Integration of Wind power plants and impact of DVR into a power system

ISSN (e) 2520-7393
ISSN (p) 2521-5027
Received on 15 Sept, 2018
Revised on 4 Oct, 2018
www.estirj.com

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Abstract: Renewable energy sources are used mainly due to increasing environmental concerns. Integration of Wind energy with power system network has many advantages such as, it is fuel free source, no pollution, reliable, increases the generation capacity but at the same time it has power quality issues, one of the main power quality issue is voltage sag which increases loses in a line, increases the size of conductor as well as cost of equipment and reduces the life of system. Voltage sag occurs when load is increased or in case of different fault conditions. This work shows how dynamic voltage regulator is used to control power quality issues of doubly fed induction generator based wind turbine in case of different faults. In this system DVR is used to regulate the voltage sag simulated by using Matlab (2016) (b).

Keywords: *Wind power plant, DVR, Renewable Energy interconnection, Experimentation, Simulation*

1. Introduction

The energy needs in Pakistan has gone high in the magnificent proportions over the past few years. Moreover, energy needs are expected to increase more in future. The oil, natural gas, hydro and nuclear power are the vibrant sources of generating electricity in Pakistan. At the moment, oil contribution is 45%, hydel power is roughly 15% and natural gas is 34% of total energy supply [**1**]**.** Based on the cost and environmental impacts of fossil fuels, it is preferred to generate electrical power from un-traditional sources. It has motivated the planners and experts to search for other alternative energy resources of low cost. **[2].**

Integration of distributed energy means is developing as rising power phenomena for electric power generation, distribution as well as transmission infrastructure worldly consisting on the visible issues, like fossil fuel scarcity in coming time, largely spread supply of latest renewable energy sources, public knowledge and deregulation on environmental effects regarding the generation of electric power through traditional methods. As the knowledge on environmental hazards is rising; non-conventional power generation methods are getting preference in modern power situation. Integration of renewable energy sources and loads in the form of micro grid have many advantages like it enhances reliability, generation capacity and decrease the congestion of load on conventional utility grid or power system and at customer ends **[3]** .

In the last years, wind energy is widely used in electrical system, causes to increase of the requirements to integrate wind generators. As the wind turbines do not cause environmental impacts so wind energy is preferred more reliable to generate electrical power by the advancement of technology and rising capacity **[4]**.

The wind turbines with Doubly Fed Induction Generator (DFIG) are the most successful variable speed configuration **[5].** As the wind plants causes some power quality issues to it is necessary to implement new technologies to solve these problems and easily and safely integrate wind power with power system. Now a days Flexible ac transmission systems (FACTSs) are best solution to improve the power quality issues. **[6]**

FACTs devices include STATCOM, DVR, static var compensator (SVC), UPFC, TCSC and so on. One of the FACTS devices such as DVR used in this research work to regulate the voltage variations**. [7]**

2. Related Work

In 2008,R. Billinton, Y. Gao**[8]**discussed STATCOM-based control technology which improve the power quality issues related to the private wind plants.

In 2008, M. Tsili S. Papathanassiou **[9]** discussed the technical requirements that are to be complied by the wind power plant connected to power system. The paper has however considered grid codes, the most important requirement of wind farms which are a part of most of the grid codes. These include active and reactive power support by wind farm and its regulation, voltage and frequency operating limits and especially how wind farm is going to respond to grid disturbances. The paper finally also discusses the advancement undergoing in wind turbine technology, with the special reference to contribution of this improvement in satisfying grid code.

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In 2013, Morris Brenna **[10]** discussed the impact of wind induction generators integrated with weak distribution grids. The impact to the weak distribution grid has been evaluated by considering a wind turbine employing a fixed speed induction generator. The paper concludes with the result that connecting wind farms to weak grids causes an increase in the disturbances on the distribution network and may pose stability issues that can be mitigated with fast acting torque regulators and by employing an electronic interfacing while connecting with electric network**.**

In 2015Berk Rona, Önder Güler**[11]**describes the integration of the wind plant with the national grids and observed the power quality issues generated at the wind farms. With Matlab software program, the distribution system of Trakya (Turkey) area has been analyzed in.

