Performance Improvement of Integrated Microgrid Based Predictive Control Scheme

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Abstract. The voltage quality of a renewable energy system may be undermined by variable power demand and erratic energy source outputs. The suggested approach entails the use of both a Model Predictive Based Voltage and Power control (MPVP) method and a Model Predictive Based Current and Power (MPCP) control method. The proposed MPCP algorithm can be used to manage battery storage systems dc-dc converters and stabilize voltage at dc bus by adjusting the varying output from renewable energy sources. The MPVP system is utilized in interlink converter control to ensure a steady provision of AC voltage while facilitating optimal energy transfer between the electric grid and microgrid. Moreover, an integrated system is developed for energy management to offer constant performance under a variety of operating modes. Based on the projected output current in every conceivable switching state throughout each sample interval, the resulting voltage is estimated by applying the system model. The efficacy of the adopted methodology has been affirmed through MATLAB/Simulink. To further grasp the benefits of the proposed methods encompass, traditional PI as well as sliding mode control (SMC) tactics during diverse scenarios. The postulated control technology has clear advantages over the conventional PI and SMC control performance and exceptionally low (THD) value. Ultimately, it could be claimed that the proposed method increases the bar and guarantees that the RES operates consistently.

Keywords: Storage System, Model Predictive Voltage and Power, Sliding Mode Control, Model predictive Current and Power.

1 Introduction

The rise in popularity of generation using renewable sources like solar and wind turbines has sparked increased attention toward grid tied inverters. Inverters play an important role in distributed generating systems, and inverter control has a

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K. R. Madhavi et al. (eds.), *Proceedings of the International Conference on Computational Innovations and Emerging Trends (ICCIET 2024)*, Advances in Computer Science Research 112,
https://doi.org/10.2991/978-94-6463-471-6_5

major impact on how well the grid-tied inverter system performs. Systems that are hybrid, combining several green energy sources alongside storage units, can help to maximize generation systems under financial and technical points.[1] Cascade linear control has been the predominant strategy in traditional power electronic control methodologies.However, this technique has a number of notable shortcomings, especially a complicated control framework with several feedback loops, delayed dynamic response due to PWM modulation, and delay in tuning of PID controller. In practice, microgrid may experience oscillation in voltage at dc-bus due to unpredictable resources which can further degrade ac side power quality.

In recent years, for improving the power converters of microgrids Model Predictive Control (MPC) is increasingly adopted. Using predetermined cost function, the MPC method calculates switching state which is efficient for the power converters. Although MPC has been shown to be effective in controlling single power converters, it is not yet widely used for Synchronized management of various converters within microgrids. There are a variety of algorithms suggested to conserve energy to use MPC microgrids converters, but these algorithms have only been demonstrated in simulation studies[4-7]. The main challenges in using MPC for coordinated control of multiple converters in microgrids are the computational complexity and the need for accurate models of the converters and the microgrid.

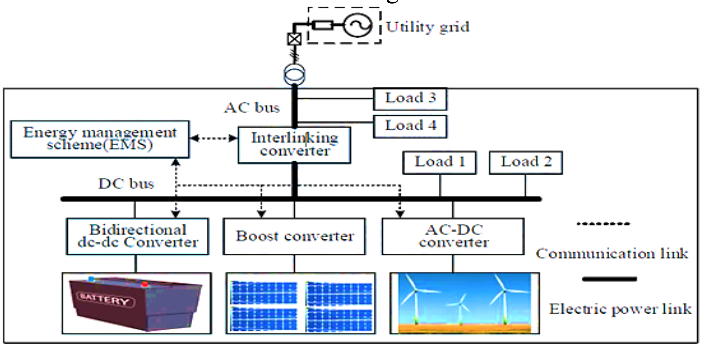

Fig. 1.The Proposed System's Layout

This research proposes a new technology based on model control (MPC) for microgrids powered by renewable energy. Figure.1 shows the topology of the microgrid. In this research, Examples include solar photovoltaic systems and wind turbines, but control systems are not limited to this feature[8-12]. The MPCP system ensures that the dc-bus voltage remains inside a safe operating range while also minimizing the tracking error among the reference current and the actual current. The MPVP system ensures that the ac-bus voltage is remains inside a safe operating range while also minimizing the tracking error among the reference voltage and the actual voltage. For the purpose of smoothing the outputs of renewable sources for maintaining bus voltages, MPCP and MPVP schemes are employed.

