



Doubly Fed Induction Generator Based Wind Energy Conversion Systems

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Abstract— Doubly Fed Induction Generator for Wind Energy Conversion Systems manages the operation of doubly fed induction generator (DFIG) with an incorporated dynamic channel abilities utilizing lattice side converter (GSC). The fundamental commitment of this work lies in the control of GSC for providing music notwithstanding its slip control exchange. The rotor-side converter (RSC) is utilized for achieving greatest power extraction and to supply required responsive energy to DFIG. Wind vitality transformation framework (WECS) fills in 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 exhibited in detail. Executed venture DFIG-based WECS is reproduced utilizing MATLAB/Simulink . A model of the proposed DFIG based WECS is produced utilizing a fluffy rationale 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 in view of their effortlessness 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 expansion in populace and industrialization, the vitality request has expanded fundamentally. The traditional vitality sources, for example, coal, oil, and gas are constrained in nature. There is a requirement for renewable vitality hotspots for the future vitality request. The other principle focal points of this renewable source are eco-invitingness and boundless in nature. Because of specialized progressions, the cost of the wind control delivered is practically identical to

that of traditional power plants. Accordingly, the wind vitality is the most favored out of 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. A large portion of the wind turbines are settled speed in light of their effortlessness and ease. By watching and actualizing wind turbine qualities, one can obviously recognize that for separating most extreme power, the machine ought to keep running at different rotor speeds at various wind speeds. An actualized cutting edge control electronic converter, the machine can keep running at customizable rates. These variable speed wind turbines can enhance the wind vitality generation. Out of all factor speed wind turbines, doubly encouraged acceptance generators (DFIGs) are favored as a result of their minimal effort. The benefits 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 powerless lattice. Free control of dynamic and responsive power is accomplished by the decoupled vector control calculation. This vector control of such framework is typically acknowledged in synchronously pivoting reference outline situated in either voltage hub or flux hub. In this work, the control of rotor-side converter (RSC) is executed in voltage-arranged reference outline. Reaction of DFIG-based wind vitality transformation framework (WECS) to lattice unsettling influence is contrasted with the settled speed WECS. Created control smoothening is accomplished by actualizing super attractive vitality stockpiling frameworks. The other assistant administrations, for example, receptive power necessity and transient strength farthest point are accomplished by including static compensator (STATCOM). A appropriation STATCOM (DSTATCOM) combined with fly-wheel vitality stockpiling framework is utilized at the twist cultivate for moderating sounds and recurrence unsettling

influences. A super capacitor vitality stockpiling framework at the dc connection of bound 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 backhanded 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 clamor in the machine. In this work, another control calculation for GSC is proposed for repaying sounds created by nonlinear burdens utilizing a circuitous current control. RSC is utilized for controlling the receptive force of DFIG. The other principle favorable position of proposed DFIG is that it functions as a dynamic channel notwithstanding when the wind turbine is in shutdown condition. Subsequently, it remunerates stack responsive power and music at wind turbine slowing down case. Reproduction exhibitions of the proposed incorporated dynamic channel based DFIG with fluffy rationale controller is introduced in this work to moderate the aggregate consonant bending in the rotor side and network side converter. The dynamic execution of the proposed DFIG is additionally shown for shifting wind speeds and changes in unequal nonlinear burdens at purpose of normal coupling (PCC).

II. SYSTEM CONFIGURATION AND OPERATING PRINCIPLE

Fig. 1 shows a schematic diagram of the proposed DFIG based WECS with integrated active filter capabilities. In DFIG, the stator is directly connected to the grid as shown in Fig. 1. Two back-to-back connected voltage source converters (VSCs) are placed between the rotor and the grid. Nonlinear loads are connected at PCC as shown in Fig. 1. The proposed DFIG works as an active filter in addition to the active power generation similar to normal DFIG. Harmonics generated by the nonlinear load connected at the PCC distort the PCC voltage. These nonlinear load harmonic currents are mitigated by GSC control, so that the stator and grid currents are harmonic-free. RSC is controlled for achieving maximum power point tracking (MPPT) and also for making unity power factor at the stator side using voltage-oriented reference frame. Synchronous reference frame (SRF) control method is used for extracting the fundamental component of load currents for the GSC control.

