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Wind Energy Conversion Systems using DFIG with Integrated Active Filter Capabilities

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Abstract— **Doubly Fed Induction Generator for Wind Energy Conversion Systems manages the operation of doubly nourished acceptance generator with an incorporated dynamic channel capacities utilizing network side converter (GSC). The principle commitment of this work lies in the control of GSC for providing sounds notwithstanding its slip control exchange. The rotor-side converter (RSC) is utilized for accomplishing most extreme power extraction and to supply required responsive energy to DFIG. Wind vitality change framework (WECS) functions as a static compensator (STATCOM) for providing music notwithstanding when the wind turbine is in shutdown condition. Control calculations of both GSC and RSC are introduced in detail. Actualized extend DFIG-based WECS is reproduced utilizing MATLAB/Simulink . A model of the proposed DFIG based WECS is produced utilizing a fluffy logic controller. The wind vitality is the favored for all renewable vitality sources. In the underlying days, wind turbines have been utilized as settled speed twist turbines with squirrel confine acceptance generator and capacitor banks. The majority of the wind turbines are settled speed as a result of their straightforwardness and minimal effort.**

Index Terms— **Doubly fed induction generator (DFIG),integrated active filter, nonlinear load, power quality, wind energy conversion system (WECS),Fuzzy logic controller(FLC).**

I. INTRODUCTION

The increase in population and industrialization, the energy demand has increased significantly. The conventional energy sources such as coal, oil, and gas are limited in nature. There is a need for renewable energy sources for the future energy demand. The other main advantages of this renewable source are eco-friendliness and unlimited in nature. Due to technical advancements, the cost of the wind power produced is comparable to that of conventional power plants. Therefore, the wind energy is the most preferred out of all renewable energy sources. In the initial days, wind turbines have been used as fixed speed wind turbines with squirrel cage induction generator and capacitor banks. Most of the wind turbines are fixed speed because of their simplicity and low cost. By observing and implementing wind turbine characteristics, one can clearly identify that for extracting maximum power, the machine should run at varying rotor speeds at different wind speeds. An implemented modern power electronic converter, the machine is able to run at adjustable speeds. These variable speed wind turbines are able to improve the wind energy production. Out of all factor speed wind turbines, doubly encouraged acceptance generators (DFIGs) are favored in light of their ease. The upsides of this DFIG are the higher vitality yield, bring down converter rating, and better use of generators.

These DFIGs additionally give great damping execution to the frail matrix. Autonomous control of dynamic and receptive power is accomplished by the decoupled vector control calculation. This vector control of such framework is generally acknowledged in synchronously turning reference outline arranged in either voltage pivot or flux hub. In this work, the control of rotor-side converter (RSC) is executed in voltage-situated reference outline. Reaction of DFIG-based wind vitality transformation framework (WECS) to matrix aggravation is contrasted with the settled speed WECS. Created control smoothening is accomplished by executing super attractive vitality stockpiling frameworks. The other helper administrations, for example, receptive power necessity and transient solidness point of confinement are accomplished by including static compensator (STATCOM).A circulation STATCOM (DSTATCOM) combined with fly-wheel vitality stockpiling framework is utilized at the twist cultivate for alleviating sounds and recurrence unsettling influences. A super capacitor vitality stockpiling framework at the dc connection of brought together power quality conditioner (UPQC). improving power quality and unwavering quality. The sounds pay and responsive power control are accomplished with the assistance of existing RSC. A roundabout current control method is basic and shows better execution for taking out music when contrasted with direct current control. The Harmonics are infused from the RSC into the rotor windings. This makes misfortunes and commotion in the machine. In this work, another control calculation for GSC is proposed for remunerating music created by nonlinear burdens utilizing an aberrant current control. RSC is utilized for controlling the responsive force of DFIG. The other fundamental favorable position of proposed DFIG is that it fills in as a dynamic channel notwithstanding when the wind turbine is in shutdown condition. In this manner, it remunerates stack receptive power and sounds at wind turbine slowing down case. Reproduction exhibitions of the proposed coordinated dynamic channel based DFIG with fluffy rationale controller is displayed in this work to alleviate the aggregate symphonious bending in the rotor side and matrix side converter. The dynamic execution of the proposed DFIG is additionally shown for shifting wind speeds and changes in uneven nonlinear burdens at purpose of basic coupling (PCC).

II. System Configuration and Operating Principle

Fig. 1 demonstrates a schematic outline of the proposed DFIG based WECS with incorporated dynamic channel abilities. In DFIG ,the stator is straightforwardly associated with the matrix as appeared in Fig. 1. Two consecutive associated voltage source converters (VSCs) are put between the rotor and the matrix. Nonlinear burdens are associated at PCC as appeared in Fig. 1. The proposed DFIG fills in as a dynamic channel notwithstanding the dynamic power era like ordinary DFIG. Sounds produced by the nonlinear load associated at the PCC bend the PCC voltage. These nonlinear load symphonious streams are moderated by GSC control, so that the stator and lattice ebbs and flows are without consonant. RSC is controlled for accomplishing most extreme power point following (MPPT) furthermore to make solidarity control figure at the stator side utilizing voltage-arranged reference outline. Synchronous reference outline (SRF) control technique is utilized for separating the basic segment of load streams for the GSC control.

