"REAL TIME IMPLEMENTATION OF MODEL PREDICTIVE CONTROL ON 7 LEVEL PACKED U- CELL INVERTER"

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Abstract*— In the paper a model prescient control (MPC) has been planned and actualized on the Packed U-Cell (PUC) inverter which has one olated DC source and one capacitor as a helper DC interface. The MPC intended to manage the capacitor voltage at the ideal greatness to have seven voltage levels at the yield of the inverter. Since lattice associated application focused by th application, the inverter ought to be fit for providing mentioned measure of dynamic and responsive force at the purpose of regular coupling (PCC) too. Subsequently, MPC ought to likewise consider the line current control so as to screen the trading of responsive force with the lattice while infusing suitable dynamic force at low THD. Different exploratory tests remembering change for DC source voltage, dynamic force variety and activity at various force factor (PF) have been performed on a research facility model to approve the great exhibition acquired by the proposed MPC. The dynamic exhibition of the regulator during abrupt changes in dc capacitor voltage, flexibly current and PF shows the quick and exact reaction and the predominant activity of the proposed regulator

Keywords: PUC Inverter, Multilevel Inverter, Model Predictive Control, Grid-Connected PV, Power Quality.

I.INTRODUCTION

These days, staggered inverters (MLIs) are in fast turn of events and have become an exceptionally helpful answer for environmentally friendly power assets applications because of its capacity to manage distinctive force rating, exchanging semiconductors, working recurrence, and applied voltage and current MLI geographies like Cascaded H-Bridge (CHB), Flying Capacitor(FC), Neutral-Point Clamped(NPC), and Packed U-Cells (PUC) inverters. PUC inverter (delegated FC inverter) has a great deal of focal points contrasted and other MLI geographies A model prescient control (MPC) has been planned and executed on the Packed U-Cell (PUC) inverter which has one separated DC source and one capacitor as an assistant DC connect. The MPC is intended to direct the capacitor voltage at the ideal extent to have seven voltage levels at the yield of the inverter. Since matrix associated application is focused by this application, 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 mill 2 level converters, development converters will offer partner degree prudent option in contrast to high power applications, giving a prime quality yield voltage, expanding the strength and heartiness, and lessening the attraction impedance. Energy strength, reliableness, power thickness, straightforwardness, value adequacy, decreased structure with lower scope of dynamic and latent parts, high force quality, and application field ar the most themes for particular totally various geographies of development converters . Specialists wherever the globe are payment pleasant endeavors to present new geographies for staggered converters. As of late, a part of development converters is risen, during which their 'decreased structure' geographies use lower scope of gadgets contrasted with the available geographies . to encourage a worth effective convertor, lower scope of parts moreover as prime quality waveforms, development converters with a 'diminished structure' (MCRS) are fitting for top or medium force frameworks. Multilevel inverters (MLIs) have been widely used in interruptible power supplies, renewable energy integration, and motor drive applications due to their high power quality, reduced switching losses, higher number of levels (better voltage waveform), and possible operation in high power applications Various MLI topologies have been reported in the literature for different applications Recently, the packed U-cell (PUC) inverter has been considered as one of the most interesting single DC source MLI topologies due to its high reliability (reduced number of active and passive lements), *high power quality, and large multilevel voltage synthesis versatility However, the effective operation of the PUC inverter depends mainly on the appropriate selection of the switching patterns to guarantee high tracking accuracy of the state variables and minimization of the switching losses. When a proportional–integral (PI) controller is used, the inclusion of the system nonlinearities becomesa major problem. Model predictive control (MPC) has been considered as a promising alternative tostandard controllers, especially in the presence of system nonlinearities*

Thus, MPC is one of the most interesting control methods for MLIs as it combines the discrete characteristic of the controller in a simple way with the discrete characteristic of the converter a finite control set MPC (FCS-MPC) was proposed as an optimized control solution to achieve good dynamic performance using an optimized cost function. However, one of the greatest technical challenges in the design of the MPC algorithm is the determination of appropriate weighting

factors to obtain the desired control objectives.The best sellection of the cost function is a challenging task, where a bad design could lead to system instability. In this context, trial and error techniques have been mostly used for selection of the

most suitable weighting factor that can lead to the aimed control performance [19]. However, these techniques are time-consuming and noneffective when applied at different operational conditions in which the selected weighting factor could be optimized locally. In order to decrease the computation time, a branch-and-bound method was investigated in , where the weighting factor is selected empirically. The study in proposed a recursive multi criteria optimization algorithm for the tuning of the weighting factors. The authors in proposed a weighting factor optimization technique based on estimation of the absolute error of the state variable tracking. In , an adaptation strategy of online weighting factors was presented using an analytical variant. However, the proposed method has no constraint on the average switching frequency,

II Literature Review

1) Mohammad Babaie ; Mohammad Sharifzadeh proposed "A 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.., IEEE Explore. vol. 25, no. 74, pp. 6273–4582, July. 2019[1]. 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.

