A Fuzzy Logic Based Mppt Controller for Wind-Driven Three-Phase Self-Excited Induction Generators Supplying Dc Microgrid

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ABSTRACT

In this paper, a straightforward strategy for tracking the maximum power (MP) accessible in the wind energy conversion system for dc microgrid is proposed. A three-phase diode bridge rectifier alongside a dc-dc converter has been utilized between the terminals of wind-driven induction generator and dc microgrid. Induction generator is being worked in self-energized mode with excitation capacitor at stator. The output current i.e., dc grid current act as a control variable to track the MP in the proposed WECS. In this manner, the proposed calculation for maximum power point tracking (MPPT) is autonomous of the machine and wind-turbine parameters. Further, a technique has been created for deciding the obligation proportion of the dc-dc converter for working the proposed system in MPPT condition utilizing wind turbine qualities, relentless state proportionate circuit of prompting generator and power balance in power converters. Circuit straight forwardness and basic control calculation are the significant points of interest of the proposed setup for supplying energy to the dc microgrid from WECS. The fruitful working of the proposed calculation for Fuzzy logic based MPPT has been shown with broad exploratory results alongside the simulated values.

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1. INTRODUCTION

With a perspective to meet out the continuous and expanding energy demand, numerous nations have begun the procedure of liberalization of their electric systems, opening access to transmission and conveyance networks for associating little or medium scale generators. These distributed generated systems reduce the energy misfortune and base expense for transmission systems, since DGs are associated near the load focuses. Moreover, renewable energy sources, for example, wind and sunlight based are broadly conveyed in distributed generated systems, which further helps for the contamination free environment.

It is realized that the electrical output from DGs utilizing renewable energy sources is of variable voltage dc or ac amounts. In the present day situation most of loads, for example, LED lighting, PC burdens and variable rate drives request dc as the source. Nonappearance of reactive power, no symphonious issues, less power change stages and simple to interface vitality stockpiling gadgets, specifically, battery, module electric vehicles and super capacitors are alluring alternatives for dc microgrid with DGs. Lasting Magnet Alternators (PMAs) and Self-Excited Induction Generators (SEIGs) are the reasonable decisions for such little scale wind generators utilized in dc microgrids. Tough rotor development, nonattendance of slip rings, brushes and a different dc sources for excitation and simplicity of support are the fundamental explanations behind inclining toward actuation machines, with renewable vitality frameworks.

For separating maximum power (MP) accessible from the wind, the wind turbine (WT) must be worked to convey the greatest mechanical output power for a given wind speed as appeared in Figure 1. The numerical demonstrating of WT attributes given in Fig.1From this figure, it could be watched that the rotor speed of the wind-generator system must be permitted to differ generally to extract the most extreme conceivable power accessible in the wind.Different power electronic topologies have been proposed in the writing for this motivation behind supplying energy to the ac network. In this way, the greater part of the examination directed so far has focused on ac network operations. With respect to network, just not very many articles are in the current writing.

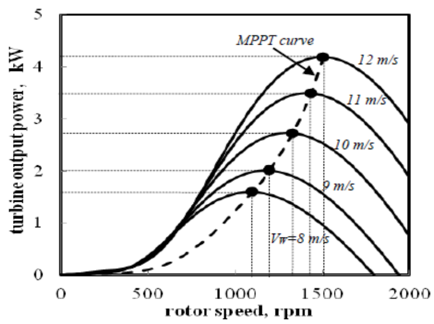


Figure 1. Wind Turbine Output Power Curve for Various Wind Velocities

2. PROPOSED SYSTEM FOR WIND-DRIVEN SEIG SUPPLYING DC MICROGRID

In this paper, induction generator is proposed to work in self-energized mode so that the WT system can be worked over a wide speed range for extricating MP accessible in the wind. The reactive power necessity of the generator is supplied locally through capacitor banks. Utilizing DBR at the generator terminals, helps in diminishing the responsive force load on the excitation capacitor banks following the removal element at the uncontrolled rectifier is solidarity. In perspective of these, DBR has been decided for making the proposed system basic in both setup and control. Further, to have the basic control procedure for MPPT in the proposed dc microgrid application, a dc-dc converter is proposed to be utilized at the matrix side. The general schematic of the proposed WECS supplying the dc microgrid is appeared in Figure 2.

