compared to other bi-directional topologies. Additionally, the PUC has higher power quality when compared to the traditional H-bridge. Compared to the traditional PI controller, Model Predictive Control (MPC) is attracting more interest due to its good dynamic response and high accuracy of reference tracking. Through the minimization of a user-defined cost function, the proposed MPC technique can simultaneously achieve unity power factor, low total harmonics distortion of the grid-side current and balance the PUC capacitor's voltages at the grid side, and control bi-directional power flow in the batteries-PUC system. The presented topology and proposed control technique are verified by simulating a 600 W reduced-scale prototype. The theoretical principles are validated by implementing the controller on the prototype using dSPACE 1007 platform.

III. CONCEPT

This paper describe a photovoltaic-grid connected seven level packed u-cell inverter (PUC) topology using a finite control set – model predictive control (FCS-MPS) technique. The propose system is a single phase multilevel invert, with four pairs of switches that work in a complimentary matter, one dc source and to flying capacitor connected to the grid through a filtering inductor. This topology has the ability to generate 7 different voltage level with less number of active a passive element comparing wroth conventional multilevel inverter topology. The proposed control technique (FCS-MPS) aims at reducing the total harmonics distortion (THD) of the grid injected current while balancing the capacitor. voltages at their nominal references value robustness analysis of the proposed model including the effect of a step change in the injected currant into the grid, parameters mismatching and grid voltage sag and swell have been conducted on a single phase low power (PUC7) inverter .theoretical analysis, mathematical modelling and simulation result using MATLAB/Simulink software are present in this this paper. The global electrical consumption is estimated to rise on a positive slope for the coming years; therefore the install production capacity of classical high power station n may not be able to meet the ever increasing demand. Moreover, tolerating the conventional energy sources such as fossil fuel , nuclear and perhaps gas is becoming a social issue limiting possible implementation of such technology due to pollution impact an for safety considerations as well. In order to answer the ever growing energy demand , call

for clean and renewable type of energy sources , to fil up the gap left by holding classical plan development, is answered by the inductees now days is development commercial solar, wind, biomass ,and geothermal .

These source have become an important assets of the words energy sources because of their non-pollution nature, little maintenance at reasonable price. The solar cell behaves as a control current source which converts the radians energy directly into dc current to converts this dc current/ voltage into ac current/voltage while targeting highly efficient scheme, less polluted with low emission of harmonics, power electronics converter are necessary; moreover, multilevel family type of converters are the most appropriate topology to be considered.

Conventional inverter have some drawbacks like non-sinusoidal output voltage reach in harmonic distortion (THD),high switching losses losses and thermal stress at high switching frequency with high level of common mode noise. Multilevel inverter constitute a class of devices which present interesting feature that are naturally adapted to solar energy converted scheme and therefor constitute an interesting solution to the proliferation of solar energy technology. Multilevel invert makes use of switches an flotation capacitor to produce various symmetrical level when control properly. The higher number of voltage level produce, the lower is the harmonics contain.

Traditional multilevel inverter present many drawbacks from, they are costly and hard to implement when the number of voltage level increases. In order to attenuate the impact of such problem, several study have been conducted and new multilevel inverter topology have been proposed. One promising is the packed u-cell (PUC) which combine advances of flying capacitor (FC) and cascade h-bridge (CHB) and makes use of only one isolated dc source while the second dc bus should be regulated at desire voltage level which influence the output voltages number of level.

Several control techniques have been study concerning the PUC like hysteresis current controls, and nonlinear controller, all those controller have been implemented on the stand alone inverters or rectifier application of the PUC topology. Therefore, they were mainly dealing either unity power factor operation as well as supplying power to the stand-alone loads moreover, adjusting multiple gains and using modulator to send the require switching pulses to the power electronics devices are the main drawbacks of the reported works. Now days power inverted are asked to provide both active and reactive power for the utility in which the grid voltage and phase-shift as well as the current amplitude should be monitored and regulated online. Through the idea of MPC was developed in 1960s, it remains simple and intuitive.