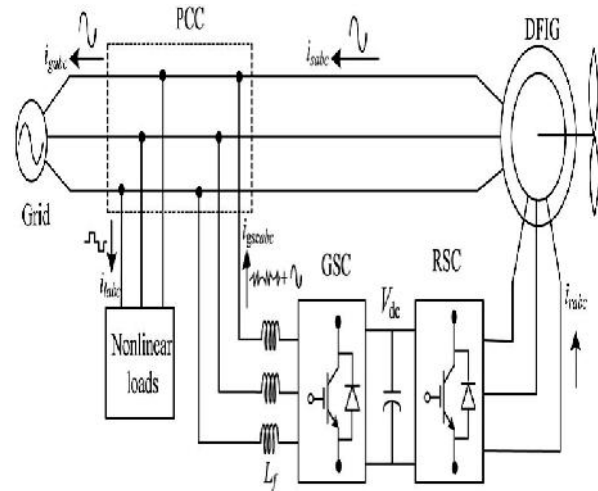


Fig 1. Proposed system configuration.

III. DESIGN OF DFIG-BASED WECS

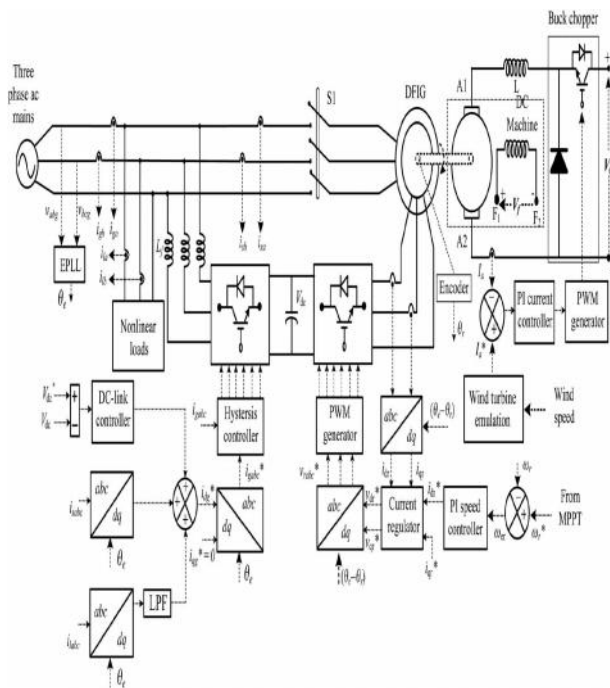
Selection of ratings of VSCs and dc-link voltage is especially imperative for the fruitful operation of WECS. The appraisals

of DFIG and dc machine utilized as a part of this exploratory framework are given in Appendix. In this area, an itemized outline of VSCs what's more, dc-connection voltage is examined for the exploratory framework utilized as a part of the research facility. Typically, the dc-interface voltage of VSC must be more prominent than double the pinnacle of most extreme stage voltage. The determination 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. Typically, the DFIG working slip is ± 0.3 . In this way, the rotor voltage is constantly not exactly the PCC voltage. Along these lines, the plan criteria for the determination of dc-connection voltage can be accomplished by considering just PCC voltage. While considering from the GSC side, the PCC line voltage (v_{ab}) is 230 V, as the machine is associated in delta mode. The rating of VSC and coupled inductor rating was figured in the paper(1)

IV. CONTROL STRATEGY

Control algorithms for both GSC and RSC are presented in this section. Complete control schematic is given in Fig. 2.

The control algorithm for emulating wind turbine characteristics using dc machine and Type A chopper is also shown in Fig. 2. The main purpose of RSC is to



extract maximum power with independent control of active and reactive powers. Here, the RSC is controlled in voltage-oriented reference frame. Therefore, the active and reactive powers are controlled by controlling direct and quadrature axis rotor currents (i_{dr} and i_{qr}), respectively. Direct axis reference rotor current is selected such that maximum power is extracted for a particular wind speed. This can be achieved by running the DFIG at a rotor speed for a particular wind speed. Therefore, the outer loop is selected as a speed controller for achieving direct axis reference rotor current. SRF theory developed in this paper to compensate currents and voltage equations in the form of direct and quadrature axis for grid side and rotor side converter.

