

# Comparative Analysis between DVR and D - STATCOM for DFIG Based WECS Integrated to Grid

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**Abstract**—The instabilities in the power supply, such as voltage spikes, transients, and distorted waves, can cause consumer electronics to malfunction or even fail altogether. It is one of the biggest worries for grid-connected WECS in the present and future. In a variety of ways, specialized power electrical devices can improve power quality. These days, power applications make use of a broad variety of flexible controllers that take use of advanced power electronic components. In order to effectively minimize various forms of power quality concerns in a grid-connected wind energy conversion system, this article evaluates the reliability of two distinctive electrical devices, the Distribution Static Compensator (D-STATCOM) and the Dynamic Voltage Restorer (DVR). MATLAB/SIMULINK is used to examine the devices' performance.

**Index Terms**— Wind turbine, reactive power adjustment, reactive power correction, voltage sag, voltage swell, grid, power quality, and double-fed induction generator.

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## 1. INTRODUCTION

In the last 20 years, people have used a lot more electricity, but power generation and transmission have not been able to keep up because of limited resources and environmental rules. Renewable energy is becoming more and more important as fossil fuels become harder to find and as pollution gets worse. Among the several renewable energy options, wind power has shown to be one of the most cost-effective due to its low environmental impact and high potential return on investment. It has various benefits over fixed speed generator systems when utilised with a wind turbine. Controlling the voltage source converter, which has active and reactive power flow in both directions, provides speed control and minimized flickers.

In the case of variable-speed generation, it is necessary to make electric power with a constant frequency from a source with a variable speed. This can be done with synchronous generators, generator grid connection is possible through static frequency converter.

One further strategy involves using a Double Fed induction generator supplied by a rotor voltage of varying frequency. This enables the generator stator to be used as a source of electrical power with a constant frequency. In its most basic form, DFIG is an ordinary rotor-wound induction machine. To the grid, the stator has a direct connection, In addition, A back-to-back PWM converter connects the rotor to the grid.

When running, DFIG requires reactive power, which may come from the grid or locally generated in capacitor banks [5]. If its mechanical speed varies, say because of wind disturbances, the WF's active (reactive) power injected (demanded) into the power grid will also vary, causing the WF terminal voltage to fluctuate owing to system impedance. Flicker, which consists of light level changes due to voltage differences, may result from these power disturbances spreading throughout the power system. In addition, these disruptions make it such that WF can't function normally. The effect is magnified when "weak grids" are taken into account. Some approaches aim to better manage WF terminal voltage and reduce flicker-causing voltage variations.

Most power grid upgrades include increasing short-circuit power at the point of common connection. PCCSo, power fluctuations and problems with regulating voltage have less of an effect [5]. The terminal voltage of the WECS is regulated, and voltage fluctuations at the point of common coupling (PCC) are reduced, both of which are the result of variations in the system load and the pulsing nature of the power provided by the WECS.

## 2. SYSTEM DESCRIPTION AND MODELING

### 2.1 Problem Identification:

In this study, we use a test setup that consists of two parallel transmission lines coupled to a three-phase power supply. The three-phase fault, the addition of capacitance reactance, and a nonlinear load all affect the first line. It will produce the harmonic, sag, and swell components in the first line's voltage and currents. These components will be produced in the first line. The second line's load point similarly has problems with power quality. Similar to the first line, the second line has the DFIG-based WECS to provide the load point with the required active and reactive powers. In order to counteract these effects, the appropriate devices are coupled at the common coupling point. In this study, a variety of fact controllers, including a Distribution Static Synchronous Compensator (DSTATCOM) with a Dynamic Voltage Restorer (DVR), are employed to address power quality challenges.