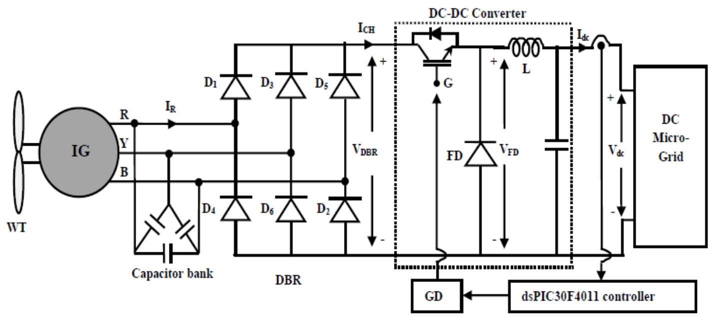


Figure 2. Schematic Diagram of the Proposed Wind-Driven SEIG for Dc Microgrid Application.WT: Wind Turbine; IG: Induction Generator; DBR: Diode Bridge Rectifier And GD: Gate Driver Circuit

A couple of analysts have depicted the execution of the dc microgrid system with various voltage levels and reasonable force electronic interface, taking into account proficiency, voltage drop, warm breaking point, expense and wellbeing issues.Consequently, in this paper 120V dc has been considered at the grid side of the proposed system. Further, financially accessible inverters of (10-20) kVA appraisals work with 120 V dc. Subsequently, this voltage level is most appropriate for such industrially accessible inverters alongside energy stockpiling systems in particular, battery banks. In this way, the controller detects this dc system current through a present sensor and contrasts it and the past worth. The outcome chooses the change (increase or decrement) in the obligation proportion of the dc-dc converter. It is to be noticed that the rotor speed of the WT system is changed for separating MP accessible in the wind according to the qualities given in Figure 1 for a given wind speed by conforming the obligation proportion of the dc-dc converter and ceaselessly observing the dc lattice current alone.

3. ANALYSIS OF THE PROPOSED SYSTEM

To show the efficiency of the proposed MPPT control technique, the system appeared in Figure 2 has been broke down both in unfaltering state and element conditions.

3.1. Steady-state Analysis

For the system comprising of the SEIG supplying energy to the dc microgrid through power converters, the unfaltering state examination has been separated into two sections. Firstly, the execution of the generator has been gotten for working the wind-generator system at MPPT condition for a given wind speed according to Figure 1. At that point, utilizing these execution amounts, to be specific, voltage and electrical power output at the generator terminal, the execution of the power electronic converter supplying energy to the dc microgrid has been acquired.

3.1.1. Analysis of WT-SEIG

For doing the consistent state investigation of SEIG, ordinary identical circuit of the induction machine is adjusted to incorporate the variable nature of the working frequency. For doing the consistent state examination of WT-SEIG, the heap should be fittingly reflected over the generator terminals. In this way, by expecting a consistent dc current at DBR, the proportional burden at the generator terminals can be spoken to as an immaculate resistive load and its quality is given by.

$$R=\frac{3V_P^2}{P_e} \tag{1}$$

Along these lines, Figure 3 demonstrates the resultant comparable circuit utilized for the consistent state examination of the WT-SEIG framework proposed in this work. In this figure, a=p.u. recurrence=f_g/f_r and b=p.u. speed=N_r/N_s. At that point, the working slip of the machine is s = (a - b)/a. It is to be noticed that as the wind speed changes, the impelled emf (E) in the SEIG and consequently the charging reactance (Xm) change with the level of immersion. Further, for this consistent state examination, all the machine parameters are thought to be known, aside from Xm and the center misfortune in the machine is ignored. For the circuit appeared in Figure 3, the circle condition can be composed as.