The following fig 1 shows the diagram of 7 level PUC inverter

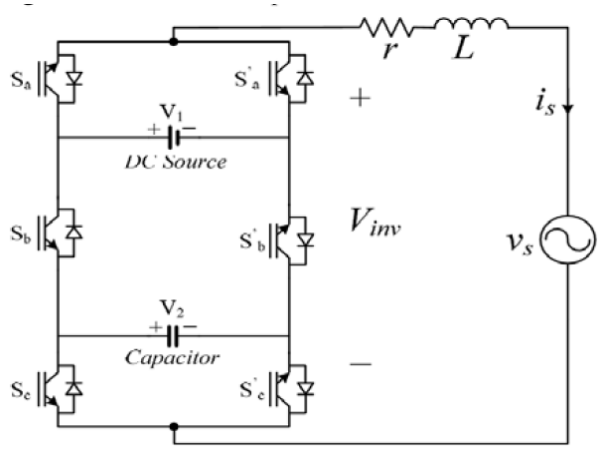


Fig 1. 7- Level PUC inverter grid –connected application

Fig 1 presents a general scheme for MPC to control the grid- connected. in general, PMC consist of measuring a variable x(k) and use it in the predictive control in order to control the future value x(K+1) of the control variable for each one of the switching state. Then, a cost function is calculated in order to choose the minimum value corresponding to the optimal state and apply it on the PUC inverter through the switching pulses

Objective

- One of the major advantages of the FCS-MPS compared to the traditional PI controller is the flexibility to control different variable, with constraint and additional system requirement. Beside, using MPC avoids the cascade structure which implies inner faster dynamic loop and outer slower dynamic loop to control system parameter; such scheme is typically using in linear controls. The drawbacks of FCS-MPC is that such controller

can operate at variable switching frequency and also it requires a high number of calculation to generates its output, compared to the classical control scheme.

- To implement different models of multilevel inverter related to thesis topic have been simulated using MATLAB/SIMULINK software for analysing the advantages and disadvantages of those reported technologies.
- To design mathematical modelling of the proposed converter topology, in order to select the suitable control technic base on switching behaviours and related performance.
- To design mathematical modelling of the selected control technique (FCS-MPC)
- To simulate model using MATLAB/SIMULINK software for the proposed inverter topology

Research methodology /planning of work

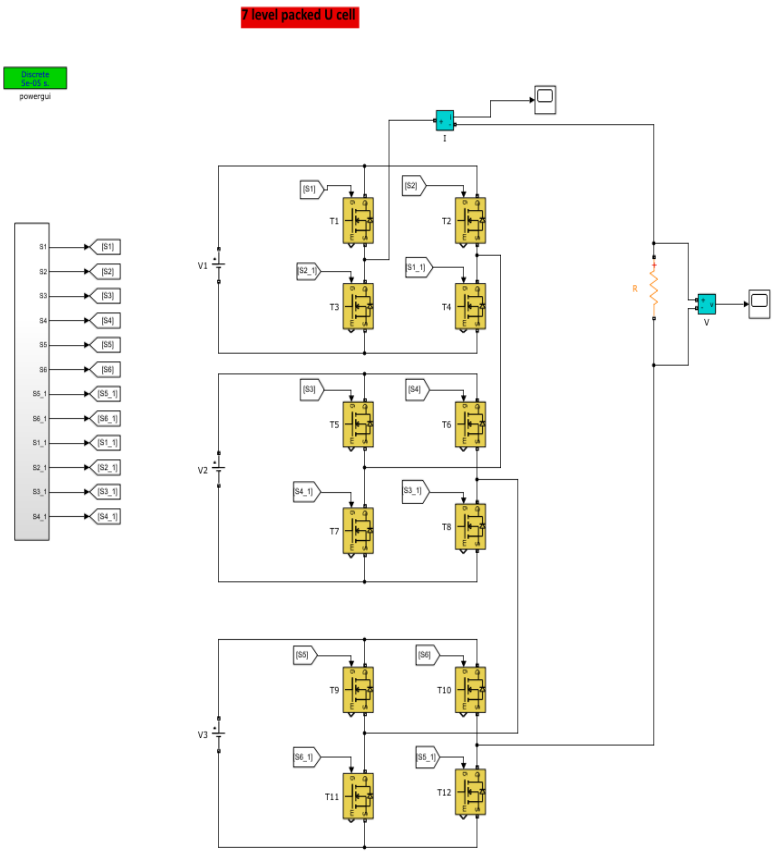
In this paper, MPC is developed for the PUC inverter for grid-connected application. The PUC inverter has been study and investigate as a renewable energy conversion device to deliver green power to the grid while generating multilevel voltage waveform with low harmonic content at the ac output consequently, the PUC inverter capacitor voltage and the grid current should be control to have desire predefine power quality regulated voltage of the second dc bus as well as the desired operating power factor by changing the grid voltage and current phase- shift accordingly. The paper is organise as follow: after an introduction to multilevel converters and MPC, include the PUC topology description an switching sequence. MPC technique applied on the PUC inverter has been investigate and design accurately.