## 2.2 Modeling of Wind Turbine

The equation for the turbine's output of wind power may be found here (1)

$$P_m = \frac{1}{2} \rho C_p (\lambda, \theta) A_r V_w^3 \quad (1)$$

The power coefficient,  $C_p$ , is denoted here. Using this equation, we can determine.

$$C_p(\lambda, \beta) = 0.73 \frac{151}{\lambda_i} - 0.58\beta - 0.002\beta^{2.14} - 13.2 e^{-\frac{18.4}{\lambda_i}} \quad (2)$$

Where

$$\lambda_i = \frac{1}{\frac{1}{\lambda - 0.02\beta} - \frac{0.003}{\beta^3 + 1}} \quad (3)$$

And

$$\text{TSR}(\lambda) = \frac{\omega_r R_r}{V_w} \quad (4)$$

## 2.3 Modeling of DFIG Wind Generator

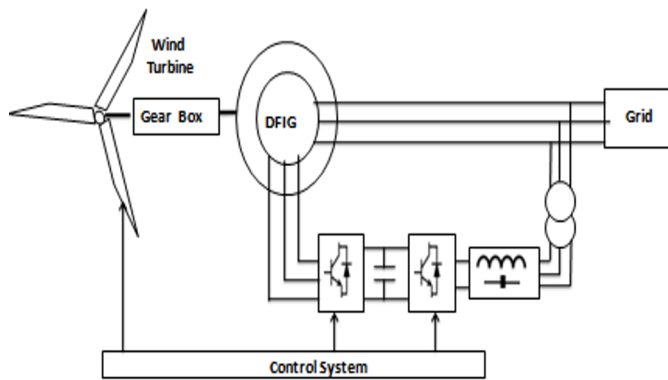


Fig.1 System for converting wind energy with DFIG

Figure 1 depicts a model that is often used for induction generators with the purpose of transferring power from wind to feed the electric grid. The rotor of a winding rotor induction machine is powered by a pair of inverters connected in series and supplied a common DC voltage by means of pulse width modulation. The stator portion of the machine is connected to the low-voltage, three-phase grid that is balanced. Grid side converters regulate power flow between the DC bus and the AC side, which in turn enable the capability of the system to operate at speeds either sub-synchronous or super-synchronous. The machine side is responsible for providing the appropriate rotor excitation. On the stator and rotor sides, the active and reactive power regulation is given by the machine side power converter using vector control, and the rotor is properly excited by the converter. DFIG has four applications since it can function as a generator, motor, sub-synchronous motor, and super-synchronous motor. When it comes to wind power generation, only two speeds—below and above synchronous—are of any concern. To make the most of a variable-speed setup, it's important to keep an eye on the torque-speed curve and adjust the motor's rotational speed as needed.

By adjusting torque, the required speed may be achieved. Active power and rotor speed determine the ideal torque speed curve, by Using current rotor speed and active power set point, one may achieve the required speeds and torques and for a given stator flux orientation, regulating rotor current yields the appropriate active power. By substituting the required power factor for the active power set point, one may get the reactive power set point [5].

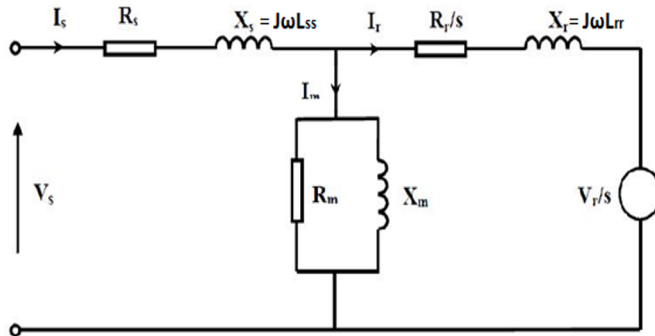


Fig.2DFIG equivalent circuit

The corresponding circuit of the DFIG is seen in Figure 2. If you want to create a DFIG like the one in the picture, you may use the following formulae.

$$V_{ds} = R_s i_{ds} + \frac{d\psi_{ds}}{dt} - \omega_s \psi_{qs} \quad (5) \quad V_{qs} = R_s i_{qs} + \frac{d\psi_{qs}}{dt} + \omega_s \psi_{ds}$$

$$(6) \quad V_{dr} = R_r i_{dr} + \frac{d\psi_{dr}}{dt} - (\omega_s - \omega_r) \psi_{qr} \quad (7)$$

$$V_{qr} = R_r i_{qr} + \frac{d\psi_{qr}}{dt} + (\omega_s - \omega_r) \psi_{dr} \quad (8)$$