$$IZ=0 \tag{2}$$

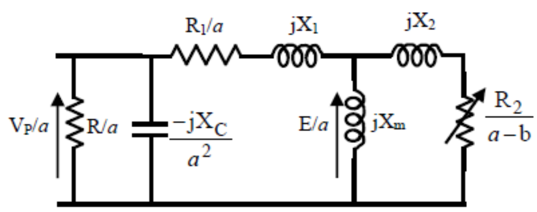


Figure 3. Equivalent Circuit of SEIG

All reactances correspond to rated frequency.
Where

$$Z=\{[\frac{R}{a}]\ ||^{el}[\frac{-jX_c}{a^2}]\}+\{\frac{R_1}{a}+jX_1\}+\{jX_m||^{el}[\frac{R_2}{a-b}+jX_2]\} \tag{3}$$

Since under consistent state condition I not equal to zero, it takes after from (2) that Z=0. For getting the working point, in particular, a and Xm for the predefined estimation of b to fulfill the above condition, some improvement method has been utilized. In this way, in the proposed plan, to get obscure parameters, to be specific, a and Xm for the predefined estimation of b, the goal capacity, f (a, Xm) (= |Z|) is minimized to zero utilizing GA strategy. After touching base at the working point, for every estimation of Xm, the comparing affected emf, E is resolved from a information of the charge normal for the machine. At that point, the execution of the SEIG is processed from the expressions got from the identical circuit appeared in Figure 3 and they are condensed as takes after:

$$V_P = \{\frac{R_L^2+X_L^2}{[(R_1/a)+R_L]^2+(X_1-X_L)^2}\}^{1/2}E \tag{4}$$

$$I_R = V_P/R \quad \text{and} \quad P_e = 3V_P I_R \tag{5}$$

Where $R_L = \frac{RX_C^2}{a[a^2R^2+X_C{}^2]}$ and

$$X_L = \frac{RX_C^2}{[a^2R^2+X_C{}^2]} \tag{6}$$

The mechanical info energy to the rotor of the generator can be composed as,

$$P_m = -3I_2^2R_2[\frac{b}{a-b}] \tag{7}$$

Where

$$I_2 = \frac{E}{[(R_2/_{a-b})^2+X_2^2]^{1/2}} \tag{8}$$

It can be seen from (1), that the estimations of V_P and Pe are required for the count of R for any given working conditions. For showing the viability of the proposed strategy for dissecting WT-SEIG system utilizing the stream graph of Figure 4, a 3-phase, 4-post, 230 V, 50 Hz (1 p.u. frequency), 3.7 kW, delta-associated squirrel-confine prompting machine has been considered. The deliberate parameters of the generator are R1=1.30 Ω, R2=1.75 Ω, X1=X2=2.6 Ω. The (E/a) versus Xm trademark acquired tentatively at the appraised frequency of 50 Hz for this generator is communicated as takes after:

$$E/a=-296.35*10^{-10} X_m^6+759.97*10^{-8} X_m^5+784.84*10^{-6} X_m^4+40.75*10^{-3} X_m^3-111.07*10^{-2} X_m^2+12.94 X_m+245.92 \tag{9}$$

To suit the rating of 3.7 kW actuation generator considered in this study, different parameters of WT model have been picked. The resultant power bend of the WT with the picked parameters, for this study is given in Figure 1. At that point, utilizing the methodology for this wind speed, relentless state execution of the WT-SEIG system has been foreordained.