Following is how the remaining portion of the paper is organized. Section 2 provides an overview of the control scheme design. In Section 3, the proposed circuit architecture is detailed. Section 4 showcases the simulation results, while Section 5 concludes the study.

2 Design of Control Schemes

2.1 MPCP Control Model

The BESS is used to regulate the power generated by RES and the load demand. The converter which connects BESS with grid can be switched between two modes-boost mode and buck mode. The buck-boost converter decreases the input voltage to a lower output voltage, which is then used to discharge the battery. The current i_b in boost mode is defined to be a positive current, there are only two possible states as shown below in equations (1) and (2).

$$L_b \frac{di_b}{dt} = v_b \tag{1}$$

$$L_b \frac{di_b}{dt} = v_b - v_{dc} \tag{2}$$

$$i_b(k+1) = \frac{t_s}{L_b} v_b(k) + i_b(k) \tag{3}$$

The cost function of battery is being charged or discharged as shown in equation (4).

$$C_v = |i_b^* - i_b(k+1)| \tag{4}$$

Subsequently, the (k+1)th power may be estimated as in eqn. (5)

$$p_b^*(k+1) = |i_{dc}(k+1) * v_{dc}^*| \tag{5}$$

Therefore, it is necessary to minimise subsequent cost equation

$$C_p = |p_b^*(k+1) - P_o(k+1)| \tag{6}$$

The switching technique for controlling the buck-boost converter will be chosen from which minimise the equation (10).

2.2 MPVP Control Algorithm

Typical MPC of interlink converter will be depicted step by step using one controller phase, as illustrated below.[2-3] Figure 2 shows the flow of the resulting MPVP control. The development and implementation of model-predicted capacitor filter voltage control consists of the following steps:

(1) Utilize discrete-time digital representation of voltages and currents to predict the behaviour of the next step.
(2) Optimize the voltage vector V(k) using the value function constraint.
(3) Figuring out how long voltage vectors having nonzero as well as zero values will last.

$$i(k+1) = i(k) + \frac{T_{sp}}{L}\left[V(k) - V_c(k) - R_c\left(i(k) - i_g(k)\right)\right] \tag{7}$$

$$V_c(k+1) = V_c(k) + \frac{T_{sp}}{C}\left[i(k+1) - i_g(k)\right] \tag{8}$$

By changing (8) into (9), the projected capacitor filter voltage is presented below for (k + 1)th instant.

$$V_c(k+1) = V_c(k) + \frac{T_{sp}}{C}\left[i(k) + \frac{T_{sp}}{L}\left[V(k) - V_c(k) - R_c\left(i(k) - i_g(k)\right)\right] - i_g(k)\right] \tag{9}$$

The ideal T_{opt} period believed to limit cost function over period must satisfy following requirement.

$$T_{opt} = \frac{|V_{C\_ref} - V_C(k) - s_0 \cdot T_{sp}|}{|s_1 - s_0|} \tag{10}$$

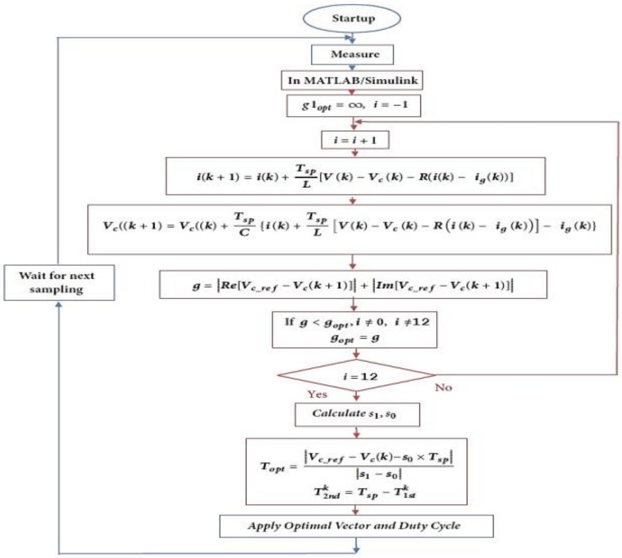

Fig. 2. Flowchart of MPVP Control

The proposed framework for the predictive voltage control mechanism is depicted in Figure 3. A current output forecast implemented to control capacitor filter voltage, and by minimising a cost function over each sampling period a switching state is obtained[18-21].

