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Voltage Restoration Capability of Grid Tied DFIG System under Various Operating Conditions

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Abstract: DFIG is a very flexible wind energy conversion system which employs power electronic interface to control the rotor currents in a way to achieve the variable speed stable operation. In this paper Performance analysis of Grid Connected DFIG based wind energy system is presented. The simulation model in Matlab Simulink has been developed. The system has been studied for various operating condition. The pre-Fault and post-Fault condition of DFIG are examined depending upon which, a grid side converter (GSC) control topology has been proposed to restore system voltage when the system under-going faults.
The focus of the research is to develop the voltage restoration capability of the DFIG with the help of three level inverter and active filter to mitigate harmonic.

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I. INTRODUCTION

There has been a groom in technological development of grid integration of renewable resources (RR). The two main causes for sudden increase of grid integration of RR, first scarcity in availability of conventional resources and another is that non-conventional resources are clean and green form of energy. The expanding weight on the need to heighten the support of cleaner types of energy to blend with the existing transformation frameworks, especially wind, small hydro and solar energy.

The utilization of sustainable power source innovations, both substantial and small scale, is to a great extent reliant on the geology in the territory of use. To rearrange improvement, the undertaking is coordinated towards a little scale execution. Normally this will include a provincial property or way of life piece, where the land proprietor approaches a wellspring of streaming water, and consistent breeze. In light of a normal family unit control utilization of 8000 kWh every year, this framework will mean to produce around 1 kW on average. Small scale sustainable power source applications are naturally particular to the site they are executed on. This makes it extremely hard to research and outline a framework that can be by and large connected. Thus a reasonable site has to be chosen.

Places close-by any running stream or waterway can satisfy a piece of electricity prerequisite from the energy of the running water speed. Other sustainable powers sources for the most part introduce at such areas are sun based and wind energies. The determinations of generators, integrated system topology and control calculation are the real issues while utilizing these sustainable power sources. A generous writing is accessible portraying techniques as how to sustain these secluded burdens from the sustainable power sources. These incorporate extraordinary topologies, different generators and control calculations to supply the stacks according to their voltage and recurrence prerequisites. There is a heft of writing accessible on various sorts of generators for different applications, fluctuating microgrid topologies, and assortment of controllers is accounted for in [1, 2]. In these endeavors, significant hypothetical foundation is given on various sorts of generators. A generator might be chosen for a specific application taking a gander at the appropriateness in that application. Also, there are numerous kinds of converters revealed in the writing [2], yet the choice must be made prudently. Also, a few authors [3] have portrayed about the distinctive kinds of sustainable power sources and their operational perspectives in grid associated and off grid mode.

Other than the above mentioned sustainable sources, there is another popular wind energy generation system which Doubly Fed Induction Generation (DFIG). The favorable causes of the DFIG are the higher vitality yield, lower converter rating and better use of generators [8]. These DFIGs additionally give great damping execution to the powerless framework [9]. Free control of dynamic and receptive power is accomplished by the decoupled vector control calculation exhibited in [10-11]. This vector control of such framework is as a rule acknowledged in synchronously pivoting reference outline situated in either voltage hub or transition hub. In this work, the control of Rotor Side Converter (RSC) is actualized in voltage arranged reference outline.

The research objective is to develop GSC control for harmonic improvement generated by various load patters especially nonlinear load. RSC is utilized for controlling the receptive energy of DFIG. The other fundamental favorable position of proposed DFIG is that it functions as a dynamic channel notwithstanding when the wind turbine is in shut down phase. So it adjusts stack receptive power and adjusts wind turbine speed. The simulation model in MATLAB is developed and the dynamic performance of proposed DFIG is also demonstrated for varying wind speeds and variable nonlinear loads at PCC (Point of Common Coupling).

- Using an indirect current control, a new control algorithm for Grid Side Converter (GSC) is proposed for compensating harmonics produced by unbalanced system.
- The other advantage GSC is, it not only synchronized the system with the grid but also helps to retain system voltage stability and frequency stability at the time of fault or unbalanced loading.
- The proposed converter work on voltage oriented reference frame.
- The converter designed is a direct current control type; whereas the base paper uses indirect current control type topology.