3.1.2. Analysis of Power Converter

Having assessed the voltage furthermore, electrical power output at the generator terminals for working the WT-SEIG at MPPT condition by receiving the system created in the before sub-segment, it is of interest to build up the system for anticipating the execution of the power electronic controller interfaced with the proposed system.

$$V_{DBR}=\frac{3\sqrt{2}V_s}{\pi} - 2V_{D(ON)} \tag{10}$$

For the known estimation of dc matrix voltage, V_{dc} and inductor resistance (R_{ind}), the voltage over the freewheeling diode, V_{FD} is given by

$$V_{FD} = V_{dc} + P_{dc}R_{ind} \tag{11}$$

where, the dc grid current

$$I_{dc} = \frac{P_{dc}}{V_{dc}} \qquad (12)$$

At that point, the obligation proportion of the buck converter, δ can be figured utilizing

$$\delta = \frac{V_{FD}}{V_{DBR} - V_{C(ON)}} \qquad (13)$$

Where, $V_{C(ON)}$ is the on-state voltage over the IGBT. At that point, the electrical power yield of the generator, Pe , dc network force, P_{dc} and aggregate power misfortune in the converter, P_{TL} can be connected as.

$$P_e = P_{dc} + P_{TL} \qquad (14)$$

From (9-13), it can be seen that the estimation of I_{dc}, P_{dc} and P_{TL} are required for the figuring of obligation proportion. Nonetheless, in the start of the fate procedure, these qualities are obscure. Subsequently, a strategy has been produced taking into account the power balance condition given in (13) and other known parameters.

3.2. Simulation Study

The proposed arrangement of Figure 2 has additionally been recreated utilizing SimPowerSystems tool stash as a part of MATLAB programming. The same machine considered in the before area alongside different parameters has been utilized for the recreation. To suit the rating of 3.7 kW impelling generator considered in this study, different parameters of WT model have been picked. This capacity consistently faculties the dc framework current and properly conforms the obligation proportion of the dc-dc converter for any given wind speed to concentrate MP accessible in the wind according to the attributes given in Figure 1.

3.2.1. Steady-state Execution

To learn the fruitful working of the proposed MPPT controller, reproduction has been done for the given wind speed and the unfaltering state execution and alongside the anticipated qualities. For instance, alluding to Figure 1, for separating most extreme conceivable estimation of mechanical force yield of 4.19 kW at 12 m/s wind speed, WT ought to be made to pivot at a rotor pace of 1500 rpm. For accomplishing this, shut circle controller consistently screens the dc grid present according to the rationale depicted and changes the obligation proportion to 41% for this 12 m/s wind speed.

3.2.2. Dynamic Performance

To approve the agreeable element execution of the proposed system with the MPPT controller, reproduction has additionally been done for step change in wind speed. In this reproduction, wind speed has been changed from 8 m/s to 10 m/s and back. Every interim was kept up for 0.4 s. The reenacted waveforms of rotor pace (N_r), mechanical torque of the WT (Tm), electromagnetic torque (T_e) of generator, stator output power (P_e), stator voltage (V_S), stator current (I_s), capacitor current (Ic) and rectifier input current (I_r) alongside the dc grid current (I_{dc}) and dc system power (P_{dc}) have been watched for the progression change in wind speed (V_w) and they are displayed in matlab/simulink.

4. IMPLEMENTATION OF FUZZY LOGIC CONTROLLER

4.1. Introduction

Fuzzy Logic is about the relative importance of exactness: How vital is it to be decisively right when an unpalatable answer will do?. You can use Fuzzy Logic Toolbox programming with MATLAB specific figuring programming as an instrument for dealing with issues with soft method of reasoning. In this sense, soft method of reasoning is both old and new in light of the fact that, regardless of the way that the present day and effective craft of cushioned justification is still young, the possibility of cushy basis relies on upon age-old aptitudes of human thinking.