2) X Hamza Makhamreh ; Mohamed Trabelsi ; Osman Kükrer, investigated In this paper, a novel and simple controller for seven-level packed U-cell (PUC) grid-connected inverter is presented. The control method is derived based on sliding mode control theory," IEEE Explore., vol. 41, no. 3, pp. 3286–9210, Nov. 2019. . Simulation results are presented to show the effectiveness of the proposed simple controller in tracking the desired values

3) 3) Rajesh Vasu ; Sumit Chattopadhyay ; Chandan Chakraborty proposed in" Seven-Level Packed U-Cell (PUC) Converter with Natural Balancing of Capacitor Voltages IEEE Explore. 2019) IEEE Explore) . 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.. Performance of the converter is validated in simulation by MATLAB/Simulink and testing of the converter is done for resistive as well asinductive

4) 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.

5) 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*

6) Mohammad Babaie ; Mohammad Sharifzadeh ; Majid Mehrasa investigated in " Adaptive Neural Fuzzy Inference System Controller for Seven-Level Packed U-Cell Inverter," IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society In this paper, an improved Adaptive Neural Fuzzy Inference System (ANFIS) based controller has been designed to regulate the capacitor voltage and load current of Seven-Level Packed U-Cell (PUC7) inverter. PUC7 is an affordable topology due to the least power switches and DC sources; but, it suffers from unstable adjusting capacitor voltage level. Proportional Integral (PI) as a simple linear control method causes overshoots and undershoots in transient response and conducts the system to unstable mode when some uncertainties are existed in the load. However, the proposed ANFIS control method regulates the load current and balances the capacitor voltage without any overshoot or undershoot and transient response even in presence of nonlinear loads. Simulation results of stand-alone mode of operation of PUC7 obtained by MATLAB software also confirm usability of ANFIS control loop to achieve unity power factor, minimum Total Harmonic Distortion (THD) and minimum capacitor voltage ripple while the PUC7 inverter is connected to an AC dynamic load..

7) 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.

8) 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..

9) 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

10) 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 describes a photovoltaic-grid connected Nine Level Packed U Cell (PUC9) topology using a Finite Control Set – Model Predictive Control (FCS-MPC) technique. The proposed system is a singlephase multilevel inverter, with four pairs of switches that work in a complementary matter, one DC source and two flying capacitors connected to the grid through a filtering inductor. This topology has the ability to generate nine different voltage levels with less number of active and passive components comparing with conventional multilevel inverter topologies. The proposed control technique (FCS-MPC) aims at reducing the total harmonic distortion (THD) of the grid injected current while balancing the capacitors' voltages at their nominal reference values. Robustness analysis of the proposed model including the effect of a step change in the injected current into the grid, parameters' mismatching, and grid voltage sag and swell have been conducted on a single phase low power (PUC9) inverter. Theoretical analysis, mathematical modelling and simulation results using MATLAB/SIMULINK software are presented in this paper. The global electrical energy consumption is estimated to rise on a positive slope for the coming years; therefore the installed production capacity of classical high power stations 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 implementations of such technology due to pollution impact and for safety consideration as well. In order to answer the ever growing energy demand, call for clean and renewable type of energy sources, to fill up the gap left by holding classical plant development, is answered by the industry which nowadays is developing commercial Solar, Wind, Biomass, and Geothermal.

These sources have become an important asset of the world's energy resources because of their non-polluting nature, little maintenance, at acceptable price. The solar cell behaves as a controlled current source which converts the irradiance energy directly into DC current. To convert the DC current/voltage into AC current/voltage while targeting high efficient scheme, less polluted with low emission of harmonics, power electronic converters are necessary; moreover, multilevel family type of converters are the most appropriate topologies to be considered.