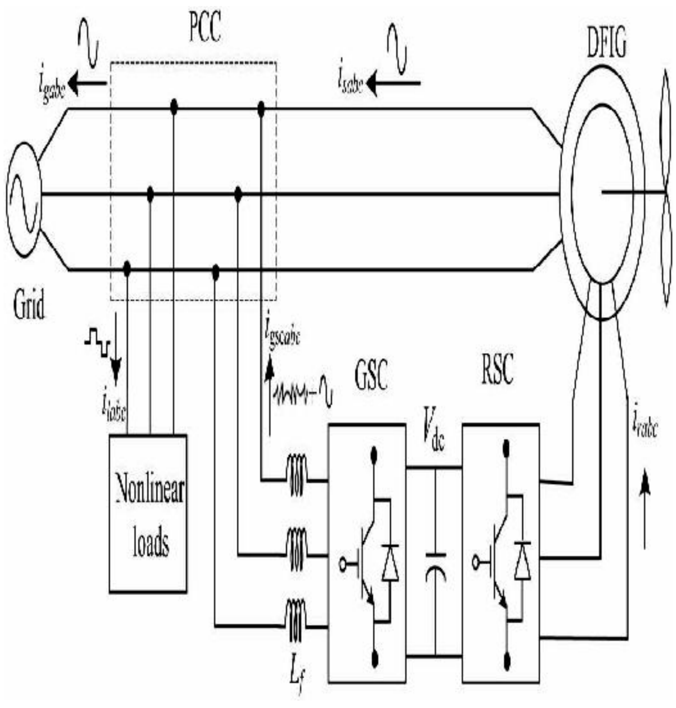


Fig 1. Proposed system configuration.

III. Design of DFIG-Based WECS

Choice of evaluations of VSCs and dc-connect voltage is especially essential for the fruitful operation of WECS. The evaluations of DFIG and dc machine utilized as a part of this test framework are given in Appendix. In this segment, an itemized outline of VSCs also, dc-connect voltage is examined for the trial framework utilized as a part of the research center. Ordinarily, the dc-connect voltage of VSC must be more noteworthy than double the pinnacle of most extreme stage voltage. The choice of dc connection voltage relies on upon both rotor voltage and PCC voltage. While considering from the rotor side, the rotor voltage is slip times the stator voltage. DFIG utilized as a part of this model has stator to rotor turns proportion as 2:1. Regularly, the DFIG working slip is ±0.3. In this way, the rotor voltage is constantly not exactly the PCC voltage. In this way, the plan criteria for the choice of dc-connection voltage can be accomplished by considering just PCC voltage. While considering from the GSC side, the PCC line voltage (vab) is 230 V, as the machine is associated in delta mode. The rating of VSC and coupled inductor rating was computed in the paper(1)

IV. CONTROL STRATEGY

Control calculations for both GSC and RSC are exhibited in this segment. Finish control schematic is given in Fig. 2.

The control calculation for copying wind turbine attributes utilizing dc machine and Type A chopper is additionally appeared in Fig. 2.The primary reason for RSC is to concentrate most extreme power with autonomous control of dynamic and responsive forces. Here, the RSC is controlled in voltage-situated reference outline. Accordingly, the dynamic and responsive forces are controlled by controlling direct and quadrature pivot rotor streams (idr and iqr), individually. Coordinate pivot reference rotor current is chosen with the end goal that most extreme power is extricated for a specific wind speed. This can be accomplished by running the DFIG at a rotor speed for a specific wind speed. Along these lines, the external circle is chosen as a speed controller for accomplishing direct pivot reference rotor current.SRF hypothesis created in this paper to repay streams and voltage conditions as immediate and quadrature hub for framework side and rotor side converter.

V. FUZZY LOGIC CONTROL

FLC dictated by the arrangement of etymological guidelines. The scientific demonstrating is not required in fluffy controller because of the transformation of numerical variable into etymological factors. FLC comprises of three section: a. Fuzzification, b. Obstruction motor, c. Defuzzification. The fluffy controller is portrayed as; For every information and yield there are seven fluffy sets. For effortlessness a participation capacities is Triangular. Fuzzification is utilizing ceaseless universe of talk. Suggestion is utilizing Mamdani's "min" administrator. Defuzzification is utilizing the "tallness" technique. FLC square outline as appeared in figure 3.

