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# Review on Voltage Stability of DFIG Wind Turbine by Using DVR

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## ABSTRACT

In this paper ,Among the most rigorous power system disturbances, voltage sags, swells, interruptions & transients degrade the power quality. Though voltage sags last only for few cycles, it is enough to bring entire power plant out of synchronism from grid, causing the considerable economic loss. It has been identified that power quality can be degraded both due to utility side abnormalities as well as the customer side abnormalities.

When these types of wind farms are connected to the microgrid, then it is difficult to predict their time of uninterrupted operation. Because, when wind farms are connected to grid, the grid codes are to be satisfied. One of the important requirements is the fault ride through ability of the wind farm. When momentary faults on the system occur the system is subjected to variations in the output. Thus, fails to satisfy the grid codes. Faults in the power system affect the magnitude of current & voltage of the system. These fluctuations in the parameters create disturbance in the operation of the generators. The fluctuations bring generators into instability which may in turn result into loss of synchronism. The problems related to the voltage stability may be cleared by the use of custom power devices. These devices provide the customized ability to control the power in the circuits. One such reliable customer power device used to recover the problems related to the voltage is the Dynamic Voltage Restorer (DVR). The DVR is applied to DFIG for maintaining the voltage output constant.. The DVR compensates the faulty line voltage, during that the DFIG wind turbine continues its nominal operation as demanded in actual grid codes.

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Key words: wind turbine, DVR, DFIG, PWM.

## I.INTRODUCTION

We know the development in the power system has been increased the practice of power electronic components. The industrialized devices are typically based on power electronic devices like programmable logical controllers & electronic drives. These devices essentially need

The common power quality problems are as shadows .

1. Voltage dip is defined as the decrease in rms value of the voltage to a value between 0.1pu to 0.9 pu & lasting for the period between 0.5 cycles to 1 minute, Fig. 1.1. System faults are the core reasons of the voltage sags & contingent up on the fault clearing time; it may last for the 3 cycles to 30 cycles as the voltage regulation devices

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comes in action after the 60 seconds of voltage dip.

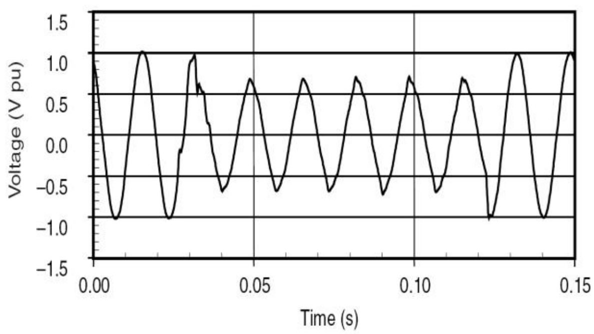


Fig. 1.1 Voltage Sag Waveform

2. Voltage swell is defined as the upswing in rms voltage that is between 1.1pu to 1.8pu for the time period of 0.5 cycles to 1 minute, Fig. 1.2. Single Line to Ground fault may give upswing to the voltage swell in the healthy phases. Switching of large capacitor bank is too the reason of voltage swell production.

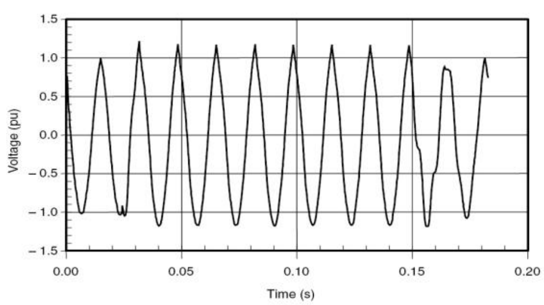


Fig. 1.2 Voltage Swell Waveform

3. Interruptions are nothing but the reduction in supply voltage or load current below 0.1pu for time not more than 1 minute, fig. 1.3. The origin of interruption is either by system fault, equipment failure or by control miscarriage.

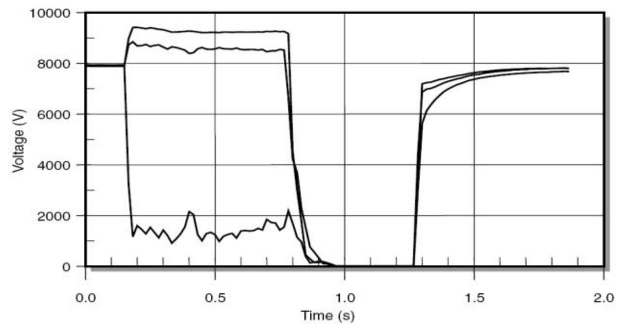


Fig. 1.3 Voltage Interruption Waveform

4. Transients are momentary undesirable voltages that appear on the system. Transients are high over-voltage disturbances that last for a very tiny time duration, Fig. 1.4. The transient happens due to Lighting loads, capacitor switching, nonlinear loads etc.

