VIVA-TECH IJRI
ANNUAL RESEARCH JOURNAL
VIVA-TECH INTERNATIONAL JOURNAL
FOR RESEARCH AND INNOVATION
ANNUAL RESEARCH JOURNAL
ISSN(ONLINE): 2581-7280

Modelling and Simulation of Dynamic Voltage Restorer connected to Wind Power Distribution

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Abstract: *Implementation of large-scale wind power generation into the grid is growing quickly. Appropriate activity relies upon the accessible innovation to mitigate the conceivable adverse consequences, for example, loss of generation for frequency support, voltage sag, and power variety because of the variable speed of the wind. The danger of voltage collapses because of absence of reactive power support is one of the basic issues, with regards to possibilities in the power systems. This requires quick control strategy with least energy requirement. In this paper, a WTG system connected to a distribution network with a DVR is considered for analysis. Three phase system has been designed with three phase source, three phase transformer, three phase breaker and 3 phases parallel RL load. A three-phase fault has been created and results are analyzed using MATLab/Similink.*

Keywords -*Dynamic Voltage Restorer (DVR), Wind-Turbine Generators (WTGs), Voltage sag, Voltage Swell Electrical fault*

I. INTRODUCTION

Implementation of large-scale wind power generation into the grid is growing quickly. The general stability of the framework ought not be debased rather it ought to be improved with the coordination of wind power generation system. Appropriate activity relies upon the accessible innovation to mitigate the conceivable adverse consequences, for example, loss of generation for frequency support, voltage sag, and power variety because of the variable speed of the wind. The danger of insecurity because of lower level of controllability can't be disregarded [1].

In past, wind-turbine generators (WTGs) were permitted to separate from the framework during a fault. As wind turbines will supplant the traditional generation eventually, there is an expanding prerequisite that they ought to stay associated with the power grid during network disturbances. Because of this, system administrators in numerous nations have as of late settled transmission and distribution system grid codes that indicate the scope of voltage conditions for which WTGs should stay associated with the power system. These are ordinarily alluded to as the fault ride-through specifications.

The danger of voltage collapses because of absence of reactive power support is one of the basic issues, with regards to possibilities in the power systems. Firmly connected to this is the LVRT capacity, which is quite possibly the most requesting requirement that have been remembered for the grid codes. Wind farms utilizing doubly fed induction generators (DFIG) and cage induction generators are straightforwardly associated with the system or through a step-up transformer to the point of common coupling (PCC) bus. Particularly cage induction generator will most intensely experience the ill effects of the new demands, since they have no direct electrical control of torque or speed, and would ordinarily disengage from the power system when the voltage drops more than 10–20% beneath evaluated esteem [3]. This requires quick control strategy with least energy requirement. The transient conduct of wind power generators is recorded in various literatures [4]-[6] in the event of changes in the grid voltage and other anomaly in the network. Voltage source static VAr Compensator, for example, Thyristor controlled static VAr compensators (SVCs) and the static compensators (STATCOMs) can be utilized to manage voltage to further develop the grid interface capacity of straightforwardly associated asynchronous wind generators. Improvement of transient stability of induction generators utilizing STATCOM have been accounted for in [7] and an overall examination of the ride through capability of fixed-speed wind farms with a STATCOM is given in [8].

II. BASIC STRUCTURE OF DVR SUPPORTED WIND FARM

A WTG system connected to a distribution network with a DVR is considered for analysis, and the single line diagram of which is shown in Fig. 1. The system is supplied by the wind farm with three phase balanced voltage source (V_S). There are two feeders connected in the distribution system. The load L-1 is connected to bus B-1 that is supplied by Feeder-1 with impendence of $R_{S1}+j\omega L_{S1}$. This load has two components- an unbalanced RL component and nonlinear component that is drawing inter harmonic currents i_{hl1}. The Feeder-2 with impendence of $R_{S2}+j\omega L_{S2}$ is connected to the end of Feeder-1 and terminates at bus B-2. The loads L-2 and L-3 are connected at the bus B-2. The B-2 bus voltage is denoted by v_t.