In 2015 Muhammad A. Saqib, Ali Z. Saleem **[12]** described the particular problems which are caused by wind plants. By considering 50MW wind form integration with Pakistan power system (HESCO network, the power quality and reactive-power compensation in particular are analyzed. MATLAB/ Simulink is being used for the modeling and simulation purpose**.**

In 2016Bhadane at el **[13]** discussed the power quality issues related to integration of renewable sources. Integrating these renewable systems into grids can make them vulnerable to the issues which have to be paid attention otherwise grid functionality might get affected. Among such issues the worth mentioning can be voltage regulation, frequency deviation and power Quality.

In 2017FredeBlaabjerg, Yongheng Yang **[14]** discussed some trends in the power electronics technologies used for improvement of power quality problems using wind turbines and some future power quality improvement solutions have been discussed.

In 2018, Agalar at el. **[15]** simulated the results of STS and DVR by using PSCAD/EMTDC program. The purpose of this work is to improve power quality.

3. Methodology

3.1 System model

Block diagram of the system is shown in Fig.1 shows the Proposed system consists of wind power plant is connected with power system network through 24km line. Dynamic voltage regulator (DVR) is used to regulate the voltage sag in case of fault occurs on bus.

.2. Proposed DVR System with Wind Power Plant

The Grid integration study has simulated by building a 50 2MW wind farm in Matlab. Nordex N100 type wind turbine will be simulated in Matlab 2016(b) as shown in figure 2.Each turbine has been rated 2.5 MW. In total twenty such turbines will be utilized. The generate in each turbine produces 660 V. Thus these 20 turbines making a 50 MW wind farm (2.5 MW x 20) having 660 V output are connected to 660 V bus. The 660 V output of generator is connected to step up transformer which steps the voltage up to 22 kV. The transformer is rated 60 MVA (3 MVA x 20). The 24 km collector cables collecting power from wind farm are connected between 22 kV bus and medium voltage substation. The cables have cross sectional area 240 mm^2 and are shown by equivalent Matlab pi section line. The wind farm has auxiliary load of 0.5 MW connected to 22 kV bus.

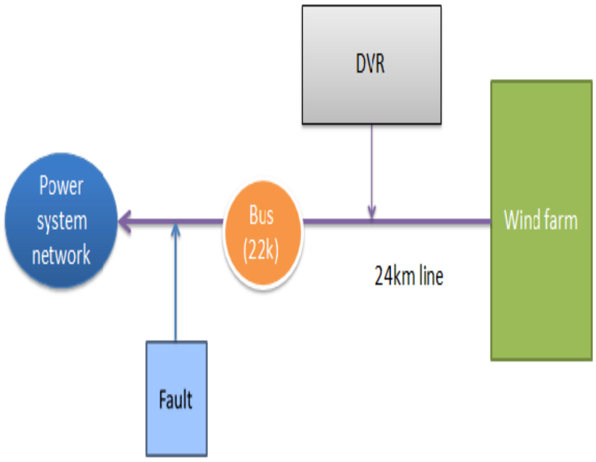

Figure.1 Block diagram of DVR connected with the wind power plant

The power now again goes through a step up transformer which steps up the voltage to 132 kV. The transformer has a rating of 60 MVA. The output of the transformer is connected to a 132 kV bus. This bus is actually the point of common coupling (PCC) for the wind farm. Since there is no ground wire the grounding is provided through a grounding transformer. A neutral grounding resistor is also connected on low voltage side of 132 step up T/F.

When some increasing megawatts of power are integrated with power system by the wind farm, they are required to have low voltage ride through capability.

In this section it will be demonstrated how by using FACTS devices such as DVR helps to achieve this requirement. The test system that will be used for this purpose is same shown in Fig.1. Different types of faults at the MV bus (22 kV) will be applied to simulate the grid fault. The resulting response of the system with and without DVR will be observed. The proposed system with DVR as shown in fig. 2.