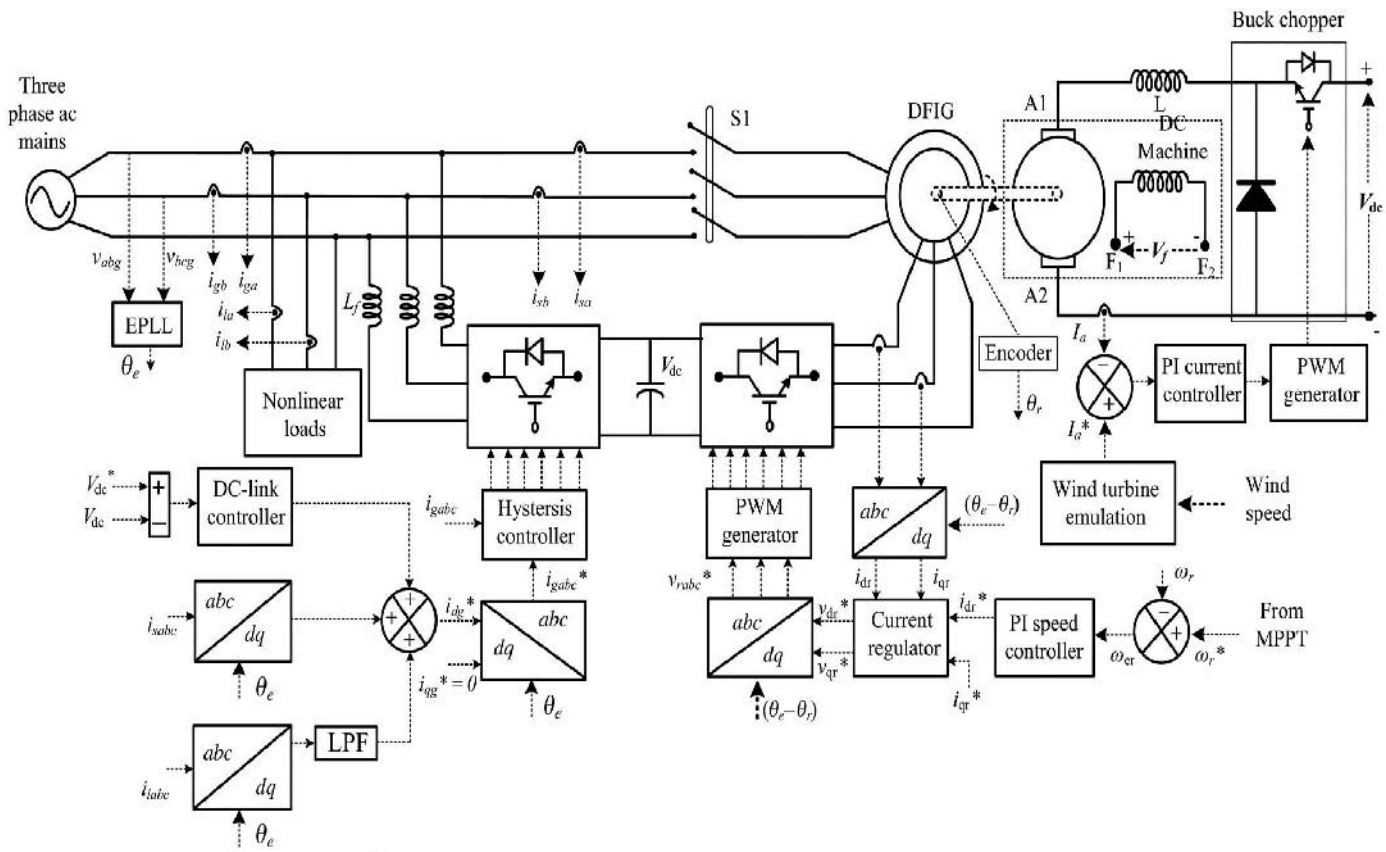


Fig. 2. Control algorithm of the proposed WECS.