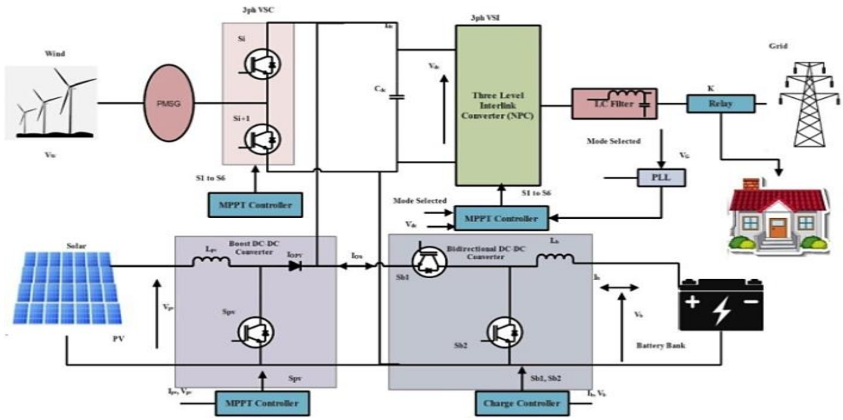

Fig. 3. Proposed controller's control scheme

Phase-locked loop (PLL) technology serves a crucial function in grid synchronization enabling the determination of both the frequency and amplitude of the grid voltage [15-17]. Next, cost functions reference voltage is fixed at slightly higher frequency with the same amplitude Furthermore, the voltage reference is locked to the phase of Vc during previous operation. The grid's voltage phasor as well as the microgrid voltage phasor rotates in same direction upon equal amplitudes yet with distinct angular speeds. When phase angles associated with the ac voltages remain in phase, a microgrid can be linked to the grid[13-14].

3 Topology of the Circuit Proposed

A 3-phase, 3-voltage level diode clamped inverter is a common multilevel inverter employed in this paper. It is created using the figure 4 architecture, which includes six clamping diodes and twelve switching devices.

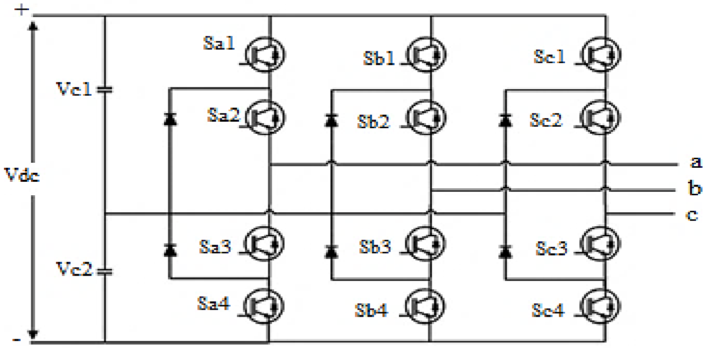

Fig. 4. Topology of 3-level Interlink Converter

Twelve separate active voltage vector were created by combining variables in twelve different ways. The voltage vector from V_1 to V_{12} is not zero. A three-phase reference voltage is used to define the sector and then corresponding voltage vector is selected to get required signals to run converter as inverter.

4 Results and Discussions

The proposed SMC, MPVP&MPCP control methods are specified configuration has been developed, examined, and reported using a MATLAB/Simulink model. For modelling purposes, a solar PV cell consisting of 12 modules with a voltage of 64.2 V, a power of 305 W, and a current rating of 5.96 A is taken into account. For the purposes of the simulation, the wind farms having the following specifications are used: Power=500W, voltage = 250 V, and wind speed = 11 m/s.