The flux linkage symbol is expressed as:

$$\psi_{ds} = L_{ss} i_{ds} + L_m i_{dr} \quad (9) \quad \psi_{qs} = L_{ss} i_{qs} + L_m i_{qr} \quad (10)$$

$$\psi_{dr} = L_{rr} i_{dr} + L_m i_{ds} \quad (11) \quad \psi_{qr} = L_{rr} i_{qr} + L_m i_{qs} \quad (12)$$

### 3. COMPENSATING FACTS DEVICE MODELING IN THE DESIGN PROCESS

Infusing voltage in series and active-reactive power at bus 2's point of common coupling (PCC), dynamic voltage adjustment may be accomplished. The various FACT devices are then connected to the PCC in order to do this. In this research both of them Dynamic Voltage Restorer (DVR) and the Distribution Static Synchronous Compensator (DSTATCOM) are used.

### 3.1 Concept of D-STATCOM

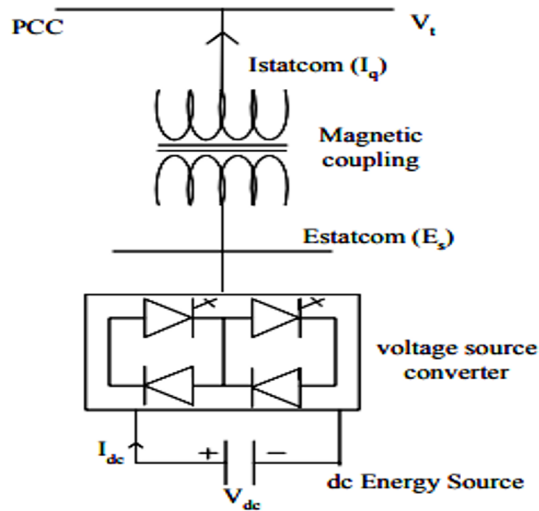


Fig.3 Block diagram of STATCOM

When used in a good Flexible AC Transmission System (FACTS), a Static Synchronous Compensator (STATCOM) may inject and absorb reactive power. The STATCOM is often implemented in order to achieve voltage support targets. It is connected in shunt to the distribution network, it includes an energy storage device, Voltage Source converter (VSC), and coupling transformer. The VSC takes the alternating current (AC) across the battery and transforms it into a series of three-phase alternating current (ac) output voltages. By continuously adjusting the converter voltage amplitude to the line bus voltage, the STATCOM is able to inject or absorb reactive power by causing a regulated current to flow via the tie reactance connecting the STATCOM to the distribution network [4]. A block schematic of Statcom's connection to the grid through coupling transformer is shown in Fig. 3.

By using power electronics and IGBT-switches, a Static Synchronous Compensator (STATCOM) converts voltage at the source. The VSC in Fig. 2 has an inductor for injecting or absorbing reactive power into the grid. It may be used to lessen the effects of both constant and fluctuating disturbances. Compared to SVCs, STATCOMs can respond faster, cause less interference, and work better at lower voltage levels.

When used to induction-machine-based wind farms, this may reduce flicker caused by fluctuations in the reactive power they consume. When compared to an SVC, the STATCOM is better at reducing flicker because it responds more quickly. As a result of the controller's assessment of the wind farm's reactive power needs, the STATCOM is driven to produce the specified amount, dramatically lowering reactive power flows to the grid and the resulting flicker[7].

### 3.2 Concept of DVR

It is important to note that the Dynamic Voltage Restorer (DVR) is a regulated device it is linked in series. Primarily, it may be used for the purpose of minimizing voltage drop at the point of connection. The DVR has the same structure as the DSTATCOM, with the addition of a coupling transformer that is linked to the ac mains. The fundamental structure of a DVR is shown in figure 4. The main problem with it is that it is expensive and hard to set up. The

converter makes a three-phase voltage that can be changed in both phase and size. By injecting these voltages into the AC distribution network, the load voltage may be kept constant at the set point[8-10].