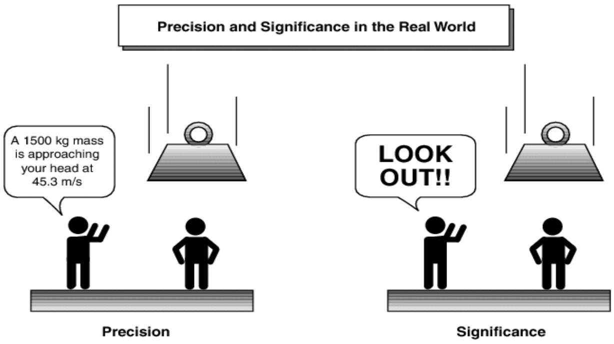


Figure 4. Fuzzy Description

4.2. Fuzzy Logic Tool box

The Fuzzy Logic Toolbox extends the MATLAB particular enlisting environment with gadgets for plotting systems in perspective of fuzzy method of reasoning. Graphical customer interfaces (GUIs) guide you through the movements of fuzzy prompting system plot. The apparatus compartment allows you to model complex system works on using essential reason guidelines and after that completes these precepts in a fuzzy finding structure. You can use the toolbox as a standalone fuzzy construing engine. Of course, you can use fuzzy derivation obstructs in simulink and reproduce the soft structures within an extensive model of the entire component system.

4.3. Working with the Fuzzy Method of Reasoning Device Compartment

The Fuzzy Logic Toolbox allows GUIs to offer you to perform conventional fuzzy system change and case affirmation. Using the toolbox, you can make and look at fuzzy instigation structures, make flexible neuro fuzzy gathering systems, and perform fuzzy gathering. In like manner, the apparatus stash gives a fleecy controller piece that you can use in Simulink to show and copy a fuzzy justification control system.

4.3. Building a Fuzzy Inference System

Fuzzy inferring is a methodology that unravels the qualities in the information vector and, considering customer portrayed standards, dispenses qualities to the yield vector. Using the GUI editors and viewers in the Fuzzy Logic Toolbox, you can manufacture the rules set, describe the support limits,and explore the behavior of a soft induction system (FIS). The going with editors and viewers

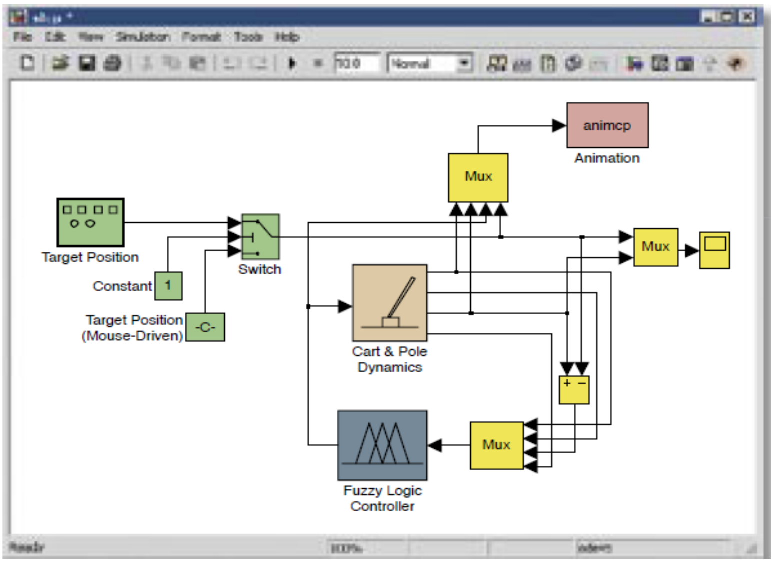
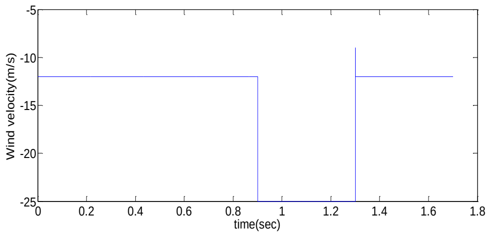
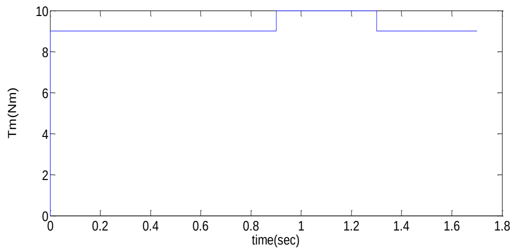