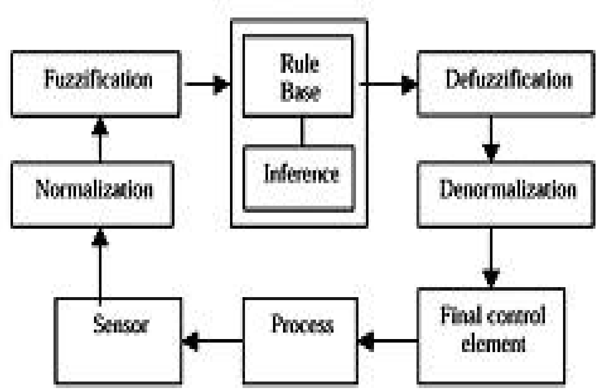


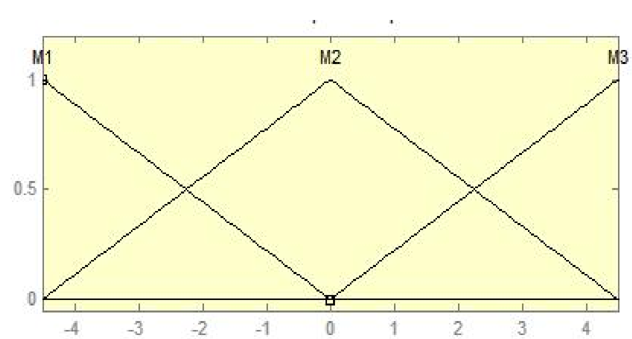
Fig. 3. Fuzzy Logic Controller

a. Fuzzification

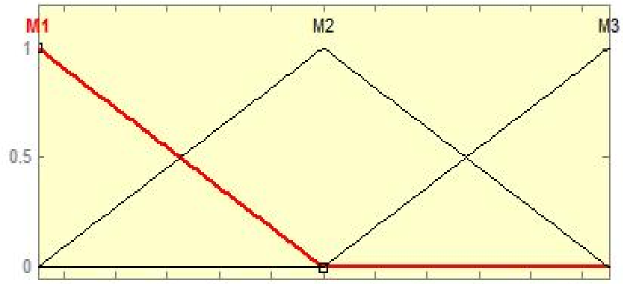
Participation work qualities are doled out to the phonetic factors, utilizing seven fluffy subsets: NB(Negative Big), NM(Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small),PM(Positive Medium) and PB (Positive Big). The parcel of fluffy subsets and the state of participation capacity adjust the take care of business to proper framework. Input mistake E(k) and change in blunder CE(k) of qualities which is standardized by an info scaling element as appeared in table 1.

In this system the input scaling factor is between -1 and +1 has design. The triangular shape of the membership function of this arrangement presumes that for any particular input there is only one dominant fuzzy subset . The input error E(k) and change in error C(k) for the FLC is given as

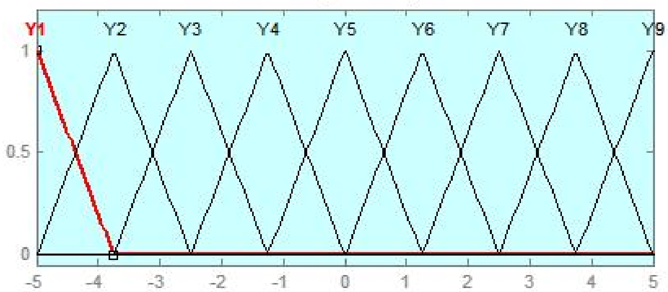
ཀ= ཀ−(−1)



Input(a)



Input(b)



. Ouput(c)

Fig. 4.(a)(b)(c) Membership functions

b. Inference Method

Several composition methods such as Max-Min and Max-Dot have been proposed and Min method is used. Minimum operator and Maximum operator of output membership function is of each rule and it is shown in Table 1.

c. Defuzzification

As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, "height" method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of Fuzzy controller are: error, change in error and output as shown in Figs.(3), (4). In the present work, for fuzzification, non uniform fuzzifier has been used. If the exact values of error and change in error are small or large, they are divided conversely. The α is self-adjustable factor and to regulate operation. E is the error of the system, C is the change in error and u is the control variable. If the system is not in balanced it indicates an error 'E' if the value is large. While the error 'E' value is small it indicates that the system is near to balanced state. If system is unbalanced, the control variables should be enlarge to balance the system as early as possible. For system stability overshoot plays an important role. For restraining oscillations and system stability it requires less overshoot. 'C' plays an important role, while the role of 'E' is diminished. The optimization is done by α.

VI.SIMULINK BLOCK DIAGRAM AND RESULTS

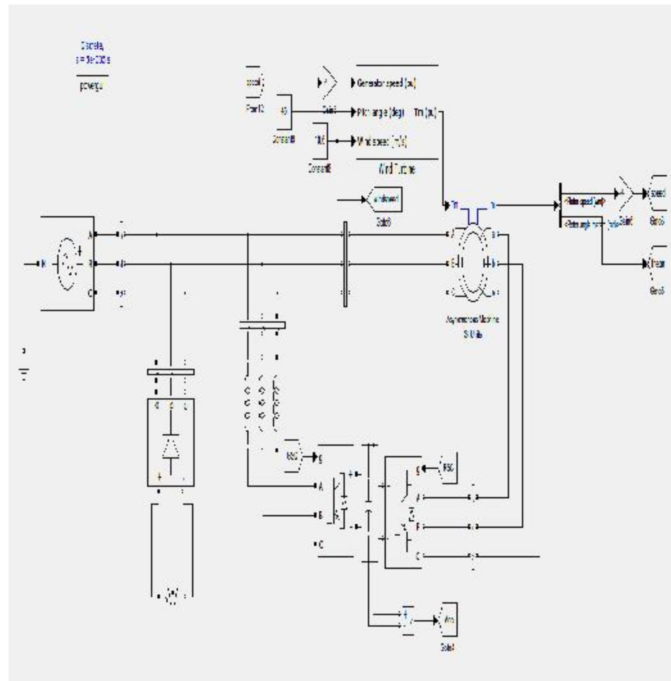


FIG 5.1 Block diagram of proposed DFIG-based WECS at fixed wind speed of 10.6 m/s (rotor speed of 1750 rpm).