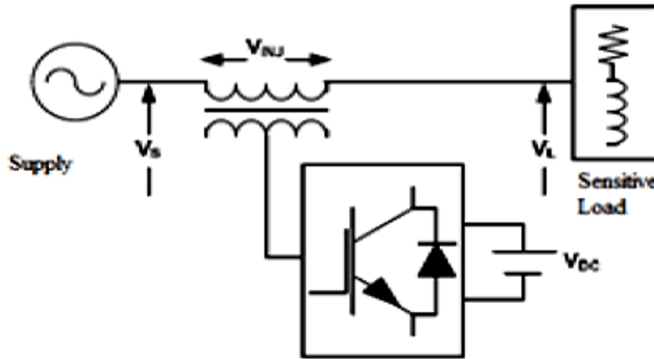


Fig. 4 A block schematic of the DVR system

## 4. ANALYSIS OF RESULTS

### 4.1 Devices for testing without any facts

Fig.5 shows the testing system MATLAB/SIMULINK model, which does not include any fact devices. Two transmission lines run in parallel to carry electricity, and their operation has a knock-on impact on the other line since it draws power from the same generators. The alterations are made to the first transmission line, and the second line is responsible for the impacts on the many kinds of power quality problems, including swell, sag, and harmonics. If a defect occurs in the first transmission line between the times of 0.3 and 0.5 seconds, the voltage drop in the second line will also be noticeable. When the first transmission line has a capacitive reactance added to it between 0.7 sec and 0.9 sec, the voltage goes up. As can be seen in Fig.6, between  $t = 0.9$  sec and 1.1 sec, The nonlinear load linked to first transmission line adds harmonics to the network. The voltage and current at the B3 location on the second transmission line are shown in Figs. 6 and 7.

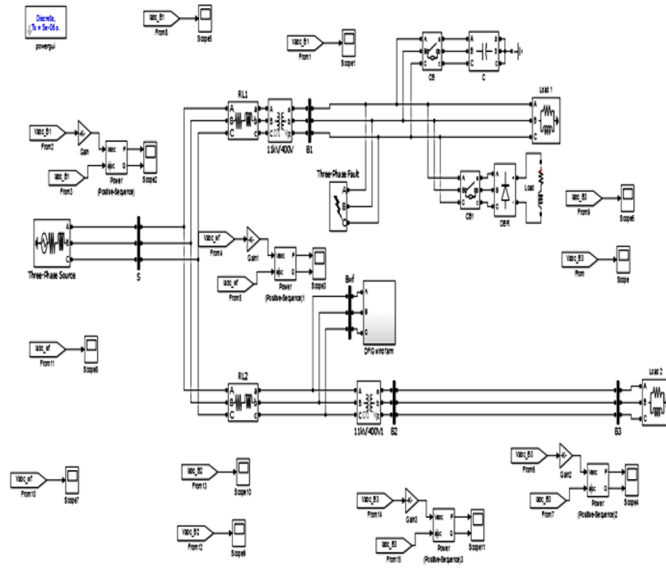


Fig.5 Test System Model in MATLAB/SIMULINK

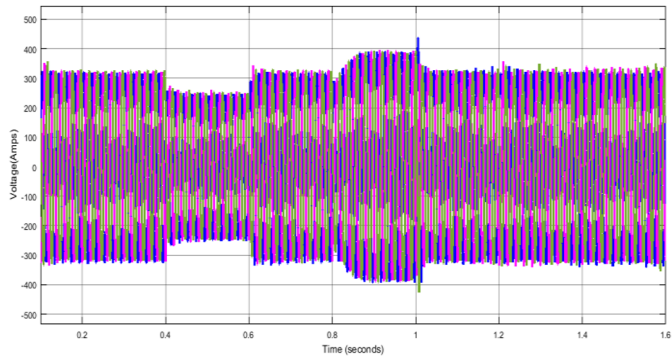


Fig.6 Waveform of Voltage at the B3 Point.



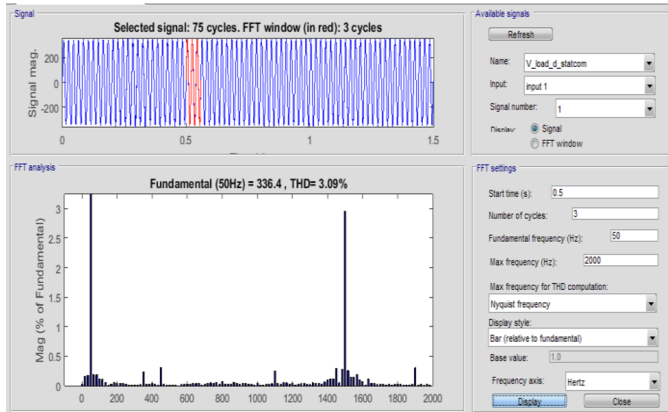


Fig.9 At  $t = 0.5$  ms, load voltage harmonic spectrum (for Sag Condition)