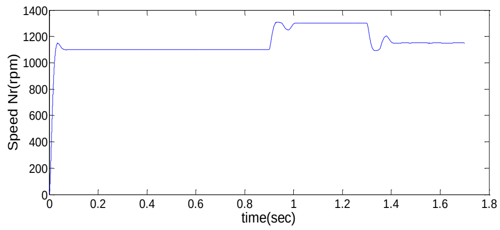
Figure 5. Fuzzy Interference System

5. SIMULATION RESULTS

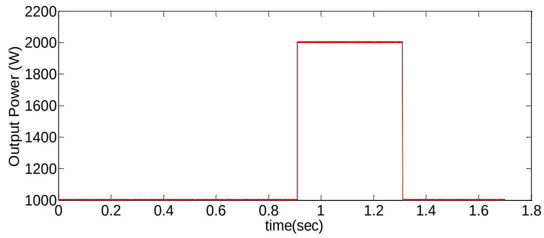




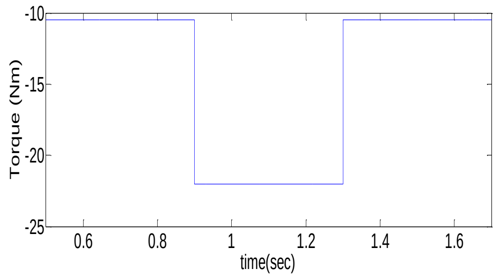
Using Incremental Conductance Method



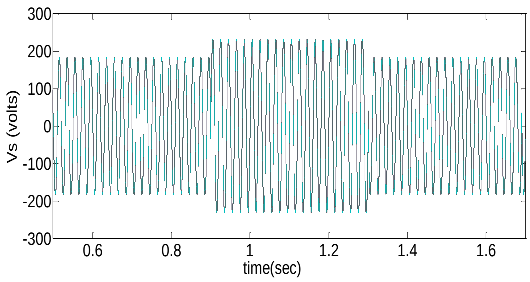
Mechanical Output Torque Rotor speed (Nr)



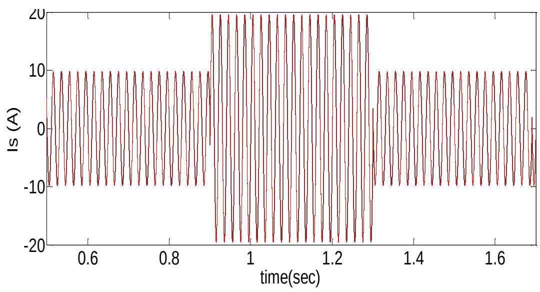
Stator Output Power (Pe)



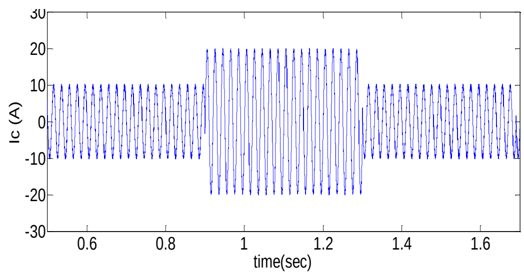
Elecro Magnetic Torque (Te)



Stator Voltage (Vs)

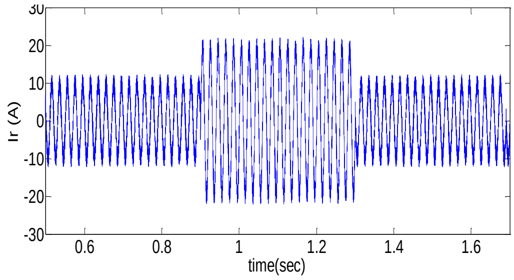


Stator Current (Is)

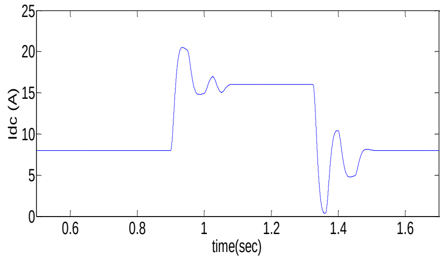


Capacitor Current (Ic)