V. FUZZY LOGIC CONTROL

FLC determined by the set of linguistic rules. The mathematical modeling is not required in fuzzy controller due to the conversion of numerical variable into linguistic variables. FLC consists of three part: a. Fuzzification, b. Interference engine, c. Defuzzification. The fuzzy controller is characterized as; For each input and output there are seven fuzzy sets. For simplicity a membership functions is Triangular. Fuzzification is using continuous universe of discourse. Implication is using Mamdani's "min" operator. Defuzzification is using the "height" method. FLC block diagram as shown in figure 3.

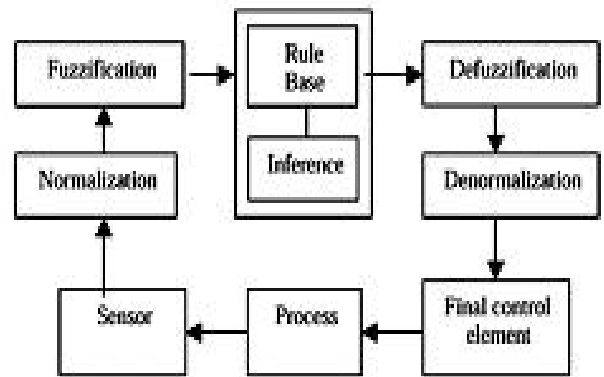


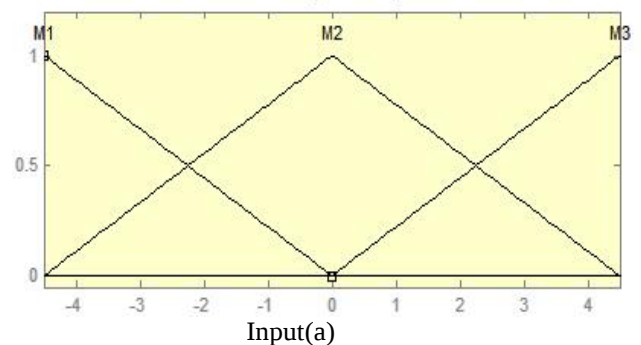
Fig. 3. Fuzzy Logic Controller

a. Fuzzification

Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB(Negative Big), NM(Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM(Positive Medium) and PB (Positive Big). The partition of fuzzy subsets and the shape of membership function adapt the shape up to appropriate system. Input error $E(k)$ and change in error $CE(k)$ of values which is normalized by an input scaling factor as shown in table 1.

Fig. 2. Control algorithm of the proposed WECS.

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 $\tilde{e} = \tilde{e} - (-1)$