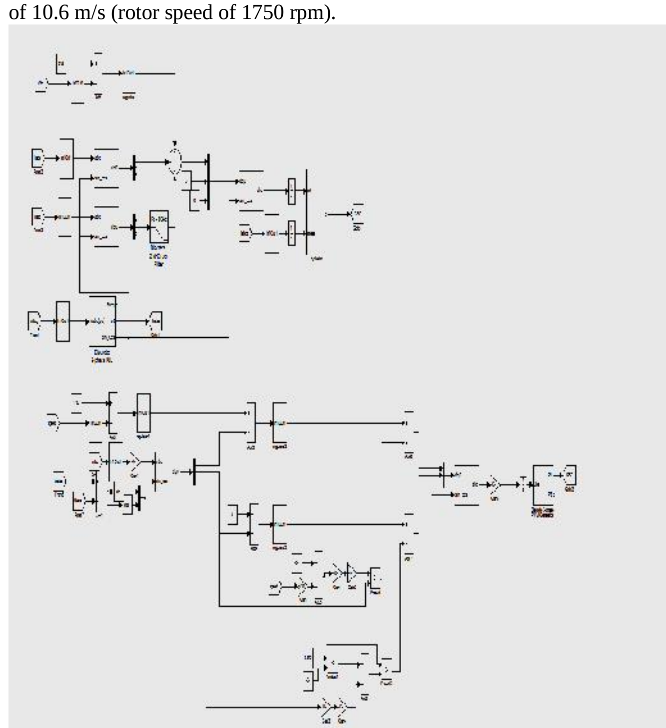


FIG 5.2 CONTROL BLOCK DIAGRAM

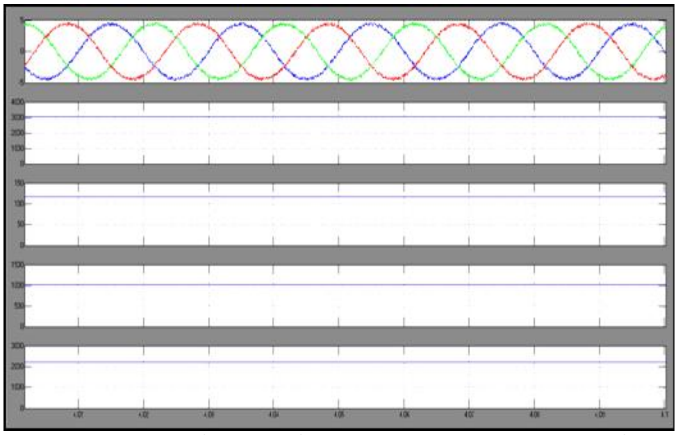


Fig. 5.3. Simulated performance of the proposed DFIG-based WECS at fixed wind speed of 10.6 m/s (rotor speed of 1750 rpm).

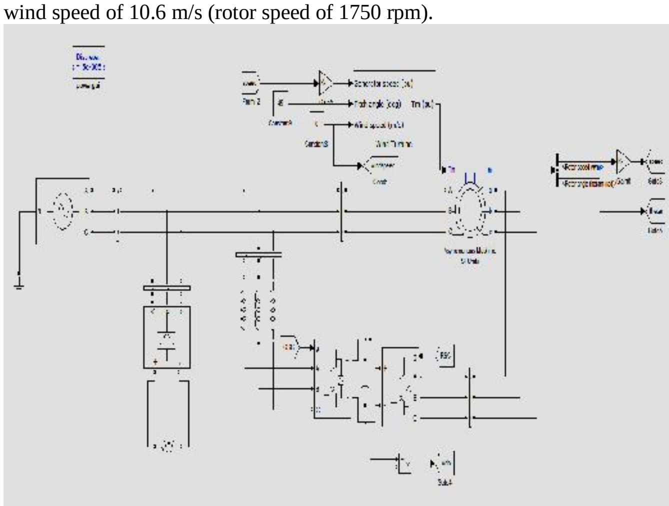
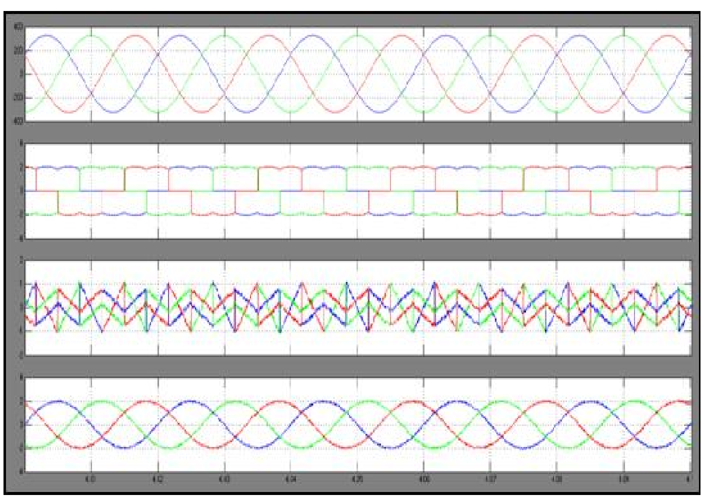


FIG 5.4 MAIN BLOCK DIAGRAM OF proposed DFIG-based WECS working as a STATCOM at zero wind speed.