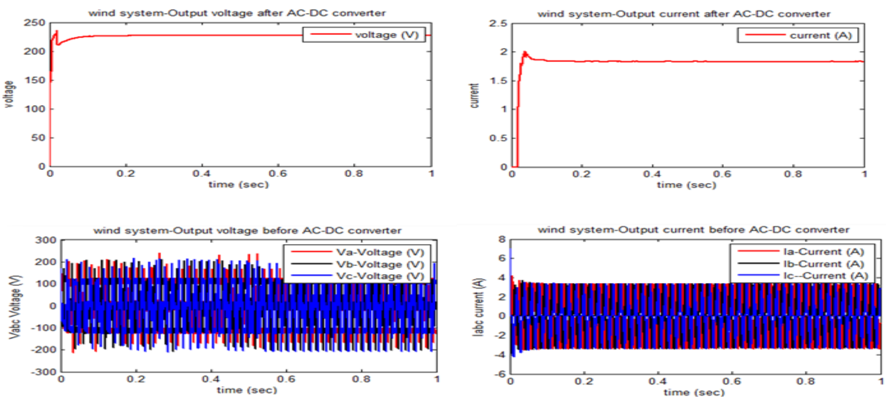

Fig. 5. Before and after the AC-DC converter, the WECS voltage and current waveforms

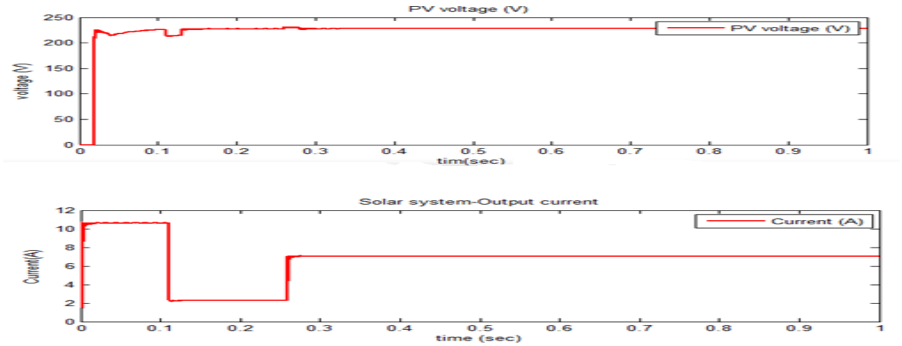

Fig. 6. Voltage and Current of Solar PV Output

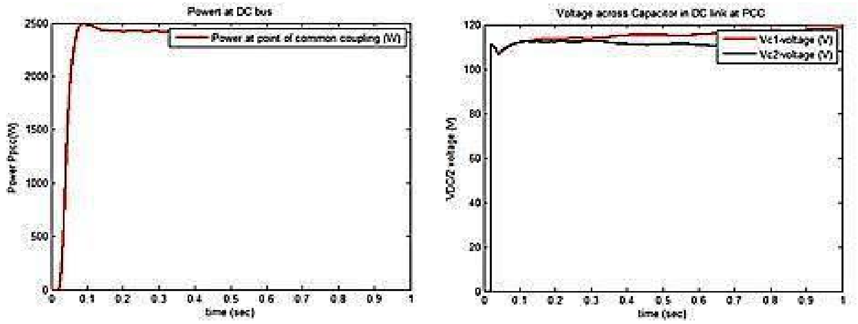

Fig. 7. Power flow and Capacitor Voltage at PCC

The Figure 5 waveforms of WECS's voltage and current before and after the AC-DC converter.Figure 6 displays the waveforms of the PV system's output voltage andcurrent. Figure 7 illustrates the voltage and power across the PCC capacitor.

