Energy Storage System with Dynamic Voltage Restorer Integrated For Wind Energy System

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Abstract. The permanent magnet induction generator (PMSG) based wind system that integrates with dynamic voltage restorer (DVR) and the energy storage system (ESS) for backup power purpose is explained in this paper. The output power transmission of the wind energy generation is interfaced with the dynamic voltage restorer in series. The energy storage system and the dc-link capacitor are parallel to the PMSG based wind system. The proposed system is to control the fluctuations in wind power and compensate the disturbed grid voltages. The bidirectional converter controls the power flow in both directions as the power flow from the source to battery and battery to the voltage source inverter (VSI) compensates the grid voltage disturbances through the voltage injection performance and transformer. The DVR-based energy storage system results for the wind energy conversion system are validated using in MATLAB/Simulink.

Keywords: PMSG base wind power generation, DVR, ESS, DC link, Bidirectional converter, grid disturbed voltages, and wind power fluctuations

1. Introduction
The wind power generation is mostly preferred in power generation of using renewable energy sources. It has rapid growth in recent years, resulting in more attention for it. Nowadays, in the power generation of using renewable wind energy, the four various generators are used [1]. However, the power generation of wind is affected by the two factors. One is fluctuations in the power which leads to the grid frequency deviation and voltage and the grid stability are affected. It can support the grid system frequency and voltage distortions during fault period. The fault ride-through (FRT) performance is required for the wind system turbine terminal concerning the voltage dips toleration [2] which controls the wind system's power fluctuations. The control method of the pitch angle is investigated to accomplish stable power response and flicker mitigation. The voltage source converters capability controls the wind system power responses, adopting the smooth fluctuations in power [3]. The energy storage systems are used for the alternative purpose, which is achieving reactive power regulation and smoothen fluctuations in active power.
Furthermore, the advantage of the ESS is to accomplish the maintenance of wind power acquisition for maximum [4]. The main responsibility of the DVR is to insert the series voltage in the terminal of the wind energy system as quickly as possible voltage generation and correction. The combination of both DVR and ESS system is proposed to improve the wind power generation with grid-connected system performances [5].

In the normal operation, the energy storage system can receive wind power and discharging while the power required for smoothening the wind energy. Due to these merits, the wind system's output power response is improved, and the power fluctuations are greatly reduced. When the fault has occurred, the DVR system can quickly compensate both voltage dips that are symmetrical and asymmetrical [6]. The terminal voltage is maintained, and the operation of the wind system remains in its operation. The grid voltage disturbances are compensated by combining both the power storage system with the grid side converter, which provides DC energy to the ESS system and converter, which flows the power in both directions. In this method can reduce the cost of the converter. The DVR system's control function interfaced with voltage source inverter is controlled to improve the grid-connected wind system's performance to avoid unexpected transients and interference. The control scheme is designed for the inverter system. The DVR system is interfaced at the wind energy system terminal to prevent the grid faults [7].

In this paper, the permanent magnet induction generator (PMSG) based wind system integrates with DVR and the ESS for backup power purpose. The proposed system is to control the fluctuations in wind power and compensate the disturbed grid voltages. The output power transmission of the wind energy generation is interfaced with the dynamic voltage restorer in series [8]. Wind system based DVR with ESS is proposed, and their control scheme is explained in detail in the following sections. The overall block diagram proposed system is described with detail. The results and analysis are obtained with simulations are discussed, and conclusions are drawn [9].

2. **Proposed System**

In this system, the DVR system is constructed in the power wind generation system for voltage compensation [10]. The DC link of the inverter system is maintained at the ESS system's connection, that stores the energy from the wind system as shown in Figure 1.

![Diagram](https://via.placeholder.com/150)

**Figure 1:** The proposed system of DVR with ESS based block diagram of the wind energy system

The output power transmission of the wind energy generation is interfaced with the dynamic voltage restorer in series. The wind power output terminal is connected with the grid side converter, which acts as a rectifier to convert the power to DC supply to maintain the DC link voltage of the capacitor [11].
The Energy storage battery system is associated with the DC link through the bidirectional power flow converter. The grid disturbances are compensated by the DVR system through the series voltage source inverter, injecting the voltage in the grid fed distribution network system.

a. Control method

In this proposed control method, the series voltage injection to wind tied grid system is achieved in following controls: detection of the sag and swells faults extraction of the reference voltage and generation of gate pulses to get the requirement of DVR injection voltage, the voltage of busbar is measured as shown in Figure 2. The detection of voltage sag is an essential one to the DVR performance.

Combining the looped phase lock (PLL) and a voltage controller is used to DVR proposed system. The busbar voltage magnitude is estimated by using both controls of PLL and voltage controller. This control is applicable for both three and single-phase systems with reliable and simple.

3. Simulation Results:

The PMSG based on wind generation system power quality fault compensation of DVR system is implemented as represented in Figure 3. The grid disturbed voltages are compensated using the DVR device, which combines with the bidirectional converter and ESS system. The DC link is maintained at the DC-DC converter, which is regulating the power supply. The wind energy generated is converted into DC supply and fed to the DC link capacitor connected with the energy storage battery system and the bidirectional converter. The sag voltage of the grid terminal voltage is shown in Figure 4. In Figure 5, the injected voltage and current for the voltage source inverter is illustrated. The series connected inverter is injecting voltage to the wind system tied grid system through the injection transformer. The compensated voltage and current in the grid terminal are achieved using the DVR system shown in Figure 6. The bidirectional converter is regulating the DC link voltage, as shown in Figure 7. The bidirectional power flow's achievement is accomplished in the energy storage battery system, which SOC is shown in Figure 8.
Figure 3: Overall DVR with ESS proposed system Simulink Model

Figure 4: Grid disturbed voltages
Figure 5: Proposed DVR system injection inverter voltage

Figure 6: Proposed system compensated voltage
4. Conclusion

The DVR with ESS system based on the wind energy system, which is interfaced with the grid system is implemented to suppress the grid power fluctuations. The DC link of the inverter system is maintained at the ESS system's connection, which stores the energy from the wind system. The DVR system is used to compensate the under voltage and maintaining grid stability can maintain the DC link voltage, and the bidirectional converter is used. The energy storage system is implemented from the wind energy provided through the grid side converter or rectifier. The DVR-based energy storage system results for wind energy conversion systems are obtained, such as DVR injected voltage, the voltage of DC link, compensated voltage, ESS charging state, and validated using MATLAB/Simulink.
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