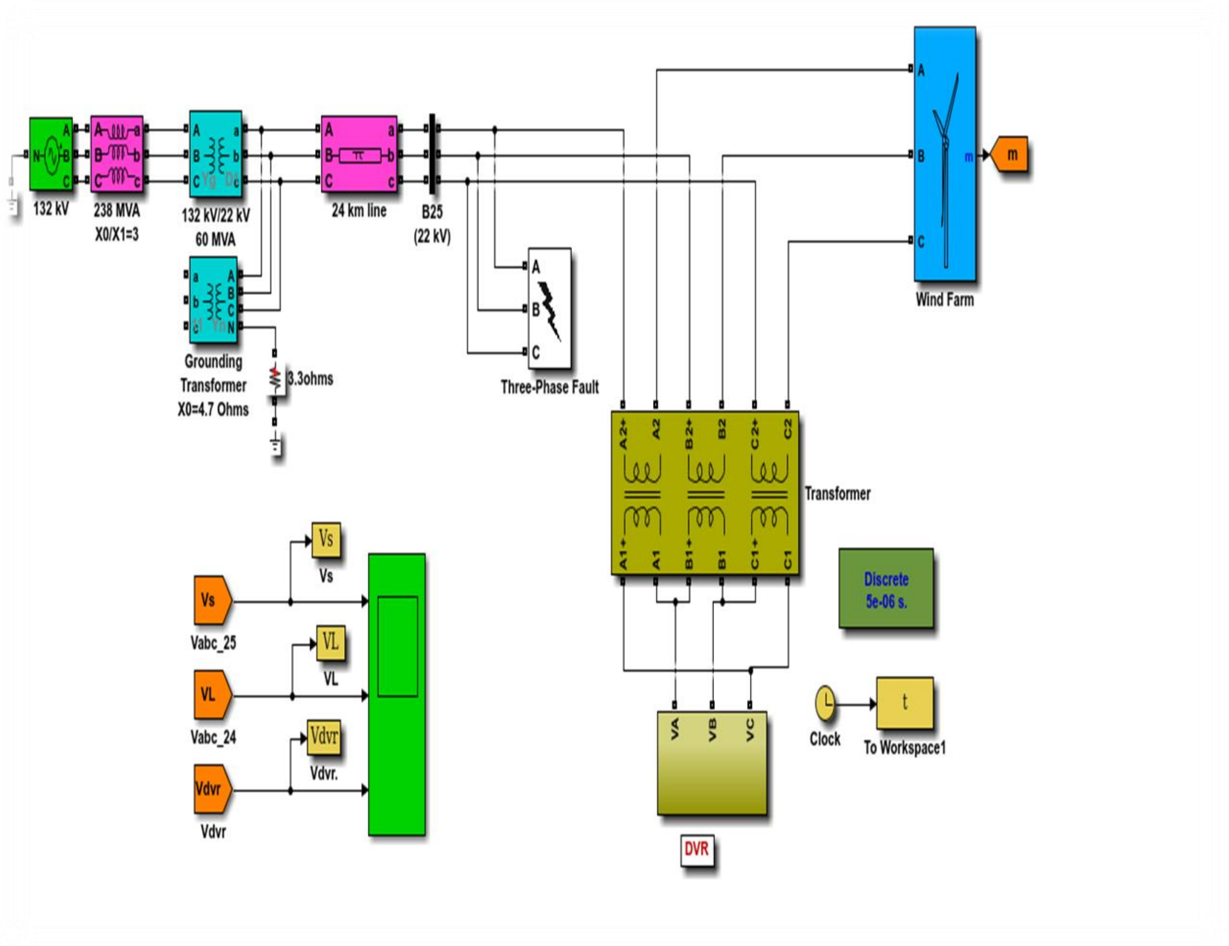

Figure.2. Proposed DVR System with Wind Power Plant

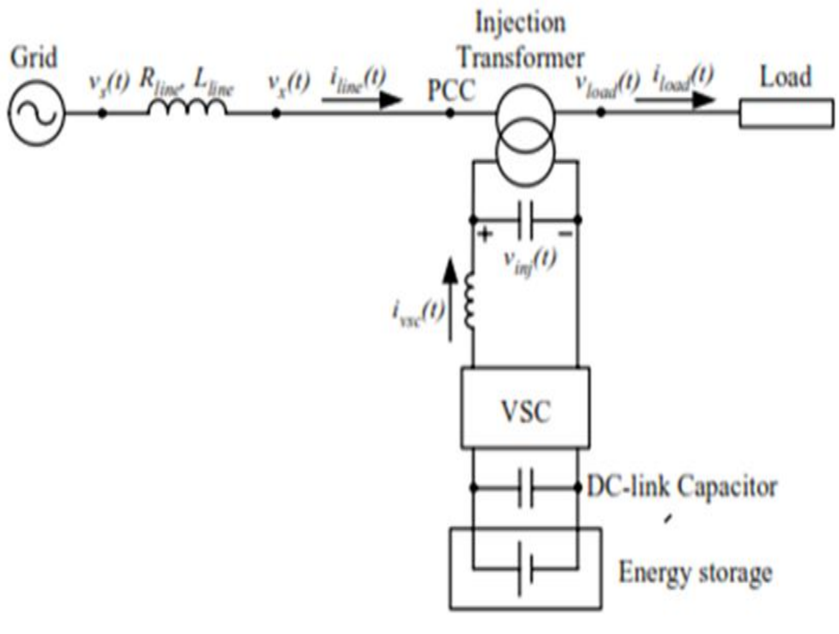

Figure.3. Dynamic voltage regulator

3.2.1Dynamic Voltage Regulator (DVR)

Dynamic voltage regulator is one of the useful device of FACTs. It can improve voltage sag of power system which is the main issue of power system mainly considered as important power quality issue in the world. Fig.3 shows the dynamic voltage regulator connected to grid.

DVR has capability to control the active and reactive power independently; it means it has bidirectional property. This can generate or absorb active and reactive power which makes it distinct in many other controllers **[16].**

3.2.2 Three Level three phase diode clamped multilevel inverter:

In Wind power integration DVR is used to control the voltage sag. This voltage sag is controlled by three level diode clamped multilevel inverter is used as shown in fig. 4. The purpose of these is to synthesize the output voltage waveform in multiple steps with less distortion compared to two-level inverters **[17].**

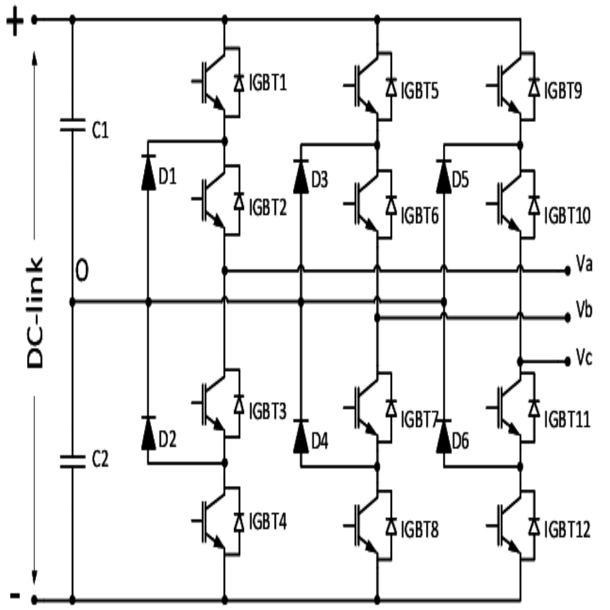

Figure.4. 3-Level three phase diode clamped multilevel inverter (used in DVR)

These converters have several other attractive features, such as less space for installation, less complex, modular structure, low cost, high efficiency, and fewer devices. These converters have high efficiency, small leakage current and simply constructed from switching devices, diodes and capacitors. In a k-level single phase MLI, the switching devices, DC link capacitors and clamping diodes can be expressed as in Eqs. (1), (2) and (3) respectively.