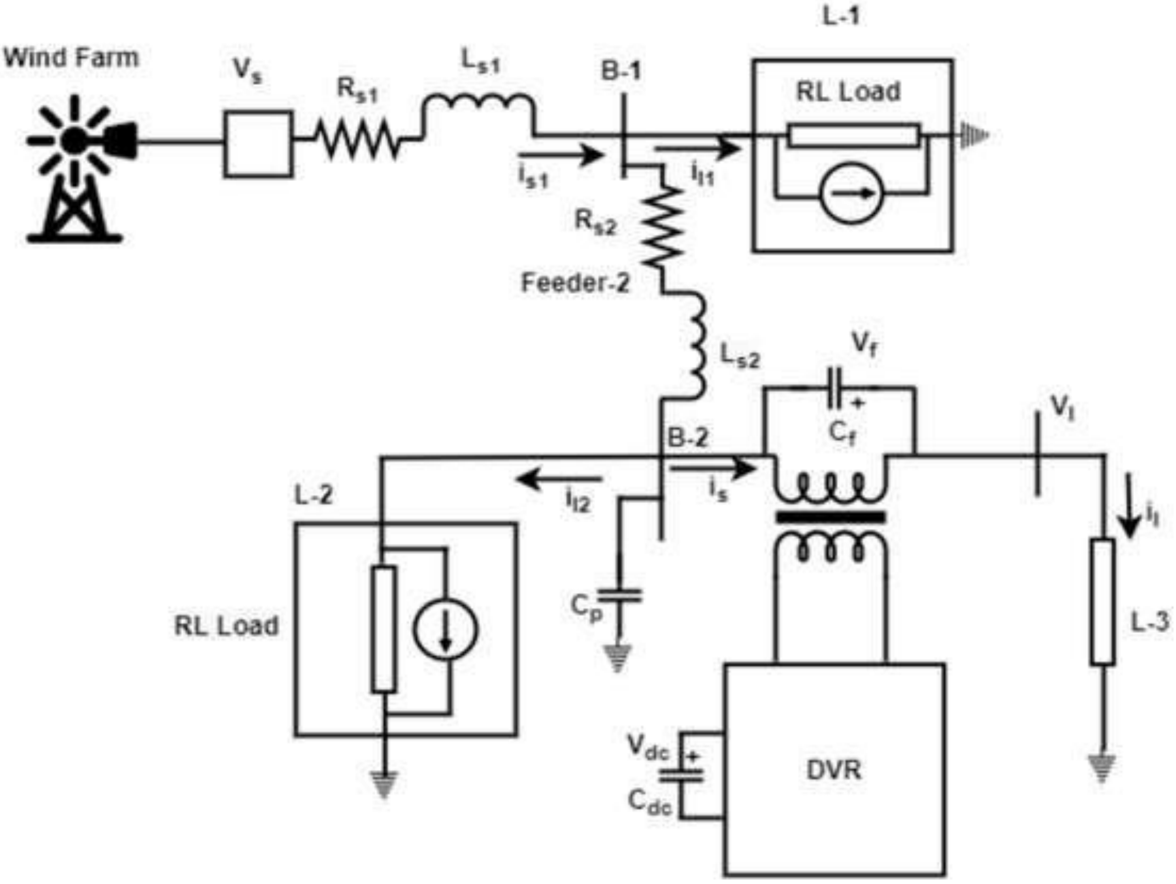

Fig.1: Single line diagram of a DVR supported wind farm

The load L-2 has also two components, i.e., an unbalance passive RL component and a nonlinear inter harmonic current component i_{hl2}. The load L-3 is a sensitive load and it requires a clean balanced sinusoidal supply. The current drawn by the three loads are indicated as i_{l1}, i_{l2} and i_l. Filter capacitors C_p and C_f are also connected in the system as shown. The capacitor C_f is connected across the secondary winding of the transformer to bypass the harmonics generated by the inverter switching. The capacitor C_p is connected in shunt with the bus B-2 to provide a low impedance path for the harmonic components flowing in the line currents i_{l2}.

III. DVR REFERENCE VOLTAGE GENERATION

The main aim of the DVR is to make the load voltage strictly positive sequence. Now we have,

$$v_t + v_f = v_l \qquad (1)$$

To force v_l to be positive sequence, from (1) we see that v_f must cancel the zero and negative sequence component of v_t. In addition, the positive sequence component of v_f must be chosen such that the load voltage is regulated at a prespecified value. Since the DVR must operate in zero power mode, we get the following relation from Fig. 1 [15].

$$P_l = P_t = (v_{ta} i_{ca} + v_{tb} i_{cb} + v_{tc} i_{cc}) \qquad (2)$$

where, P_t is the instantaneous power entering the terminal and P_l is the instantaneous power supplied to the load. Let us denote the phasor load voltage as $v_l = |v|\angle\theta$, where $|v|$ is a pre-specified magnitude and θ is an unknown angle to be computed. Note that the load voltage is strictly positive sequence, the average power to the load is also positive sequence, then we get

$$P_{lav} = |V_l|\,|I_{l1}|\cos(\theta - \phi) \qquad (3)$$

where, $|v1| \angle \varphi$ is the phasor positive sequence component of the load current. Now combining (2) and (3) we get

$$\theta = \cos^{-1}\left(\frac{P_{tav}}{|v_l|\,|i_{l1}|}\right) + \emptyset \qquad (4)$$