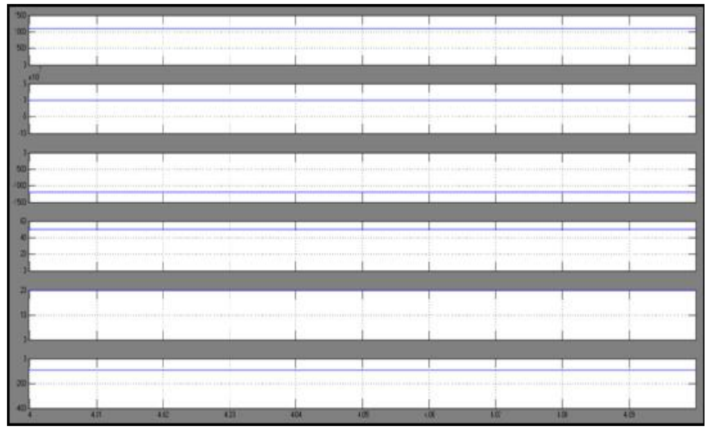


Fig.5.5 Simulated performance of the proposed DFIG-based WECS working as a STATCOM at zero wind speed.

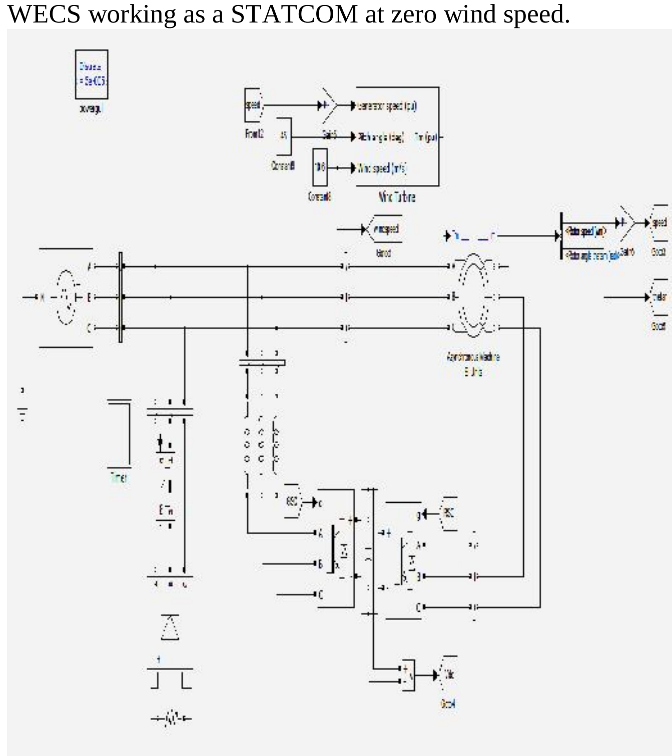


Fig. 5.6 Dynamic performance of DFIG-based WECS for the sudden removal and application of local loads.

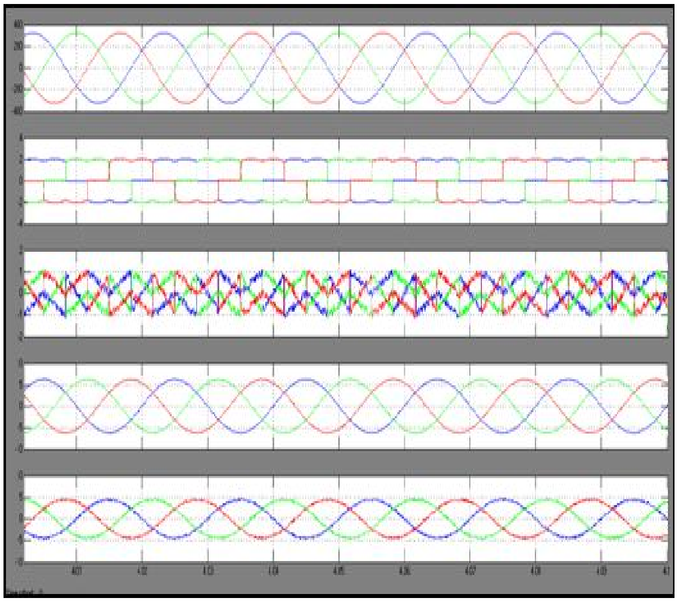


Fig. 5.7 Dynamic performance of DFIG-based WECS for the sudden removal and application of local loads.