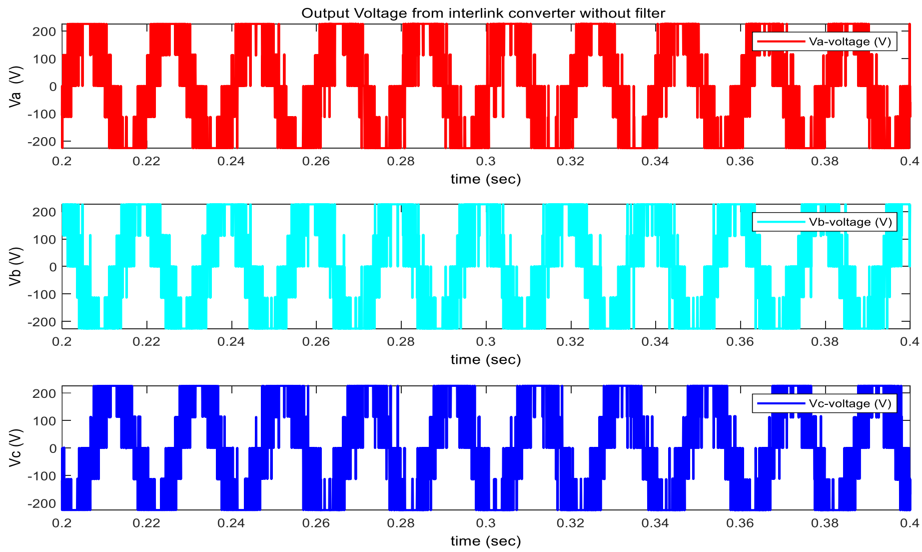

Fig. 8. Interlink Converter Voltage without a filter.

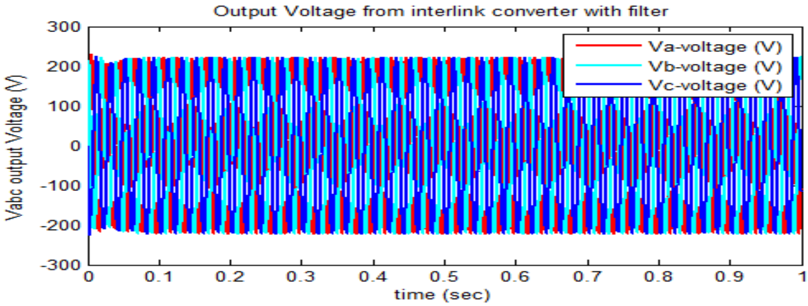

Fig. 9. Filtered voltage across interlink converter

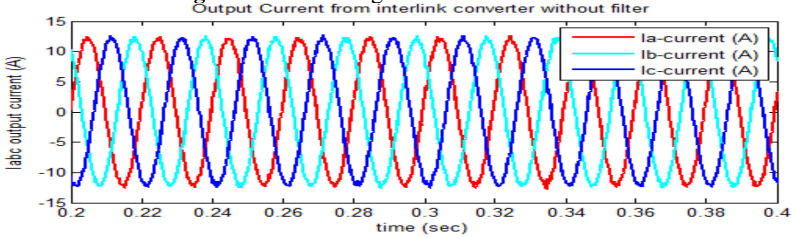

Fig. 10. Interlink Converter current flow without a filter

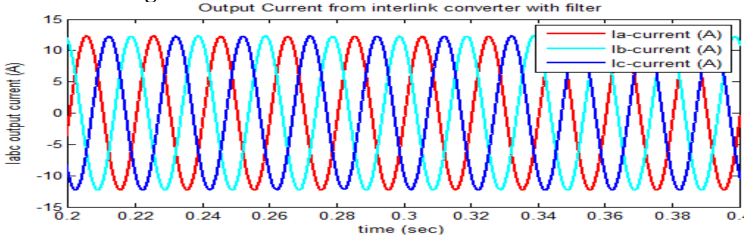

Fig. 11. Filtered current through an interlink converter

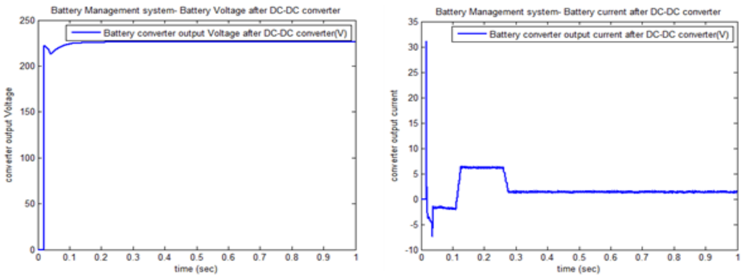

Fig. 12. Voltage and Current of BESS after the DC-DC Converter

The output voltage along suggested interlink converter is shown in Figures 8 and 9, respectively, without and with filters. Figure 11 makes this very evident showing how the planned converter and filter greatly reduce ripple. The output current obtained via the suggested interlink converter is shown in Figures 10 and 11, respectively, with and without filters. The voltage across and the current passing through the BESS afterwards the DC-DC converter circuit is shown in the figure 12.