II. DOUBLY FED INDUCTION GENERATION (DFIG)

DFIG units are becoming popular for large penetration of WPGS units and their grid integration stability aspects. The technological development of the doubly fed induction machine had made it possible to achieve more stable operation on variable speeds as compared to squirrel cage generators. DFIG has the gigantic potential for modern Wind Turbine topology. With the appearance of DFIG wind turbines having 3 MW rating are for the most part created and built to give high proficiency and execution alongside minimal effort support as cutting edge wind turbines [4], [5]. The AC-AC converter in DFIGs was utilized traditionally as a standard drive for high power and restricted speed go. These power converters just handle the rotor control. New headways in control electronic converter hardware are very much clarified in [6]. In the previous couple of decades, with the ceaseless improvement and commitment of scientists and configuration builds over the globe to enhance the power framework dependability what's more, monetary issues related with wind turbines in view of DFIG make their convenience in a substantial degree. A lot of compensation strategies for one DFIG unit are available in literature [4]–[6]. But very few control topologies for multiple DFIG units has been reported. Moreover these strategies are too rigid to be applied in a multiple DFIGs, since neither the sharing nor the compensation for multiple units of DFIGs, was adjustable. Actually, the two normal control targets, i.e., the task execution of a DFIG framework itself and the power quality at PCC, are innately conflicted, which implies the need of these two targets ought to better be movable as indicated by the down to earth circumstance. For example, the DFIG with high load should share less pay exertion, and the aggregate remuneration exertion of the entire breeze ranch ought to likewise be decreased when the breeze is solid. In this manner, it may profit both the breeze cultivate and the network to adaptably control the voltage unbalance factor (VUF) at PCC; the tradeoff can be accomplished between the DFIG task execution and the PCC control quality.

Due to the ability of DFIG to operate in a variable wind speed conditions, its application as a wind power generation system is increasing day by day. The DFIG's principle of working as an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. The basic construction principle comprises of rotor mounted on a shafted connected to the generator through the gear box as shown in Figure-1. As mentioned earlier, DFIG is fed from two ends, one end of the generator is connected to the grid and another end is to the two back to back voltage source converters (VSC). The VSC is designed using three phase 2 level universal bridge with three arms. Both the inverters are linked with Dc link capacitor to stop circulation of leakage current and proper matching of inverters. At both the ends of converter filters are connected whose parameters are mentioned in Table 3.2. Generator has two windings; one winding is directly connected to the output, and produces 3-phase AC power at the desired grid frequency. At variable frequency, the winding is connected to 3-phase AC power. This input power is adjusted in phase and frequency compensating for changes in speed of the turbine.

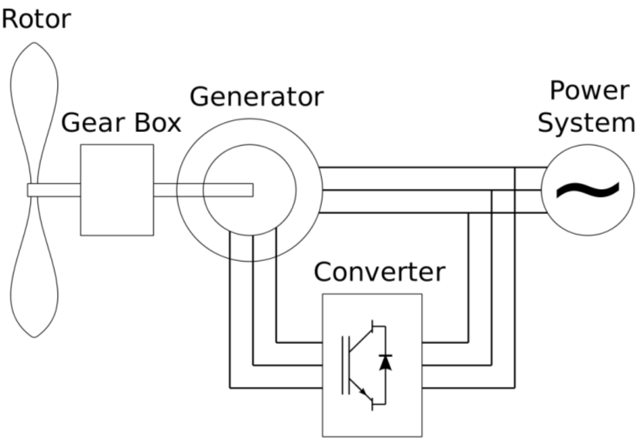

Figure-1 Principle of a Double Fed Induction Generator connected to a wind turbine

III. PROPOSED WORK

Firstly, DFIG has been modelled using Synchronous Reference Frame, so that fundamental component of voltage current can be easily extracted. Synchronous Reference Frame is achieved by applying Phase Lock Loop control using feed forward current control. The scope of the research is to synchronize the DFIG with Grid and to restore voltage stability when sudden fault is applied. The THD analysis has been done and the THD at PCC and GSC is 3.6 and 0.02 respectively which is far 4.8 and 0.3 in base paper.