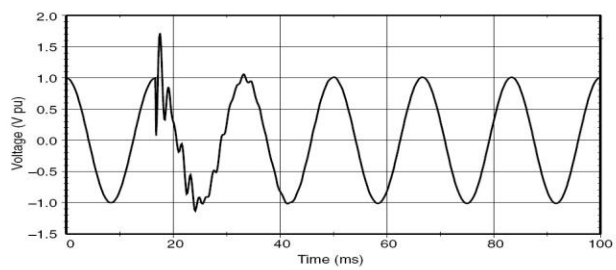


Fig. 1.4 Oscillatory Transient Waveform

5. Harmonics are the effect on the fundamental frequency of supply which produces multiples of the fundamental frequency, Fig. 1.5. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

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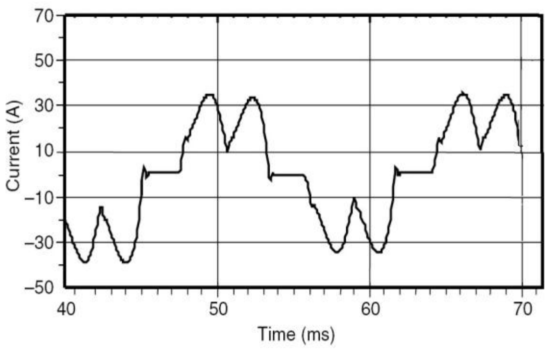


Fig. 1.5 Waveform with Current Harmonics

As an outcome of above power quality defect, the engineering may get affected out of failure of motors, loss of data on volatile memories, redundant downtime, increased maintenance costs etc. Among those abnormalities voltage sags & swells or simply the voltage variations are considered to be one of the most regular types of abnormality. Motor start up, lightning strokes, fault clearing & power factor switching are considered as the causes for fluctuating voltage conditions in the system.

## II. LITERATURE REVIEW

The power system has increased the use of renewable energy sources day by day. Among all the renewable energy sources, Wind energy is extensively utilized. The developing technology has put many efficient techniques of power generation using wind farms. One of the useful technologies of power generation using wind energy is DFIG turbines. This system comprises of the wound rotor induction motor to be used as the generator. The rotor winding is also fed the same generated supply. While feeding back, it is provided with set of back to back converter. This feeding back technique helps to maintain the output of the system constant still in the variations of the wind velocity input. Nowadays the research is being carried out to find out the performances of the DFIG system for fault ride through compatibilities. The important factor deciding the efficiency of the power system is power quality. The power quality gets affected with the use of nonlinear components in the network as well as the faults on the system. Faults affect the system by manipulating the parameters of the transmission line such as Voltage. Voltage stability of the system decides the healthy behavior of the system & life of the components in the network, as the components are rated depending up on voltage of the system.

The review of some papers that describes the basics of voltage stability & advanced research in the fields DFIG & DVR are discussed below.

### 2.1 Power Quality & Voltage Stability

The power system is affected deeply by the power quality problems. The power quality mostly deals with quality of voltage of the system. When the voltage of the system is maintained constant, the power quality is said to be better.

The author of Electric Power System Quality [1] describes the definition of power quality, its causes & effects on the power system, power quality improving devices. It explains the problems of power quality with their mitigation techniques. Problems arising due to transient over voltages, harmonics & long duration voltage variations are discussed. The paper [2] depicts the basic discussion of the power quality along with standards that are described for particular power quality issues. It specifies the categories for the power system disturbances.

Paper [3] & [5] explains the power quality problems, their effect on the industrial equipment along with their corrective measures. Paper [4] discusses the harmful effects of poor power quality on the consumers. The equipment that get deteriorated by the power quality effects are explained in this paper. The controlling techniques with which power quality can be improved are discussed.

The book on Modern Power System Analysis [6] discusses the faults on the power system. The faults on the power system cause the disturbance to the voltage of the system. Hence it leads the system towards the voltage imbalance. Book also describes the power system stability measures. Paper [7] & [8] gives the types of faults in the power system & analysis of the power system during faults. It also explains the causes of the faults & effect of faults on the sequence components of the system.