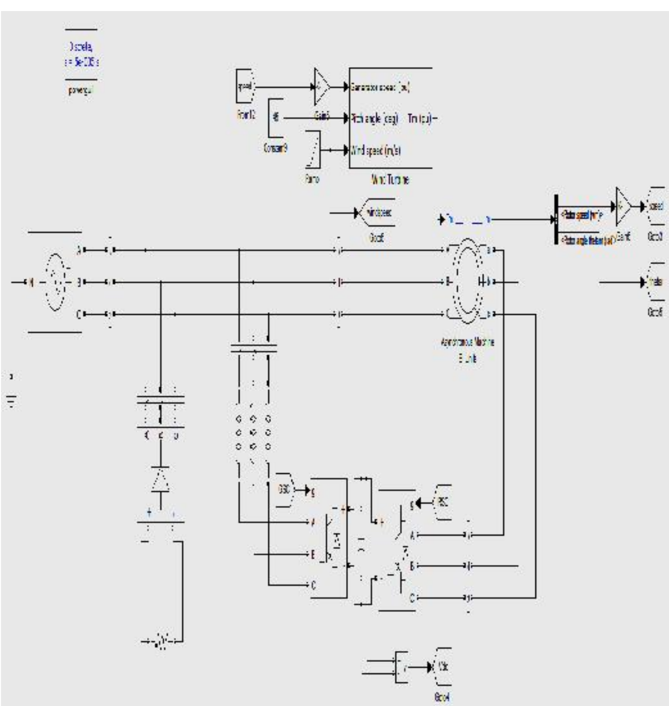
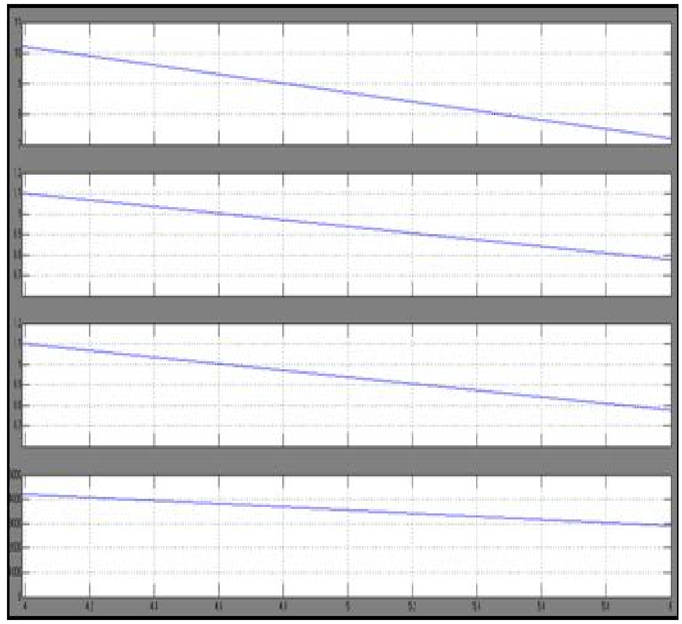


FIG 5.8 Block diagram of proposed DFIG for fall in wind speed



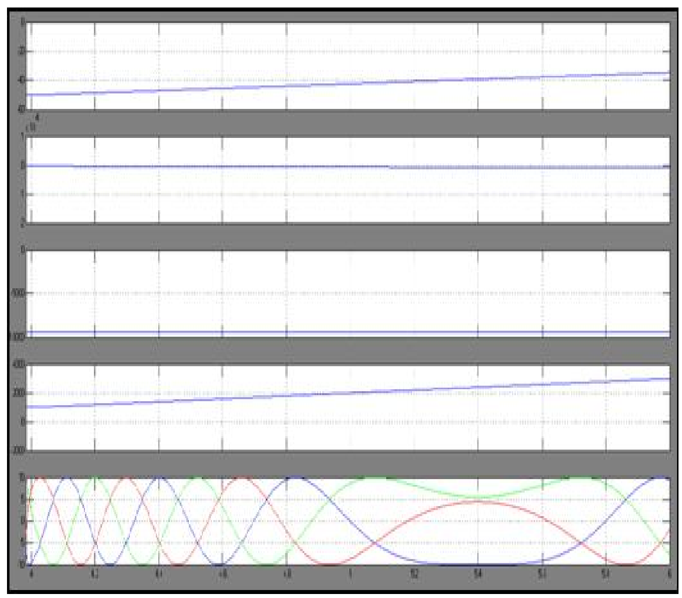


Fig5.9 Simulated performance of proposed DFIG for fall in wind speed.