Figure-2 shows a schematic diagram of proposed DFIG based WECS with Voltage stability restoration capabilities. Two back to back connected Voltage Source Converters (VSCs) are placed between the rotor and the grid. The Two converters are linked with Dc link Voltage. The system is operated for four cases and the Proposed GSC is Capable of restoring System voltage at various operating condition.

1. At constant wind Speed.
2. At variable Speed
3. When sudden fault apply
4. When working as voltage stability controller as STATCOM.

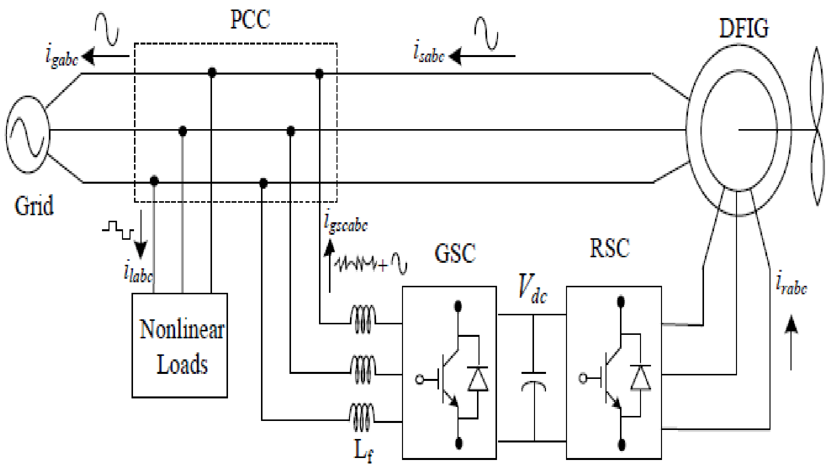

Figure-2 Circuit model for control strategy of DFIG

IV. SIMULATION AND RESULT DISCUSSION

The system is modeled in such a manner that in addition of supplying active power to the grid it also behaves as active filter to rule out harmonic distortion in the output waveforms. The stator of the DFIG is grid connected and in between rotor and grid two VSCs are placed back to back. These VSCs are interlinked with Dc link capacitors. The point where grid, converter and DFIG meet is known as Point of Common Coupling (PCC). At PCC non-linear loads are connected to study the performance of DFIG. Also efficiency of DFIG under faulty condition is also analyzed. Synchronous reference frame (SRF) control method is used for extracting the fundamental component of load currents for the GSC control.

The rated capacity of the proposed wind turbine is 9 MW. Table-1 shows the component and rating used in the proposed topology.

Table-1 Component and rating used in the proposed topology.

Components	Ratings
DFIG	9 MW
Bus (Three phase Voltage and current measurement	10 MW
Three phase transformer	10.5 MVA
Transmission Line	30 Km
Mutual inductance three phase	0.96mH
Three phase programmable Voltage source	230 V
Grounding Transformer	100 MVA

The system is operated for four cases and the Proposed GSC is Capable of restoring System voltage at various operating condition.

1. At constant speed without grid side and rotor side control.
2. At variable speed without grid side and rotor side control.
3. At constant speed with grid side and rotor side control.
4. At variable speed with grid side and rotor side control.

- **At constant wind Speed without and with grid side and rotor side control:** System is analysed for constant wind speed of 5m/s without and with grid side and rotor side control. The result for grid side, converter side and at PCC is shown in Figure 3, 4.

Figure 3 Output waveform at constant speed without GSC and RSC, grid side.