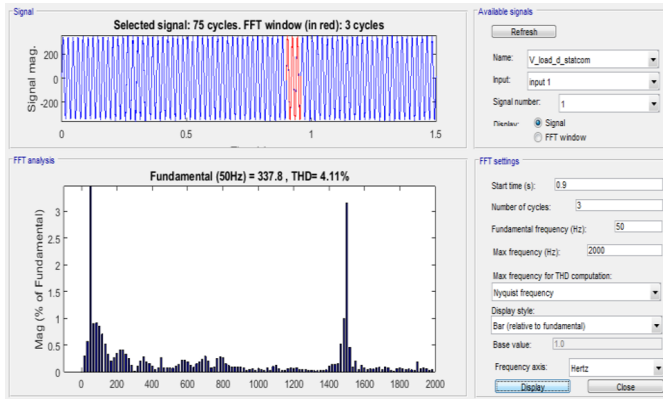


Fig.10 At  $t = 0.9$ s, load voltage harmonic spectrum (Swell Condition)

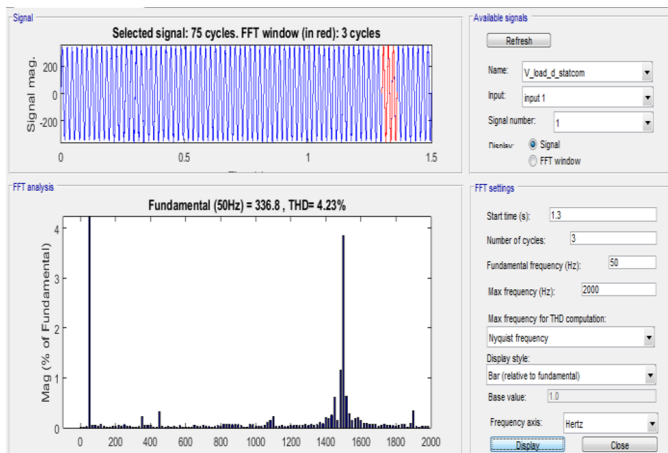


Fig.11 The load voltage harmonic spectrum was measured at  $T = 1.3$  seconds (for Harmonics Caused Due to a Non-Linear Load)

Harmonic spectra of the load voltage (at the B3 point) are seen in Figures 9, 10, and 11. From the Figures, it is observed that, At  $t = 0.5$  sec %THD is 3.09% (Voltage Sag), at  $t = 0.9$  sec %THD is 4.11% (Voltage Swell), and at  $t = 1.3$  sec %THD is 4.23% (Harmonics).

### 4.2 Proposed system with DVR

Fig. 12 depicts the voltage waveform at the load point B3, and they indicate that the DVR has effectively reduced harmonics, voltage sag, and voltage swell. The DFIG machine can provide the necessary active power and reactive power of 10 MW and 5 MVar at the load point B3.

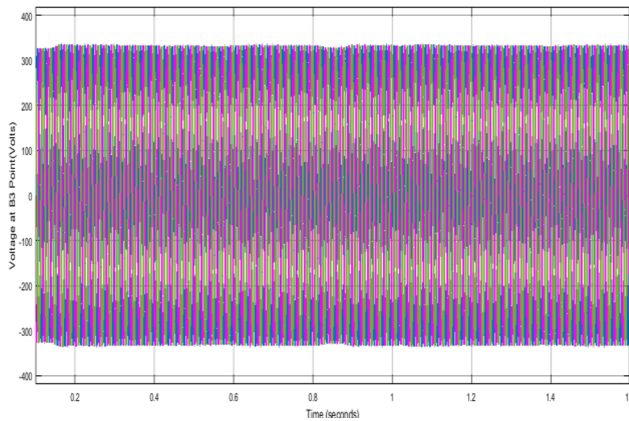


Fig. 12 The voltage wave at the B3 point

As demonstrated in Figures 13, 14, and 15, the load voltage's harmonic spectrum (at the B3 point) evolves with time. The voltage sag harmonic has a %THD value of 2.32 at time  $t = 0.5$  seconds, while the voltage surge harmonic has a %THD value of 2.37 at time  $t = 0.9$  seconds. The harmonics resulting from the nonlinear load are 2.37%, and at a time of  $t = 1.3$  seconds.