Among quantities on the right-hand side of (4), $|V_l|$ is known, P_{tav} can be calculated from the instantaneous measurement of terminal voltage and load current using half cycle averaging. The rms phasor positive sequence component of the load current (or terminal voltage) can be extracted from the sampled values of the load current (or terminal voltage), which may contain harmonics, using procedure given in [16]. Denoting the zero, positive, and negative sequence phasors by subscript 0, 1, and 2, respectively, these components are given by

$$\begin{array}{l} I_{l0} \\ I_{l1} \\ I_{l2} \end{array} = \frac{\sqrt{2}}{T\sqrt{3}} \int \begin{array}{ccc} 1 & 0 & 0 \\ 0 & a & a^2 \\ 0 & a^2 & a \end{array} e^{-j(\omega t-90)} dt \qquad (5)$$

where, a $= ^{j(12O^{\circ})}$ and T are the integration interval that is chosen as half a cycle to eliminate all harmonic components.

Once θ is obtained from (4), the reference phasor sequence components of the DVR voltages are obtained from (1) as [15]

$$V_{f0}^* = -V_{t0}, V_{f1}^* = Vl\angle\theta - Vt1, V_{f2}^* = Vl\angle\theta - Vt2 \qquad (6)$$

An inverse symmetrical component transformation as given in (7) will produce the reference phasor voltages of the DVR. The instantaneous phasor voltages then can be obtained from phasor voltages.

IV. SIMULATION MODEL

Three phase system has been designed with three phase source, three phase transformer, three phase breaker and 3 phases parallel RL load. A three-phase fault has been created in between the Transformer and the breaker with switching time 0.03 seconds to 0.07 seconds.

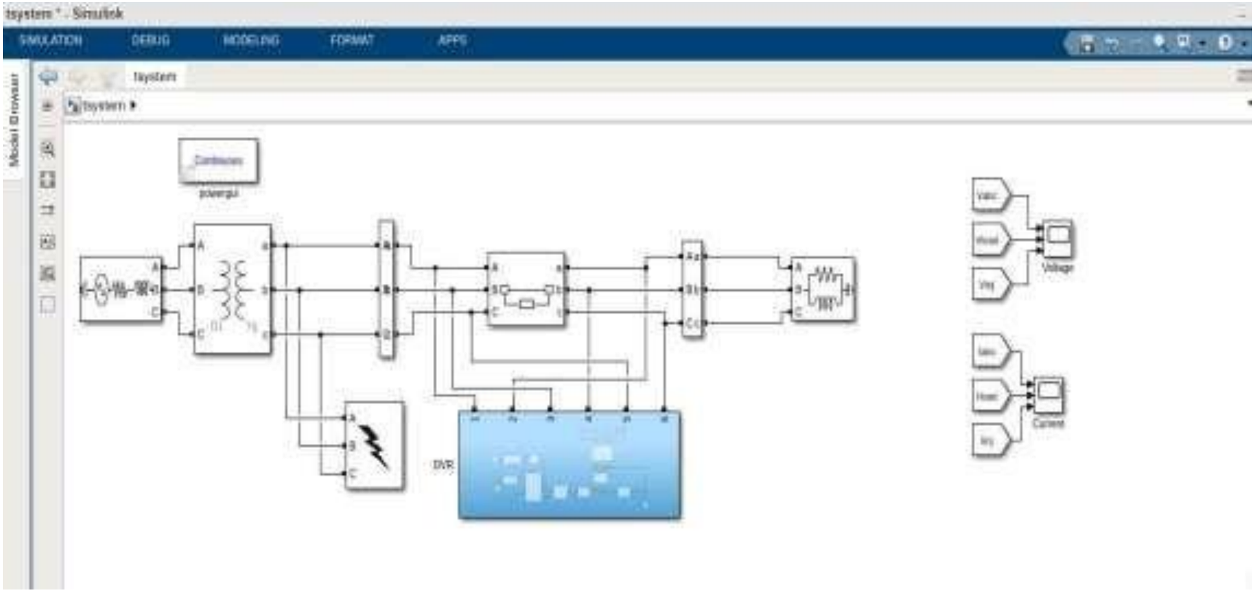

Fig.2: Main system with DVR as subsystem

3 phase VI measurement block has been used to see the system voltage and current without any fault and with fault condition. The DVR also comprises of a 3-phase breaker, 3 phase series RLC Branch. Injected voltage is fed to the system through a 3 phase 12 terminal transformer. Three phase voltage with fault is treated by the compensating voltage injected by the DVR. In order to compensate with the fault created by the fault block, a Dynamic Voltage Restorer has been modelled with multilevel Converter and dc source of 200 volts and connected with the existing system as "subsystem block". The purpose of this DVR is to compensate the voltage sag that has occurred due to 3 phase faults.