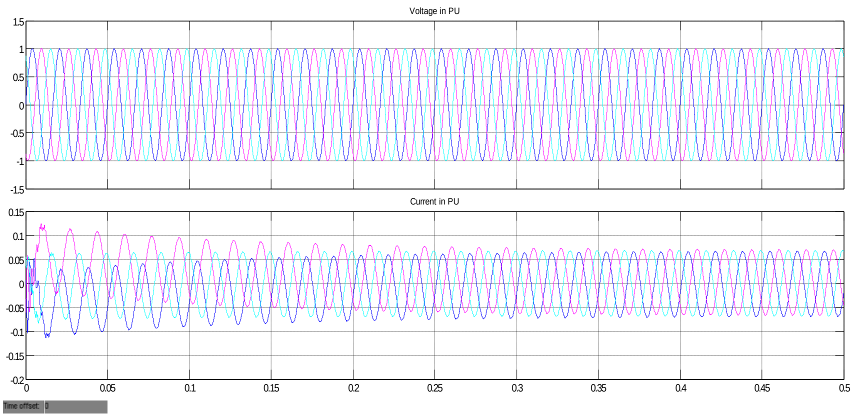

Figure 4 Output waveform at constant speed with GSC and RSC, grid side.

- **At variable wind Speed without grid side and rotor side control:**

Here performance of the grid connected system without GSC and RSC with a static series three phase loading is tested. The output waveform grid side and converter side are shown in Figure 5 and 6.From the output waveforms it is clear that a GSC and RSC with proper control topology need to be design for a successful operation of DFIG in grid connected mode. In the proposed work an inverter topology has been design which is able to synchronize the DFIG with the grid. System performance in the subsequent headings with GSC and RSC are presented for various modes of operation.

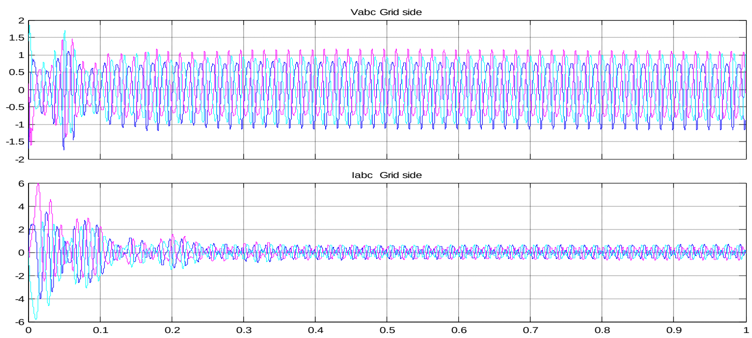

Figure 5 Output waveform at variable speed without GSC and RSC grid side.

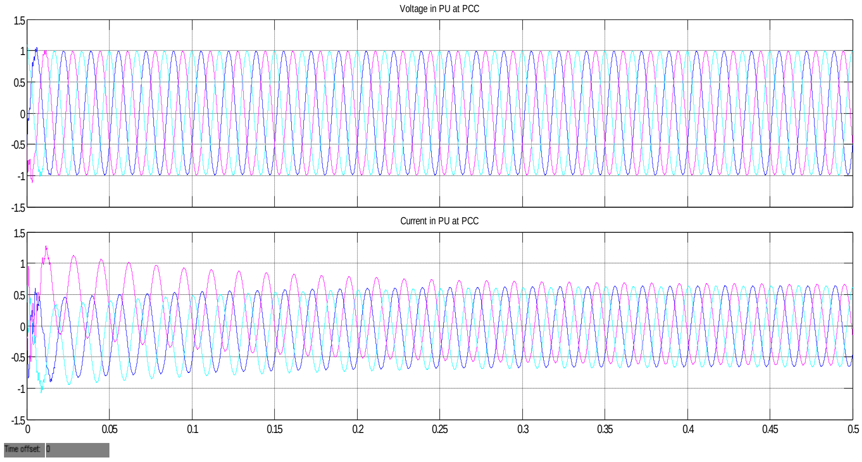

Figure 6. Output waveform at variable speed with GSC and RSC grid side.

At all operating conditions the common thing is that initially DFIG takes time to stabilize its operation. Voltage takes 3-5 cycles of fundamental waveforms and current takes tens of cycles. In this section comparative results with the base paper are presented.

For voltage restored state he value of stator side and grid side voltage current harmonic are compared. In base paper harmonic voltage and current percentage is 0.38 % and 4.51% respectively. Whereas it is 0.02 % and 0.9 % respectively in the proposed work. At stator side load current THD in the proposed topology it is 0.63%.

