Model Predictive Control for 5-Level 4-Switch DC to AC Converter

Zhanfan Yu[1], Prof. Sally Sajadian[1]
Department of Electrical and Computer Engineering, Lafayette College[1]
yuz@Lafayette.edu

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Introduction

This poster presents a finite-set model predictive control (MPC) scheme for an optimized five-level inverter with only four switches for photovoltaic applications. The classical control schemes for recently developed five-level four-switch inverters are complex, multi-nested loops, and require substantial tuning effort. The proposed efficient MPC based control schemes leverages the inherent features of the MPC to optimally determine the switching states of the recently developed five-level four-switch inverters. The optimal switch selections ensure generation of five-level outputs by just optimizing a single cost function that considers all the feasible switching states by only four-switches. The simulation and preliminarily experimental results demonstrate high power quality without requirement of burdensome tuning effort. Furthermore, the proposed controller features fast dynamic response as it is depicted in the case studies.

Finite Model Predictive Control

- **Control Mechanism**

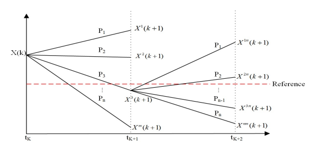

Figure 1: Finite-set model predictive control mechanism for power electronic converters

- **Cost Function**

❖ $G = |I * RLoad - Vref|$

Operation Principle of Novel Inverter

- **Inverter Circuit**

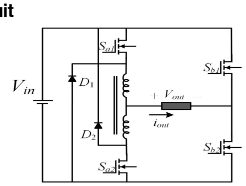

Figure 2: The Five-Level Four-Switch Converter

- **Switching States**

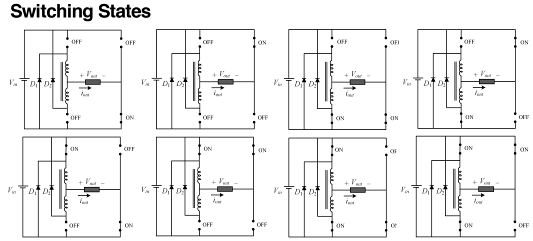

Figure 3: The feasible switching configuration of the five-level four-switch inverter

- **Equivalent Circuit**

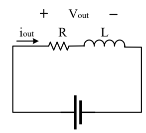

Figure 4: Simplified equivalent circuit model of the load for analysis, where V_{out} is a function of the switching configuration presented in Fig. 3.

- **Predictive Model**

$$V_{out} = i_{out} \times R + L\frac{di_{out}}{dt}$$

$$V_{out}(k) = i_{out}(k) \times R + L\frac{i_{out}(k+1) - i_{out}(k)}{T}$$

$$i_{out}(k+1) = \frac{T}{L}\left(V_{out}(k) - i_{out}(k) \times R\right) + i_{out}(k)$$

Sa1	Sa2	Sb1	V_{out}	Formula
0	0	0	$V_{in}/2$	$I_L(K+1) = \left(\frac{V_{dc}}{2} - I_L(K) * R\right) * \frac{T}{L} + I_L(K)$
0	0	1	$-V_{in}/2$	$I_L(K+1) = \left(-\frac{V_{dc}}{2} - I_L(K) * R\right) * \frac{T}{L} + I_L(K)$
0	1	0	0	$I_L(K+1) = (-I_L(K) * R) * \frac{T}{L} + I_L(K)$
0	1	1	$-V_{in}$	$I_L(K+1) = (-Vdc - I_L(K) * R) * \frac{T}{L} + I_L(K)$
1	0	0	V_{in}	$I_L(K+1) = (V_{dc} - I_L(K) * R) * \frac{T}{L} + I_L(K)$
1	0	1	0	$I_L(K+1) = (-I_L(K) * R) * \frac{T}{L} + I_L(K)$
1	1	0	$V_{in}/2$	$I_L(K+1) = \left(\frac{V_{dc}}{2} - I_L(K) * R\right) * \frac{T}{L} + I_L(K)$
1	1	1	$-V_{in}/2$	$I_L(K+1) = \left(-\frac{V_{dc}}{2} - I_L(K) * R\right) * \frac{T}{L} + I_L(K)$

Table 1: Feasible switching configuration and the corresponding predicted load current.

Proposed Control Scheme

- **Proposed MPC Algorithm**

1) Measure source voltage V_{in}, the load current at instant k, and reference voltage V_{ref}.
2) Forecast the future value of load current based on the 8 switching configurations in Table 1.
3) Compare the product of the predicted load current and the load resistor value with the voltage reference for evaluating the cost function.
4) Select the optimized control case based on the smallest cost function value.
5) Determine the S_{b1} and S_{b2} based on the voltage reference value.
6) Select S_{a1} and S_{a2} values according to the case number and apply S_{a1}, S_{a2}, S_{b1}, S_{b2} values to the circuit.

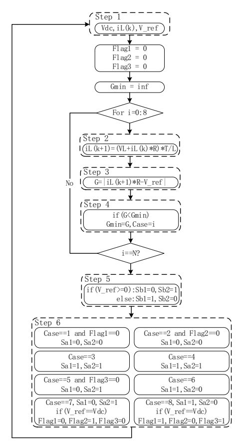

Figure 5: Flowchart of the proposed model predictive control for the five-level four-switch inverter.

Experiment Result

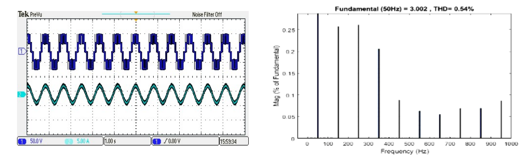

Figure 6: case study 1, blue waveform is the load voltage and green waveform is the load current in steady state condition (Left). FFT analysis and THD of the current. (Right)

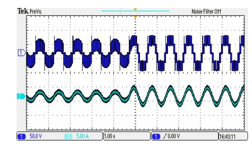

Figure 7: case study 2, blue waveform is the load voltage and green waveform is the load current. Step change happened in source voltage from 300 V to 600 V.

Conclusion

This paper proposed an efficient model predictive control scheme for recently developed five-level four-switch inverters. The proposed control scheme tackles the challenges associated with the control of this class of converters based on classical control schemes and complex PWM for practical implementation. The controller successfully experimentally tested for five voltage output levels by taking a load voltage reference signal. Significantly, the load current result is satisfying with 0.54% THD. Final paper will include additional analysis and investigating the impact of model parameter mismatch on the control performance.

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