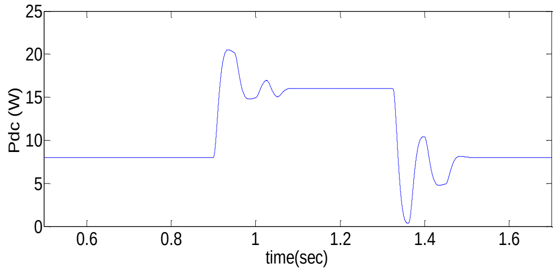
Figure 6. Dynamic Response of the Proposed WECS for Step Change in Wind Velocity.
Wind Velocity



Rectifier Input Current (Ir)



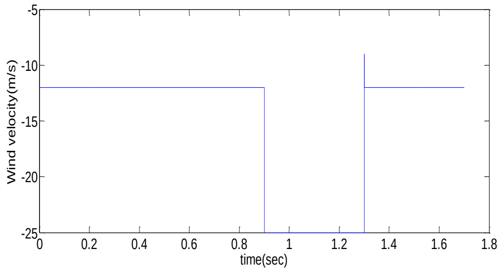
DC Grid Current



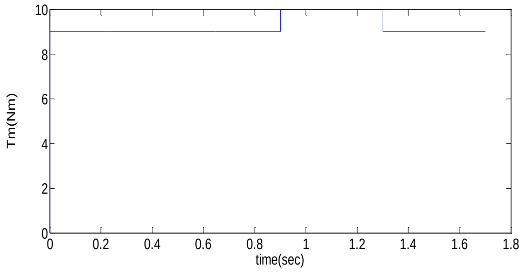
DC Grid Power

Figure 6. Dynamic Response of the Proposed WECS for Step Change in Wind Velocity.
Wind Velocity

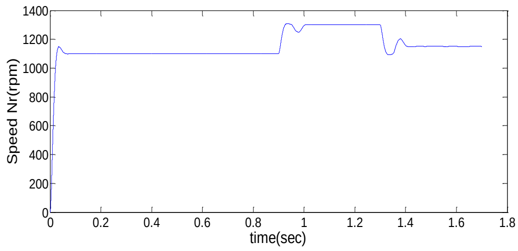
5.1. Using Fuzzy Logic Controller



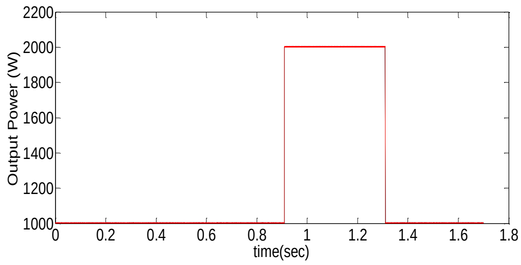
Wind Velocity



Mechanical Output Torque

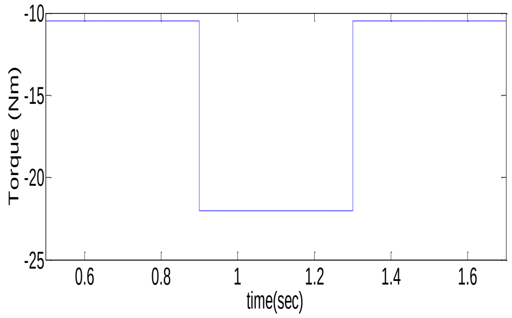


Rotor Speed (Nr)

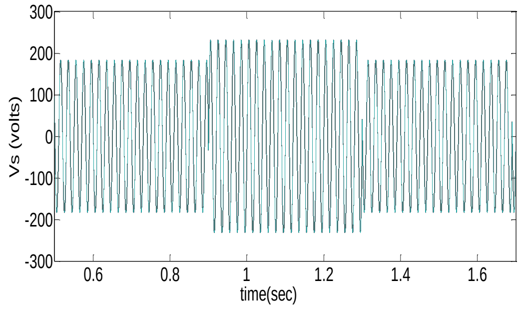


Stator Output Power (Pe)