In this research, we examine four different types of controllers, and Figure 13 and 14 compare their respective THD values for output voltage and current.

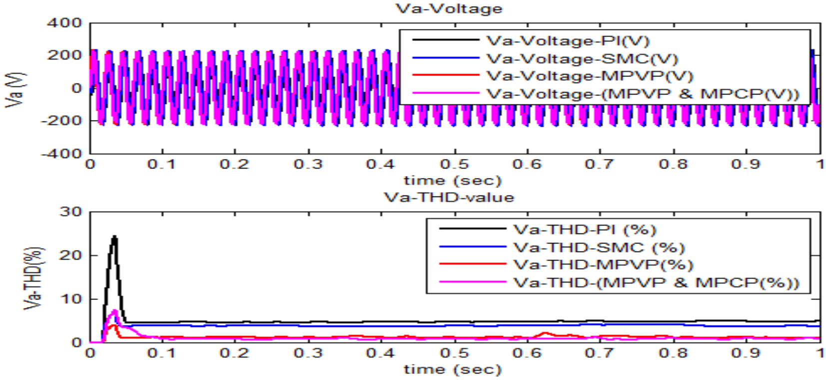

Fig. 13. Waveform of Voltage with its THD value

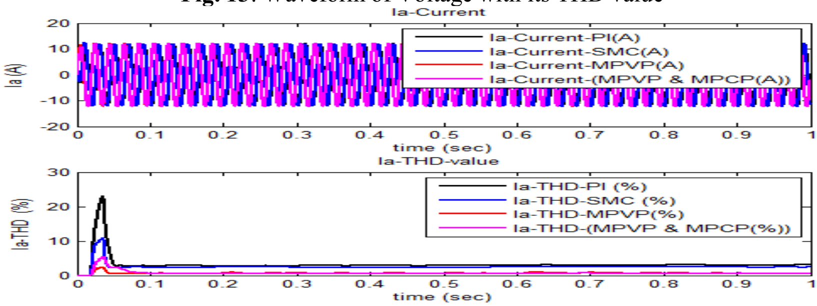

Fig. 14. Waveform of current with its THD value

Summaries based on the simulation outcomes in tables 1, 2, and 3 may be shown here.

Table 1. Analytical Evaluation - % THD with various control methods

Type of Control	THD (%) of output voltage without an LC filter	THD (%) of output voltage with an LC filter
MPVP & MPCP	31.1	0.75
MPVP	33.5	1.1
SMC	50.2	6.1
PI	67.1	14.6

Table 2. Performance Improvement of Converter Efficiency

Type of Control	Converter efficiency (%)
MPVP & MPCP	98.6
MPVP	98.1
SMC	97.5
PI	92.10

Table 3. Optimization of Setting Time Performance

Type of Control	Transient load –settling time (Sec)
MPVP & MPCP	0.035
MPVP	0.04
SMC	0.07
PI	0.09

5 Conclusion

This research study proposes, designs, and simulates a novel MPVP and MPCP controller of a a three-level interlink converter-powered hybrid system that is connected to the grid.The trained models can efficiently reduce the computing cost underlying control in real time since they are built using simple arithmetic operations independent to the intricate nature of the MPC algorithm. In every way, the recommended controller performs better than any of the other three kinds of controllers taken into consideration in this work. The proposed logic's THD values for the voltage are 0.75% as opposed to 6.1% with an SMC controller and 14.6% with a PI controller. In addition, the converter efficiency improved substantially to 98.6% from SMC and PI controllers' respective 97.5% and 92.10%. Additionally, as seen in table 3, there has been improvement in the settling time. It can be concluded that the suggested system may be used to control the ac/dc interlinking converter in order to maintain a constant supply of ac voltage and an accurate power flow across the utility grid as well as the microgrid.

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