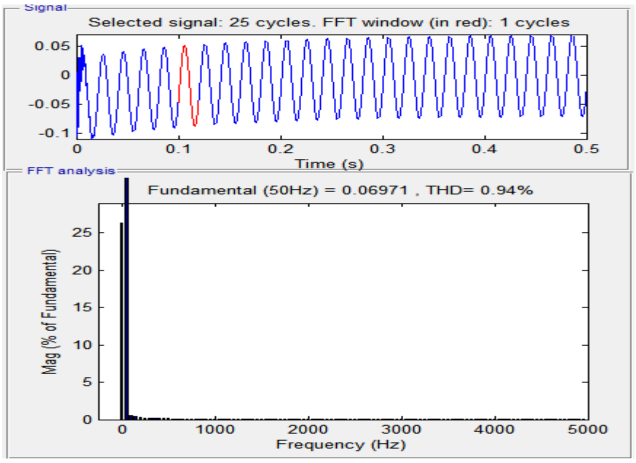

Figure-7 THD at PCC of proposed topology for Grid current

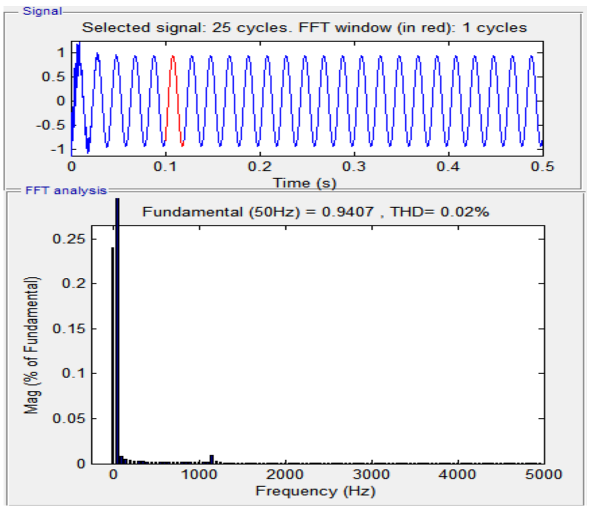

Figure-8 THD at PCC of Proposed topology for grid voltage

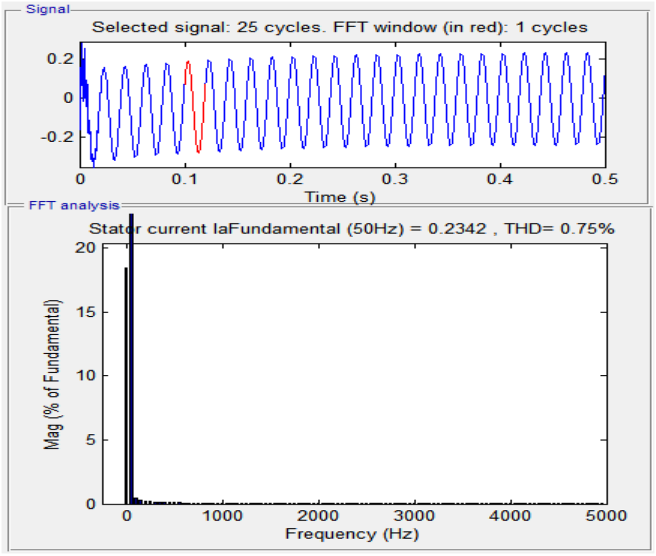

Figure-9 THD of proposed work for Stator current

V. CONCLUSION

The performance of DFIG has been studied for the constant speed and variable speed condition.Depending upon the gird connected characteristic of DFIG, a grid side converter (GSC) control topology has been proposed to restore system voltage when the system undergoing changes in speed and loading condition.

The main idea of the research is that when DFIG is connected to grid it also behaves as a Static Compensator hence suitable for voltage stability restoration in the condition of sudden load change. For the proposed DFIG system the VSC is designed in such a manner that it restores Grid voltage under all operating condition discussed in the work.

The THD for the system is 0.02% for grid voltage, for stator current 0.63% and at PCC is 0.4%, 0.63 and 0.9%. Hence the proposed GSC with active filter capabilities is better in the proposed work.

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