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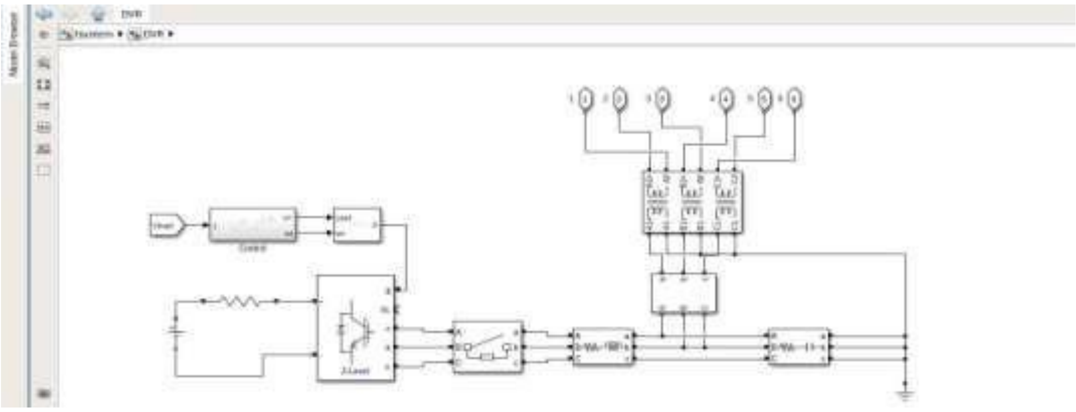

Fig. 3: DVR subsystem

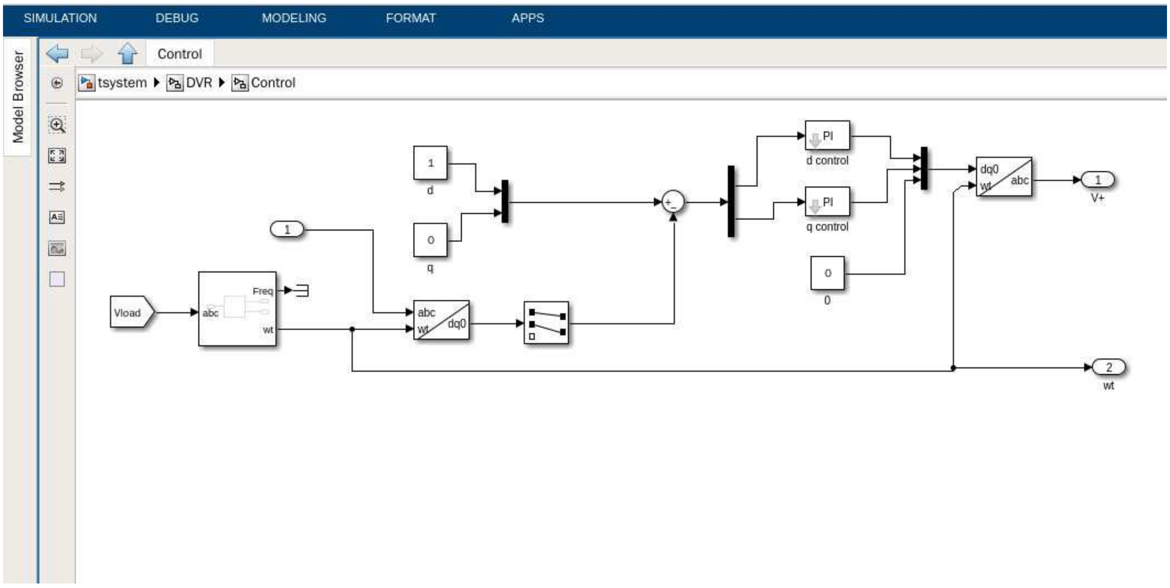

Fig. 4: Simulink Model with control Strategy

V. CONCLUSION

The principal aim of a DVR is to defend delicate loads from sags/swells and interruptions in the supply side. The capacitor supported DVR, while operating in zero power mode, regulates the load voltage even when the source and load voltages are unbalanced. The control of a DVR was examined for a small wind farm distribution system. This type of compensation is particularly economical because the voltage and power ratings of the DVR are low.

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