Paper [11] describes the comparison of the types of wind turbines with their advantages & disadvantages. The suitability of the particular wind turbine for adjustable speed generation is discussed. The effect of changing speed of the wind velocity on the different types is studied. Paper [12] describes the performance of the DFIG turbine during unbalanced voltage. The electromagnetic torque oscillations & non sinusoidal current exchange with the grid disturbs the performance of turbine at the instant of unbalance voltage. The analysis is done for the injecting active & reactive power for gaining performance during unbalance.

Paper [13] describes the strategy for facing the perturbation of the DFIG system depending up on the rotor flux control & the direct torque control. The research is done for mitigation of use of crowbars for the protection purpose. The investigation shows that efficient design of the controller of rotor flux & direct torque can eliminate the crowbars protection up to some extent.

## III.DYNAMIC VOLTAGE RESTORER

The DVR is made up of electronic switching devices, energy storage unit, voltage injection transformer & filter devices. The components are described in fig. 3.1.

### 3.1 Energy Storage Unit

The energy storage unit supplies exact amount of power for compensation of voltage during voltage sag. The reactive power exchanged between the DVR & the system is generated by the DVR without any AC passive reactive components. Real power exchanged at the DVR terminals must be provided at the DVR with DC terminal by secondary energy storage system. For DVR applications, the energy source can be an electrolytic capacitor bank.

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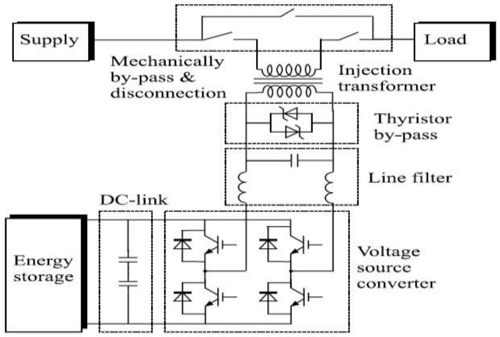


Fig. 3.1 Schematic Arrangement of DVR

### 3.2 Series Boosting / Injection Transformer

The parameters of series injection transformer should be chosen correctly to guarantee the maximum reliability & effectiveness of the system. IGBT switches are commonly utilized in series connected circuits. In bypass mode, full load currents pass through these semiconductor switches. Again, the flowing current rises during sags as power is injected for compensation. So the switches should handle the total current. It has been identified that in order to ensure the maximum reliability & effectiveness of this restoration, careful selection of the injection transformer is a prerequisite. To incorporate the injection transformer perfectly into the DVR the MVA rating, the short circuit impedance, the primary winding voltage & current ratings, the turn-ratio and winding parameters of the injection transformer should be carefully calculated.

### 3.2 DVR without Energy Storage

This technique uses the system supply to compensate the faulty line voltage. So the supply used as the source to compensate the line voltage during voltage sag will also have the same magnitude of the voltage sag & the shunt converter will charge the DC link first with that supply & the required value of voltage will be supplied by the system to compensate faulty line voltage. But this system has drawback that system load current will increase during fault condition, so higher value of current will flow through the energy storage system & it will create the voltage drop for the upstream loads. It also gives savings in the energy & the ability to compensate longer sags. A passive shunt converter is used to allow the flow of power in only one direction.

### 3.3 Shunt Converter with Supply side Connection

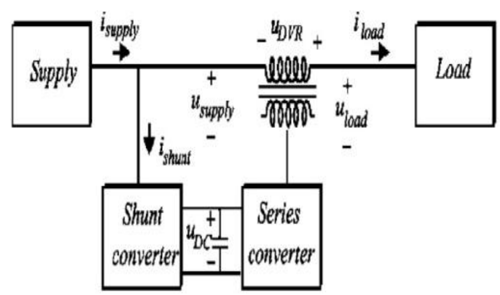


Fig. 3.2 Shunt converter with supply side connection

This system contains an uncontrollable dc-link voltage. The passive converter charges the dc-link capacitor to the actual state of the supply voltage. The dc-link voltage becomes nearly equal to the supply voltage hence; during voltage sags the dc-link voltage also drops in proportion to the sag voltage.