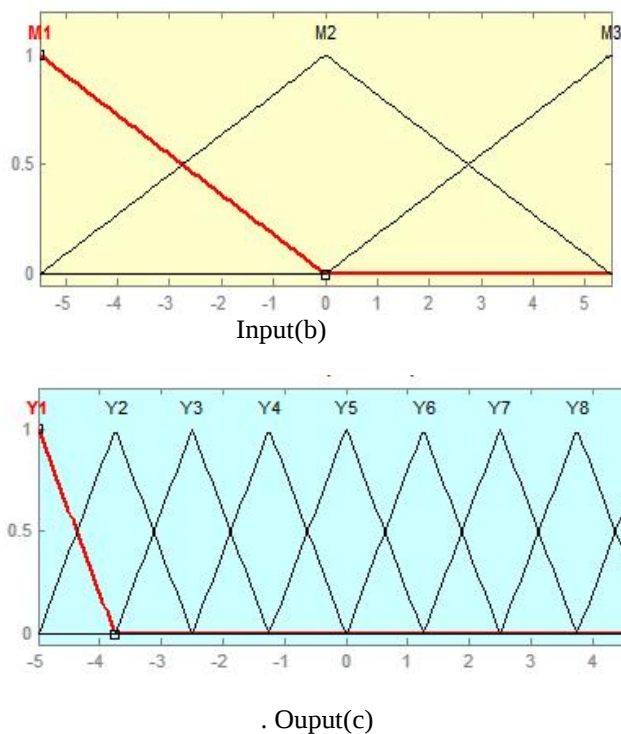


Fig. 4.(a)(b)(c) Membership functions

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

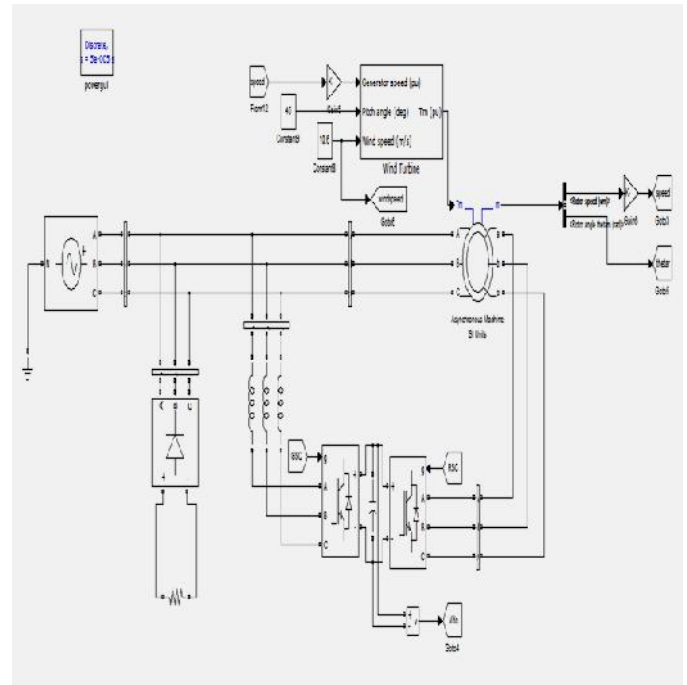


FIG 5.1 Block diagram of proposed DFIG-based WECS at fixed wind speed of 10.6 m/s (rotor speed of 1750 rpm).

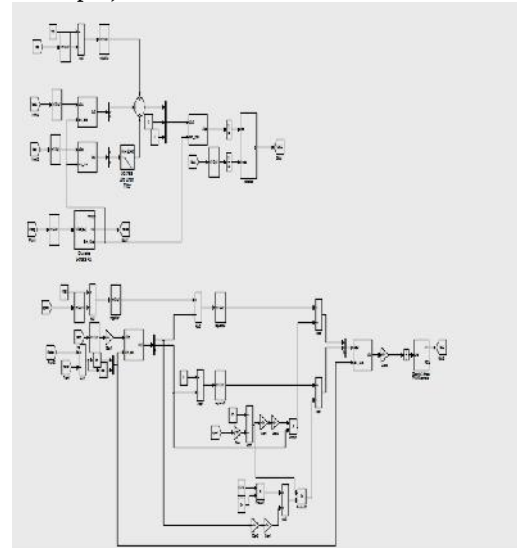


FIG 5.4 MAIN BLOCK DIAGRAM OF proposed DFIG-based WECS working as a STATCOM at zero wind speed.

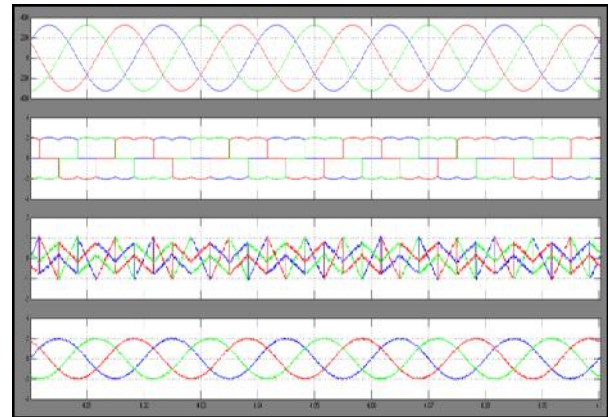
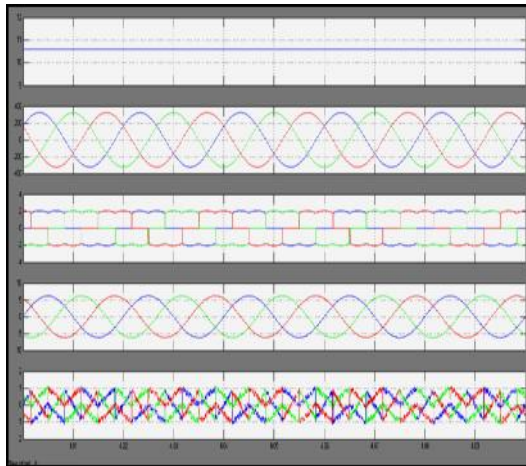