Switching devices= 2(k-1) (i)

Clamping diodes = (k-1)(k-2) (ii)

DC link capacitor = (k-1)………………..(iii)

Results and Discussion

In this paper performance of integration of wind power plant with power system has been analyzed by using MATLAB (2016)(b).

(i) Simulation Results (without fault)

Proposed system with DVR controller is simulated fig.5 shows waveform for supply voltages, wind voltage, and DVR voltage without fault conditions.

When there is no fault occurs at the bus , load voltage is same and there is no voltage sag occurs at the bus. Waveforms of Supply voltage and load voltage are as shown in figure 5. In this case DVR will be deactivated.

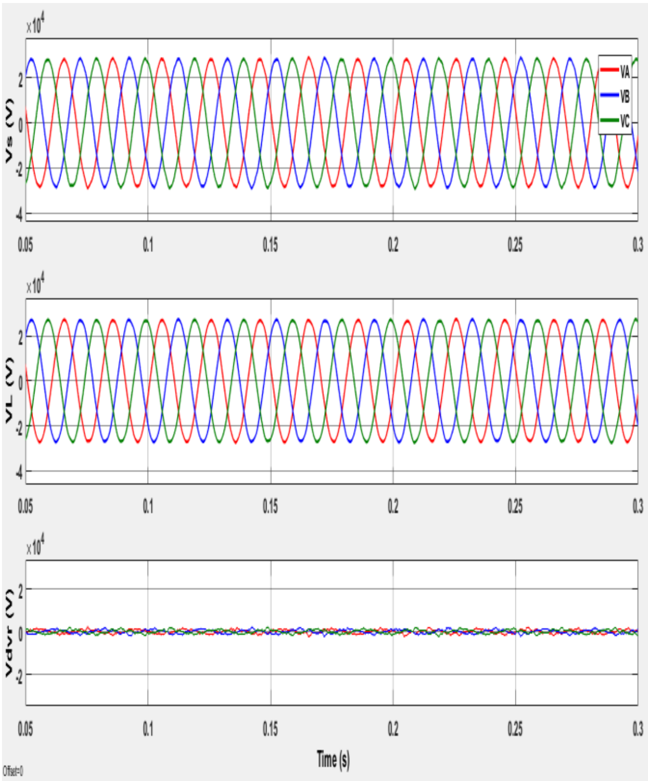

Figure.5. Simulation results of the designed system when no fault occurs on bus (22kv)

ii) Simulation Results (when three phase fault injected)

In case of three phase occurs for a time from t=0.15 to o.2s at bus which causes the voltage sag as shown in fig.6. These voltages are compensated by using DVR

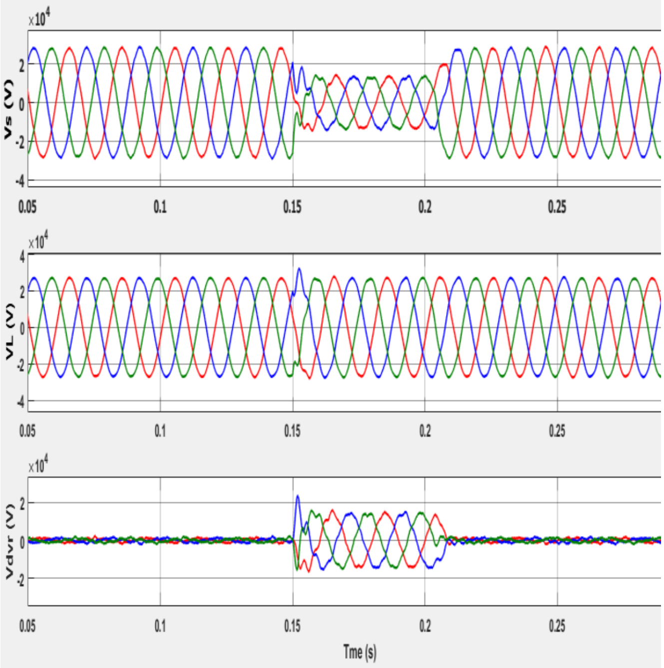

Figure.6. Simulation results of the designed system when three fault occurs on bus (22kv)

(iii) Simulation Results (when double line fault injected)

In case double line fault occurs for a time from t=0.15 to o.2s at bus which causes the voltage sag as shown in fig.7. These voltages are compensated by using DVR.