### 3.4 Shunt Converter with Load side Connection

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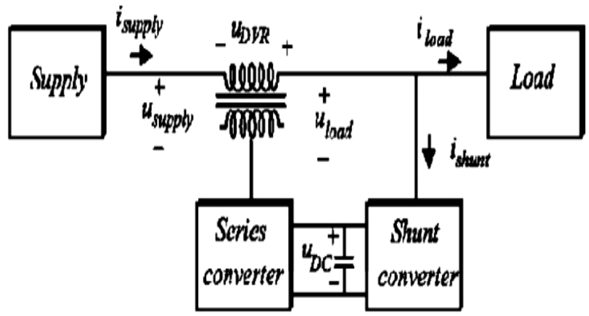


Fig. 3.3 Shunt converter with load side connection

The system having load side connected Shunt Converter has the input voltage controlled by the virtue of constant supply injected by series converter so, DC Link voltage can be maintained constant. This topology has the disadvantage of larger currents to be handled by the series converter. If the supply voltage falls then at rated load the current through the series converter is much higher followed by the moderately high current through the shunt converter.

### 3.5 DVR with Energy Storage

Maintaining a system equipped with separate energy storage device is somewhat expensive but reliable. Storing electrical energy is costly, but for some types of voltage sags the performance of the DVR can be enhanced & the strain on the grid connection is lower.

### 3.6 DVR with variable DC Link Voltage

This topology is operated with a variable dc-link voltage. Here, the stored energy is proportional to the square of the rated dc-link voltage as shown in the following expression (3.1),

$$E_{storage} = \frac{1}{2} C_{DC} V_{DC}^2 \quad (3.1)$$

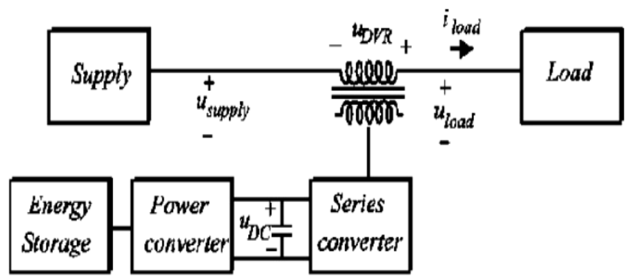


Fig. .4 DVR with Variable DC Link Voltage

Where, $E_{storage}$ is Energy that is stored in the energy storage system, $C_{DC}$ is the DC link capacitance & $V_{DC}$ is the DC link voltage.

### 3.7 Advantages

The use of DVR for the fault ride through of DFIG wind turbine has many advantages as follows.

1) DVR can compensate voltage sag or swell.
2) The voltage stability of the system is improved with the use of DVR.
3) The device is fast acting & precise in operation.
4) The reliability of the system increases with the use of DVR.
5) With the use of DVR, the system can be made suitable to follow the grid code requirements.
6) Existing systems can be employed with DVR for gaining fault ride through capability.
7) It has no impact on environment.

8) The protection against voltage fluctuations can be done for the sensitive loads
9) The DVR may be operated as the fault current interrupter.

### 3.8 **Applications**

The advanced research in the power system has increased the application areas of the DVR. The DVR in the Power System can be used for different applications as mentioned below.

1) DVR can be installed in the wind turbines for improving their fault ride through capability.
2) DVR can be utilized for the fault current interruption in power systems.
3) Use of DVR can be done instead of voltage regulators in power systems.
4) The DVR can be used for the protection of sensitive loads from the voltage fluctuations.
5) The DVR can be employed for enhancing the voltage stability of the distribution system.
6) For the industries, with large nonlinear loads, DVR can be used for maintaining reliability during voltage imbalances.

## IV CONCLUSIONS

The comprehensive literature review was carried out in order to explain & design the system of DFIG wind turbine system with DVR to overcome the problem of voltage stability. The problem was clearly emphasized & the main components, operating principle, topologies & voltage injection methods of DVR are discussed. The proposed system with DVR has shown the ability to compensate the voltage sags during the fault on the system. The comparative analysis of the obtained results of active crowbars & active DVR is done. The results have verified the efficiency, flexibility & fast response capability of the developed system. The designed DVR has supplied a regulated & sinusoidal voltage to maintain the stator voltage of the DFIG during the fault.

## V. Future Scope

There are many aspects that are not yet studied & evaluated for the operation of DVR. The future scope of this power electronic device is wide & it includes following areas.

1. Verification of the HV-DVR performance at a location with different types of voltage dips originated from faults at the transmission level & distribution level.
2.Investigation of DVR topologies including the direct connected DVR.
3. Testing a number of different loads, such as thyristor loads, motor loads, active rectifier loads to verify the robustness of the loads to protect from voltage dips.

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