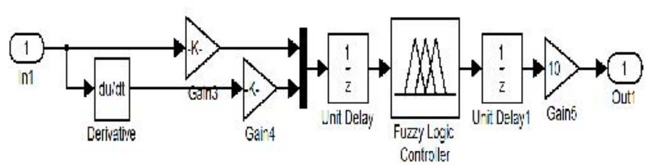


Fig5.10 Block diagram of Fuzzy logic controller

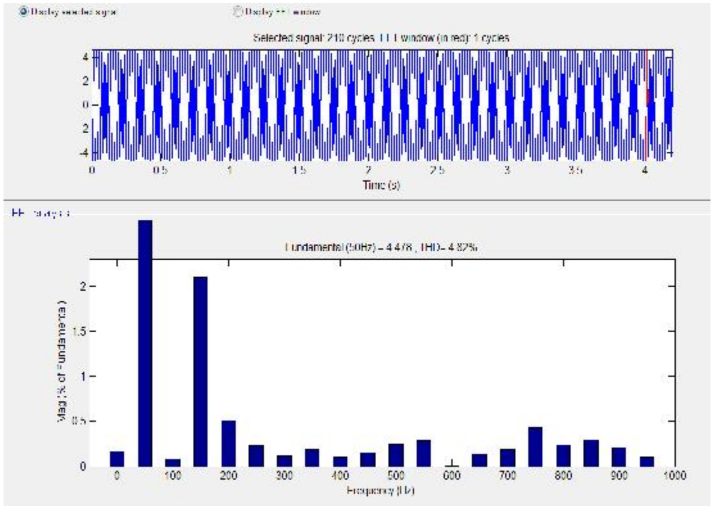


FIG 5.11 TOTAL HARMONIC DISTORTION OF GRID CURRENT

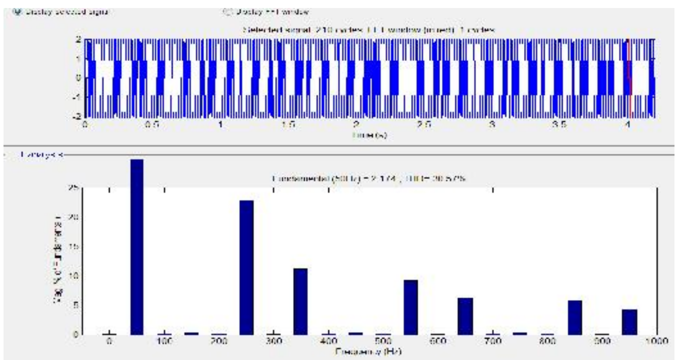


FIG5.12 TOTAL HARMONIC DISTORTION OF LOAD CURRENT

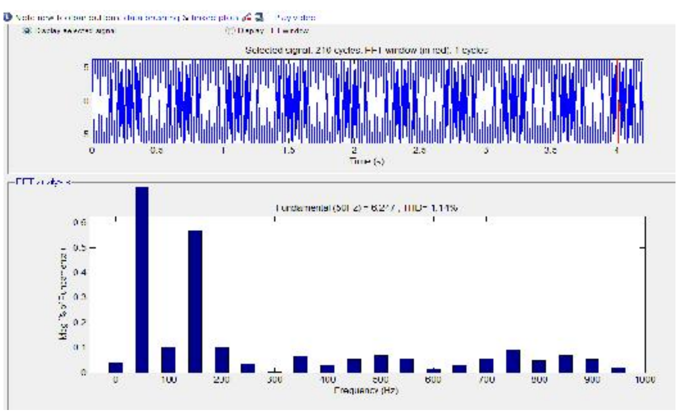


FIG 5.13 TOTAL HARMONIC DISTORTION OF SOURCE CURRENT

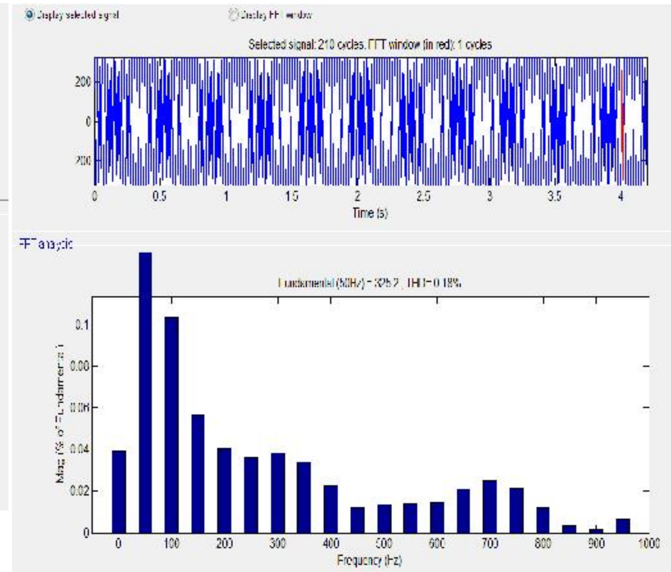


FIG 5.14 TOTAL HARMONIC DISTORTION OF SOURCE VOLTAGE

VI. Conclusion

The GSC control algorithm of the proposed DFIG has been modified for supplying the harmonics and reactive power of the local loads. In this proposed DFIG, the reactive power for the induction machine has been supplied from the RSC and the load reactive power has been supplied from the GSC. The decoupled control of both active and reactive powers has been achieved by RSC control. The proposed DFIG has also been verified at wind turbine stalling condition for compensating harmonics and reactive power of local loads. This proposed DFIG-based WECS with an integrated active filter has been simulated using MATLAB/Simulink environment, and the simulated results are verified with test results of the developed prototype of this WECS. Fuzzy controller is replaced by PI controller for the harmonic reduction of GSC and RSC controller. Steady-state performance of the proposed DFIG has been demonstrated for a wind speed. Dynamic performance of this proposed GSC control algorithm has also been verified for the variation in the wind speeds and for local nonlinear load.

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