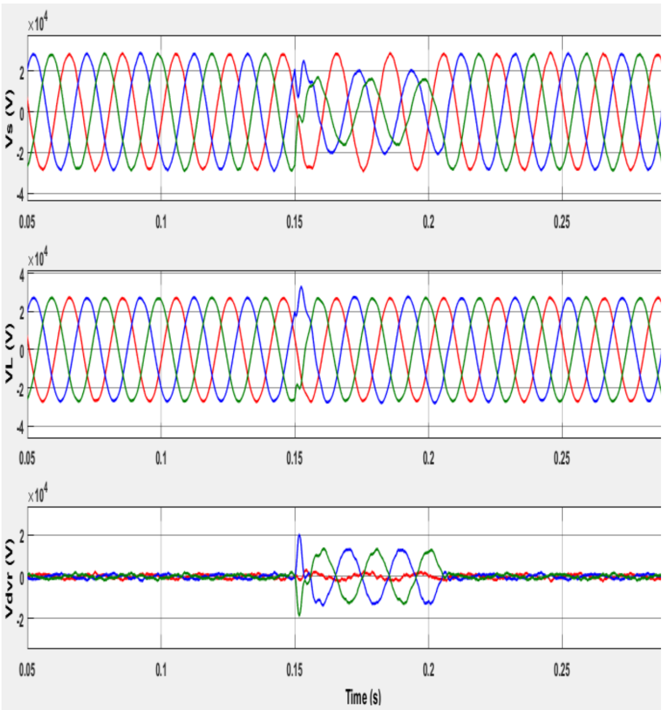

Figure.7. Simulation results of the designed system when double line fault occurs on bus (22kv)

(iv)Simulation Results (when line to ground fault injected)

Similarly line to ground fault occurs for a time from t=0.15 to o.2s at bus which causes the voltage sag as shown in fig.8. These voltages are compensated by using DVR.

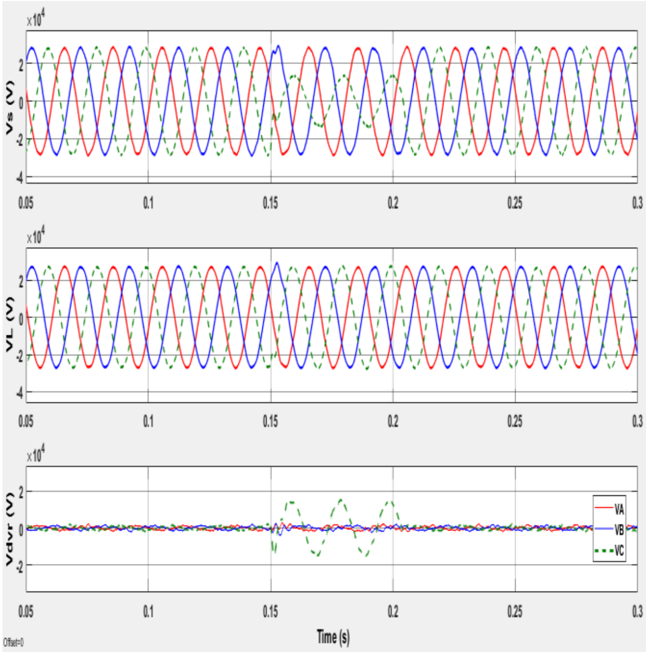

Figure.8. Simulation results of the designed system when line to ground fault occurs on bus (22kv)

5. Conclusion

In this research work DVR is used as controller which improves the power quality issue that is voltage sag in the case of any type of fault . this protects the power system during integration of wind turbine with power system. In this paper, wind integration with power system using DVR is analyzed through simulation using MATLAB/Simulink@ 2016(b). Different fault conditions can be regulated by using dynamic voltage regulator (DVR) through 3 level multilevel inverter.

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