Grid Connected Bidirectional Converter Based Ems System with Model Predictive Control

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Abstract: In this paper, the bidirectional converter that performs DC-DC power conversion is integrated with the variable speed wind energy conversion system's grid system. Generally, the voltage quality is reduced, and fluctuation in outputs is performed in renewable energy sources. The stable operation and power generation with fluctuation and power demand in the variable are ensured by developing the energy management system (EMS). In this proposed method, the bidirectional converter's control is accomplished using the proportional-integral-derivative (PID) controller, which controls the power fluctuation from the WECS to maintain constant. The DC-AC voltage conversion is achieved using the model predictive controller (MPC), which controls both power and voltage. This proposed power and voltage controller enhances the stable AC voltage supply and improves the proper power flow. The proposed method, which is validated in simulation is simple, and the results are obtained using MATLAB/Simulink.

Keywords: WECS, bidirectional converter, PID control, MPC, EMS system, power fluctuation control, DC link maintain.

1. Introduction
The power generation uses renewable energy sources, an excellent solution for the conventional power system energy generation that uses fossil fuels as the major source. Normally the inconsistent supply is obtained from renewable sources such as wind, solar power, etc. To give a solution for this problem is the energy management system (EMS) is utilized in that the battery or supercapacitor with the bidirectional power flow converter, which is performing both power flow directions of forward and reverse. Of all energy used globally, electricity demand increases at the fastest rate [1-2]. Therefore, Humankind faces a huge problem that the total socioeconomic development is never-ending uprisings for oil. In the last decade, photovoltaic (PV) installation was significantly improved due to the reduction of polysilicon costs, among the different forms of renewable energy, is one of the most
commonly used techniques. Solar power is typically generated by using a solar cell or a solar electrical system to transform the energy of the sun into electrical power[3-5].

The whole planet has drawn the solar energy, but one among its primary duties is to get the complete solar energy make it accessible in different weather conditions which also called maximum power point monitoring (MPPT). Output power flow and PV array power can change with solar radiation, temperature, and charge current functions. In building the PV arrays, no progress in the heat and solar irradiation rate can negatively affect the PV array’s load/utility outputs [6-10]. The highest power points’ regulation is very important to gain maximum energy from and shift to the solar photovoltaic panel load. This finding underlines an unstable review and views the procedure of the whole photovoltaic solar power point monitoring. The important part of the SPV structure is the Maximal Power Point Monitoring (MPPT). The maximum strength for an SPV modulus is the efficient functioning voltage and PV output current change with the amount of solar energy received by the earth and the weather condition rate. For complete power to be generated, the SPV module should also be subjected to the MPP voltage [11-14]. Many observational studies have been happening in this aspect, enhancing the total working of the machine and the cost-effectiveness. Several excellent procedures trace MPPs.

The model predictive controller (MPC) approach is utilized for the renewable-based wind systems. To maintain the DC-AC voltage at constant, the MPC is used to control and smooth the grid's power. This controller leads to fewer oscillations and overshoots under power fluctuation [15-18]. The EMS system is linked with the bidirectional power flow converter controlled by the control method to maintain the high gain voltage and constant power supply.

In this system, the wind energy is integrated with the grid system to meet the power demands and the EMS storage system with a bidirectional power flow converter. The power converter is controlled using PID control tuning to maintain the constant voltage and improve the DC link voltage efficiently. The model predictive controller (MPC) controls the AC bus bar voltage to reduce the power fluctuations and provide a stable grid system operation.

2. Proposed System

In this system, the wind energy is integrated with the grid system to meet the power demands and the EMS storage system with a bidirectional power flow converter. Proposed system block diagram is presented in fig.1. The power converter is controlled using PID control tuning to maintain the constant voltage and improve the DC link voltage efficiently. The model predictive controller (MPC) controls the AC bus bar voltage to reduce the power fluctuations and provide a stable operation for the grid system.

![Fig 1: Proposed System Block Diagram](image)
3. Proposed Bidirectional Converter System

In the proposed power conversion topology is achieving the soft-switching conditions depends on the direction of power flow automatically. This circuit has two power switches, Q1 and Q2, inductor L1 is the main inductor for the circuit, and the diodes D2, D4, and coupled inductor are composed in the proposed converter’s auxiliary circuit.

![Circuit diagram of the bidirectional converter proposed system](image)

The PWM signals are provided to the power switches in the proposed bidirectional converter, as shown in fig. 2. In positive operation, Q1 is in ON state, and it becomes OFF state due to snubber C1, C2 While zero switching has ended, the Q2 is turned on and the voltage across Q2 decreases to 0. In negative operation, the power supply is fed to load and which act as boost operation. In this inductor current is negative and in the entire time cycle.

4. Control Methods

The bidirectional converter is controlled by the operation control of the process variable. PID closed-loop control is shown in fig. 3 used in the proposed system for converter operation control to maintain the constant voltage and improve the high voltage gain from the source.

![Block diagram of the PID Control System](image)

The output feedback to the controller is to reduce the error while comparing with the reference input. The error signal e(t) is calculated from the difference between actual feedback output signal V_o(t) and input reference or set point R(t).

5. Model Predictive Controller

The model predictive controller (MPC) approach is utilized for the renewable-based wind systems. To maintain the DC-AC voltage at constant, the MPC is used to control and smooth the grid's power. This controller leads to fewer oscillations and overshoots under power fluctuation. The MPC control is presented in fig. 4 for the complex functions, and the computational cost is low. It befits loads that are immune to discrete switching. The model predictive control is determined as continuous optimization
or integer problem-based methods. The control action is synthesized for the power converter by using the MPC-based continuous control modulator’s control.

![Proposed System based MPC control Block Diagram](image)

**Fig 4:** Proposed System based MPC control Block Diagram

6. **Simulation Results**

The grid-connected wind system with bidirectional converter-based energy management system is controlled by the model predictive controller (MPC). The overall Simulink of a grid system with the EMS system using bidirectional converter RL load conditions has been developed in MATLAB/SIMULINK. The control scheme of MPC is used to improve the efficiency in a grid-connected bidirectional converter. The overall circuit configuration of the simulation block is shown below in fig. 5.

![Simulink Model of Overall grid Connected Bidirectional Converter](image)

**Fig 5:** Simulink Model of Overall grid Connected Bidirectional Converter

The dc-link voltage of the bidirectional converter using PID control is shown in fig. 6. The inverter output voltage and current are shown in fig. 7. The total harmonic distortion of the grid-connected inverter using MPC control is shown in fig. 8.
Fig 6: DC Link Voltage of Bidirectional Converter

Fig 7: Three Phase Voltage and Current waveform across Grid System

Fig 8: THD for Grid current using MPC
7. Conclusion
In this proposed method, the bidirectional converter's control is accomplished, and the DC link voltage is maintained using the PID controller, which controls the power fluctuation from the WECS to maintain constant. The DC-AC voltage conversion is achieved through MPC controller that controls both power and voltage. The proposed method validated in simulation is simple, and the results are obtained using MATLAB/Simulink. This proposed power and voltage controller enhances the stable AC voltage supply and improves the proper power flow to the grid system.

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