Fig. 5.3. Simulated performance of the proposed DFIG-based WECS at fixed wind speed of 10.6 m/s (rotor speed of 1750 rpm).

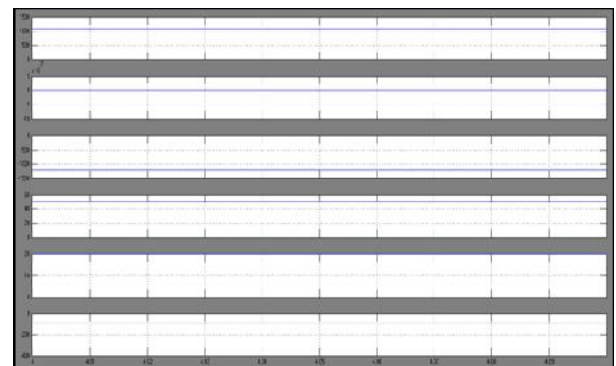


Fig.5.5 Simulated performance of the proposed DFIG-based WECS working as a STATCOM at zero wind speed.

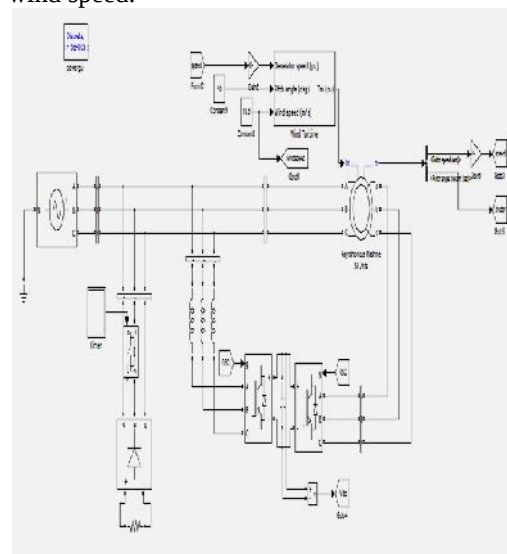
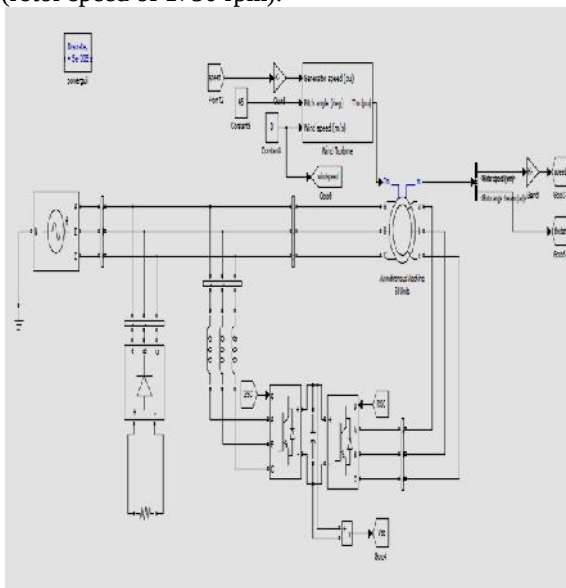