The proposed work is planned to be carried out in the following manner:

- Study of basic concept of inverter
- Finding the problem for conational system by surveying literature
- Design and study of circuit
- Analysis of the proposed topology
- Study of the control strategies

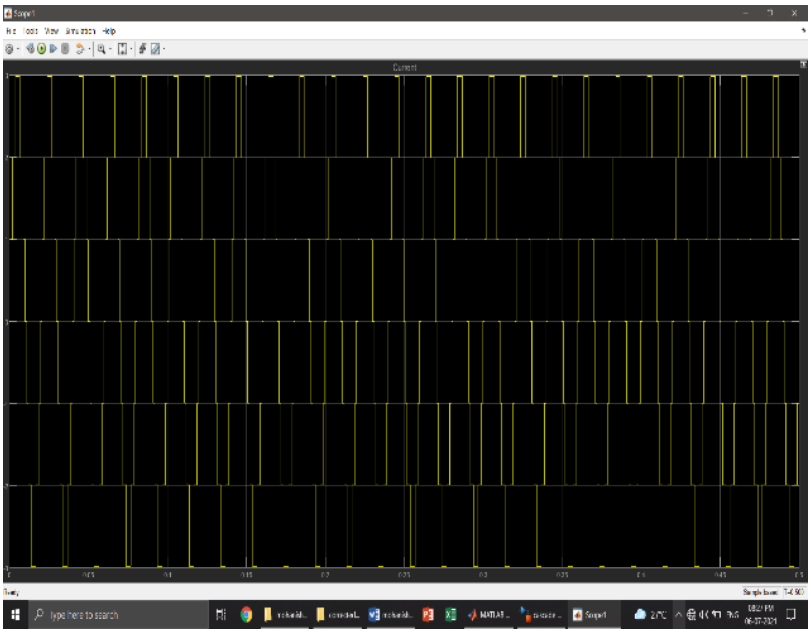
IV. Simulation And Result

MATLAB simulation for proposed system

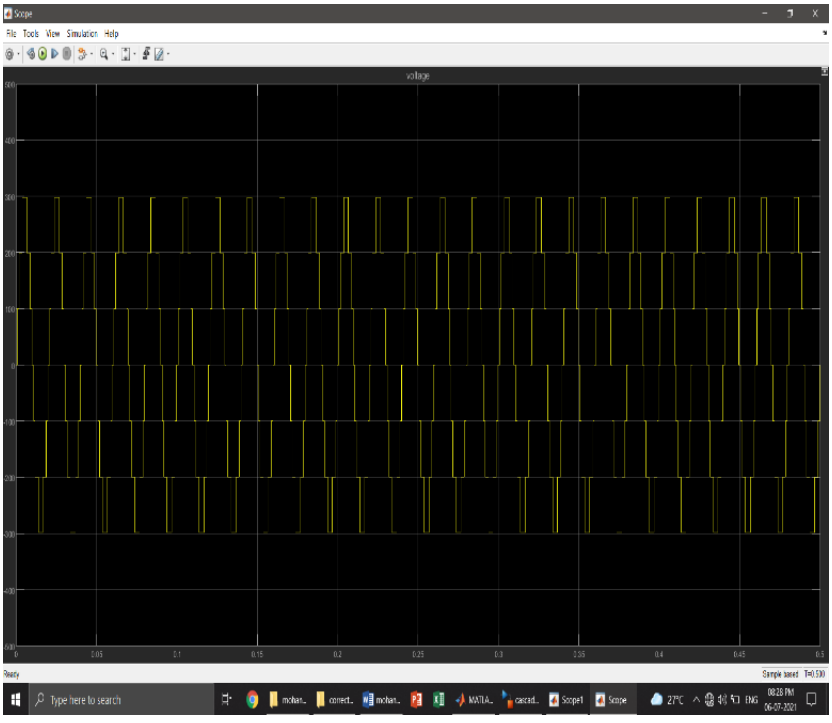


Results

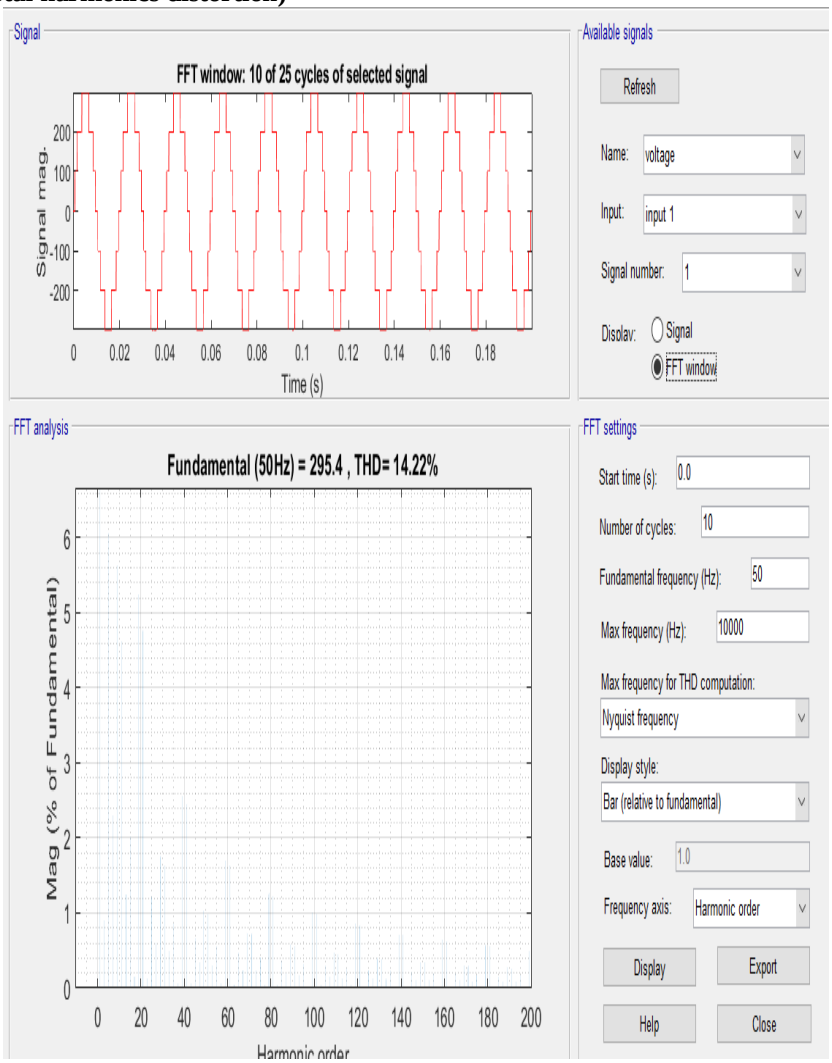
Current waveform



Voltage waveform



FFT for THD (total harmonics distortion)



V. Conclusion

In this reenactment, a Model Predictive Control has been utilized for the seven level PUC inverter in framework associated method of activity, a brilliant contender for photovoltaic and utility interface application to convey green capacity to the utility. MPC is a straightforward and instinctive technique that doesn't have befuddling increases to change. It has been exhibited that the DC connect capacitor voltage has been directed at wanted level and 7-levellvoltage waveform has been produced at the yield of the inverter. The infused current to the matrix was effectively controlled to have managed sufficiency and synchronized waveform with the network voltage to convey greatest force with solidarity power factor. Hence this 7-level PUC inverter gives the 7-level voltage waveforms at the inverter yield with basic circuit which joins favorable circumstances of flying capacitor and fell H-Bridges and utilizes just one disconnected DC source with Unity power factor and with the incredible effectiveness than the ordinary inverters. Also the THD (total harmonics distortion) is reduce here.

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