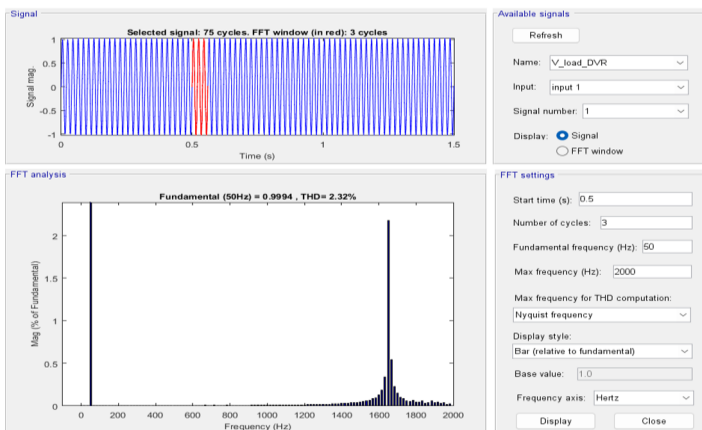


Fig. 13 At  $T = 0.5$ s, load voltage harmonic spectrum (Sag Condition)

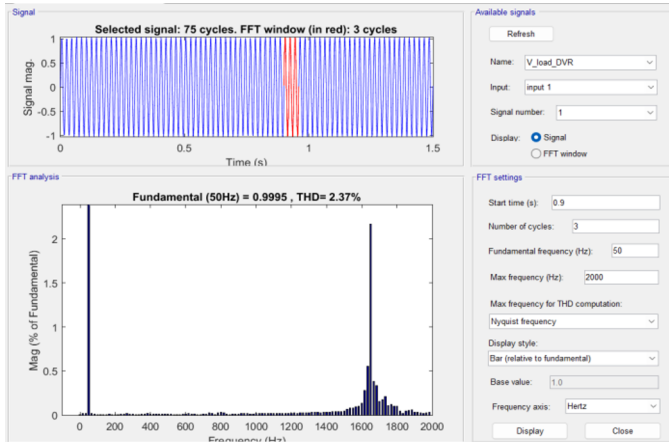


Fig.14At T = 0.9s, load voltage harmonic spectrum (Swell Condition)

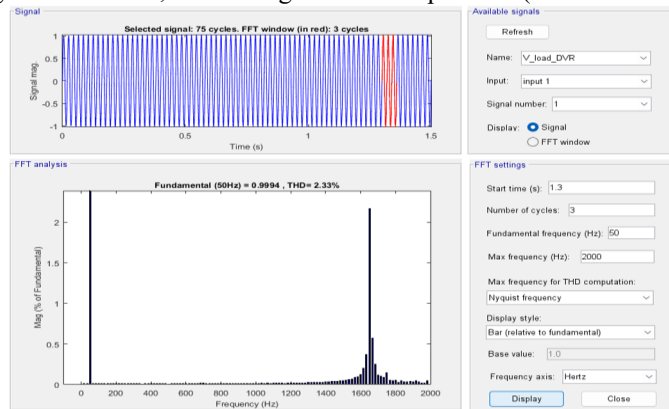


Fig.15The load voltage harmonic spectrum was measured at T = 1.3 seconds (for Harmonics Caused Due to a Non-Linear Load)

## 5. Conclusions

Sag, swell, and harmonic conditions may all cause problems for a DFIG-fed WECS, the performance of DSTATCOM and DVR has been examined. Voltage waveforms demonstrate the devices' competence in responding to sag, swell, and harmonic loads. Additionally, harmonic content is measured as necessary (at  $t=0.5$ ,  $0.9$ , and  $1.3$  sec) for all three devices when sag, swell, and harmonic have been entirely corrected for each other. This is done to ensure that the results are accurate. As a consequence of the simulation results that were produced, it is possible to make the observation that DVR has superior compensating abilities and Harmonic distortion is cut down to about 2% at different times, therefore satisfying the requirements that were set by the IEEE.

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