FIG 5.8 Block diagram of proposed DFIG for fall in wind speed

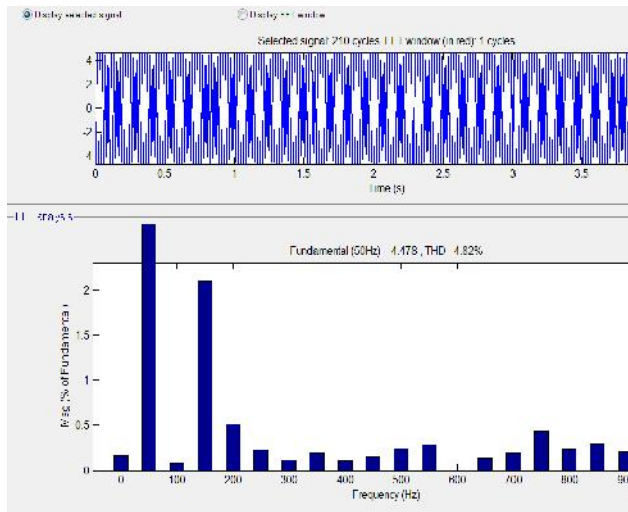


FIG 5.11 TOTAL HARMONIC DISTORTION OF GRID CURRENT

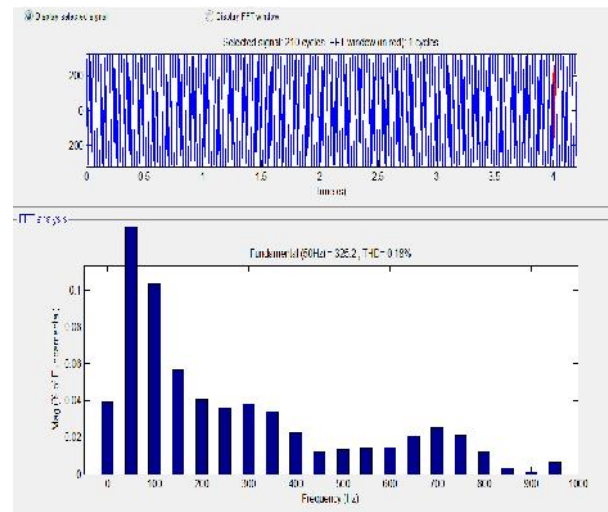


FIG 5.14 TOTAL HARMONIC DISTORTION OF SOURCE VOLTAGE

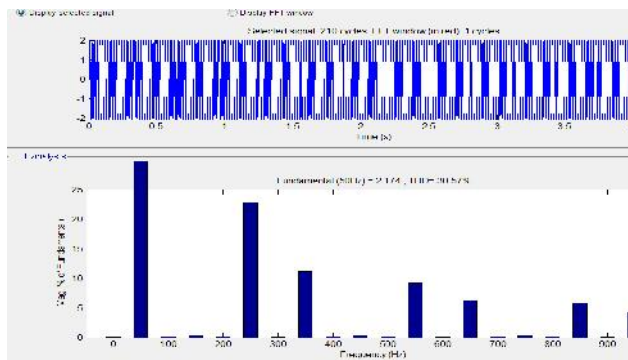


FIG5.12 TOTAL HARMONIC DISTORTION OF LOAD CURRENT

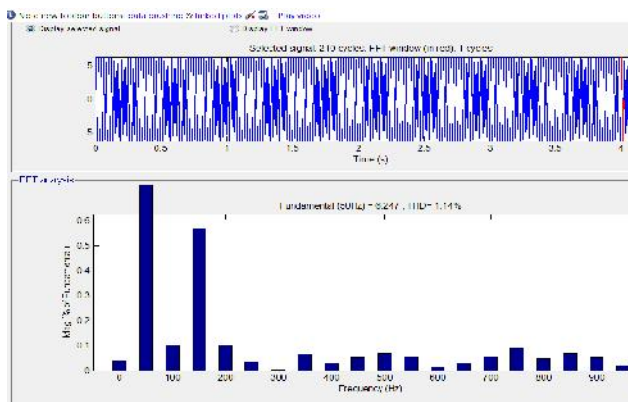


FIG 5.13 TOTAL HARMONIC DISTORTION OF SOURCE CURRENT

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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