Conventional inverters have some drawbacks like non sinusoidal output voltage rich in harmonic distortion (THD), high switching losses and thermal stress at high switching frequency with high level of common mode noise. Multilevel inverters constitute a class of devices which present interesting features that are naturally adapted to solar energy conversion schemes and therefore constitute an interesting solution to the proliferation of solar energy technology. Multilevel inverters make use of switches and floating capacitors to produce various symmetrical voltage levels when controlled properly. The higher number of voltage levels produced, the lower is the harmonic content.

Traditional multilevel inverters present many drawbacks though, they are costly and hard to implement when the number of voltage levels increases. In order to attenuate the impact of such problems, several studies have been conducted and new multilevel inverters topologies have been proposed. One promising topology is the Packed U- Cells (PUC) which combines advantages of flying capacitor (FC) and cascaded H-Bridges (CHB) and makes use of only one isolated DC source while the second DC bus should be regulated at a desired voltage level which influence the output voltage number of level.

Several control techniques have been studied concerning the PUC like hysteresis current control, and nonlinear controllers. All those controllers have been implemented on the stand-alone inverter or rectifier application of the PUC topology. Therefore, they were mainly dealing with unity power factor operation as well as supplying power to the stand-alone loads. Moreover, adjusting multiple gains and using modulators to send the required switching pulses to the power electronic devices are the main drawbacks of the reported works.Nowadays, power inverters are asked to provide both active and reactive power for the utility in which the grid voltage and current phase-shift as well as the current amplitude should be monitored and regulated online. Though the idea of MPC was developed in 1960s, it remains simple and intuitive.

IV OBJECTIVES

1. .One of the major advantages of the FCS-MPC compared to a traditional PI controller is the flexibility to control different variables, with constraints and additional system requirements. Besides, using MPC avoids the cascade structure which implies inner faster dynamic loop and outer slower dynamic loop to control system parameters; such a scheme is typically used in a linear control. The drawbacks of FCS- MPC is that such a controller can operate at variable switching frequency and also It requires a high number of calculations to generate its output, compared to a classical continuous control scheme.

2.To Implement Different models of multilevel inverters related to thesis topic have been simulated using

MATLAB/SIMULINK software for analyzing the advantages and disadvantages of those reported technologies.

3.To design Mathematical modeling of the proposed converter topology, in order to select the suitable control technique based on the switching behaviors and related performances.

4. To design Mathematical modeling of the selected control technique(FCS-MPC)

5 To Simulate model using MATLAB/SIMULINK software for the proposed inverter topology.

IV PROTOTYPE

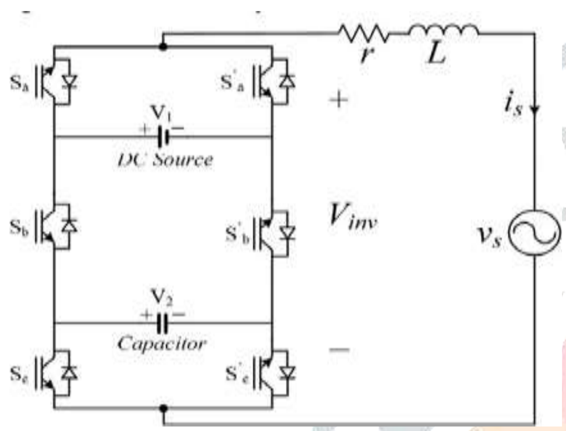

Fig 1V. 7-Level PUC Inverter in grid-connected application

Fig. iv presents a general scheme for MPC to control the grid-connected inverter. In general, MPC consists of measuring the variable x(k) and use it in the predictive control in order to calculate the future value x(k+1) of the controlled variable for each one of the switching states. 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.

V Research Methodology/Planning of Work

- *In this paper, MPC is developed for the PUC inverter for grid-connected application. The PUC inverter has been studied and investigated as a renewable energy conversion device to deliver green power to the grid while generating multilevel voltage waveform with low harmonic contents at the ac output. Consequently, the PUC inverter capacitor voltage and the grid current should be controlled to have desired predefined 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 organized as follow: after an Introduction to multilevel converters and MPC, includes the PUC topology description and switching sequences. MPC technique applied on the PUC inverter has been investigated and designed accurately.*

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

1) *Study of basic concepts of inverter.*
2) *Finding the problems from conventional system by surveying literature.*
3) *Design and study of circuits.*
4) *Analysis of the proposed topology.*
5) *Study of the control strategies*

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

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