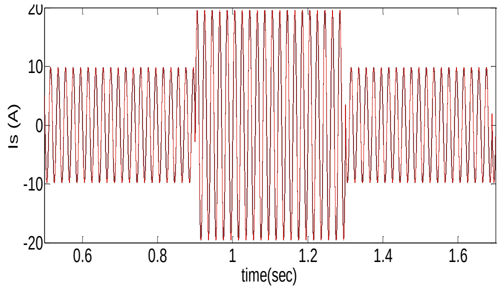
Figure 7. Dynamic Response of the Proposed WECS for Step Change in Wind Velocity.



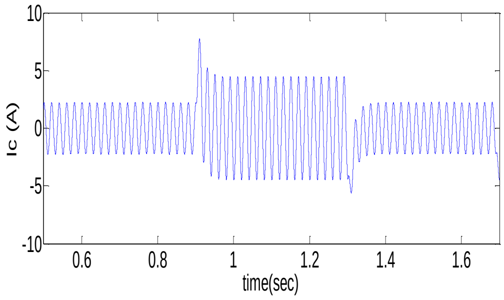
Electromagnetic Torque



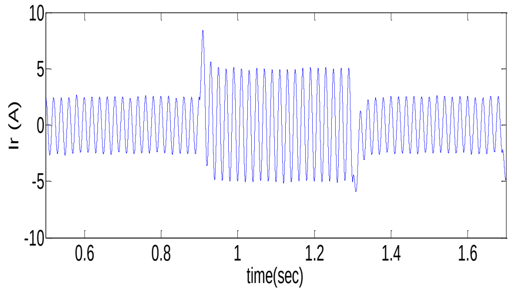
Stator Voltage



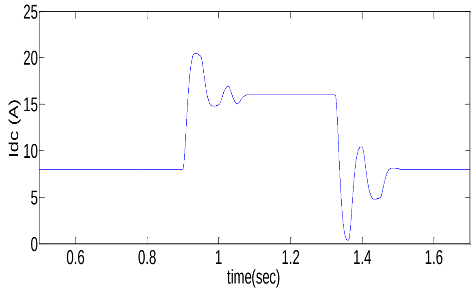
Stator Current (Is)



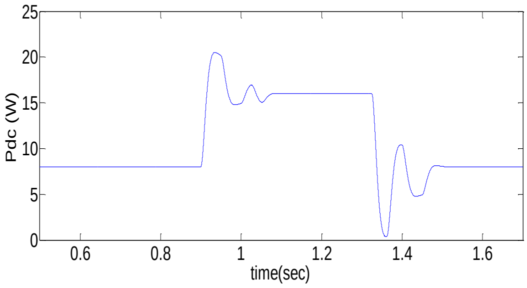
Capacitor Current (Ic)



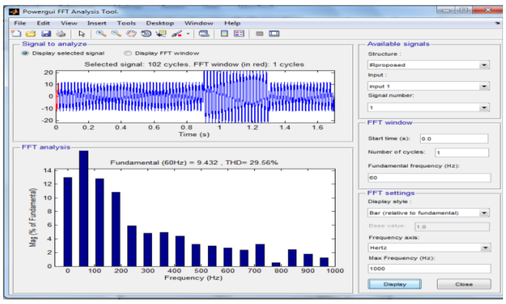
Rectifier Input Current(Ir)



DC Grid Current

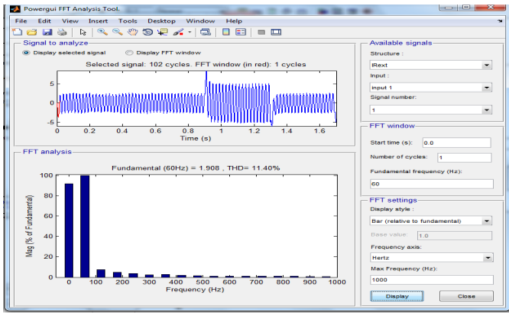


DC Grid Power

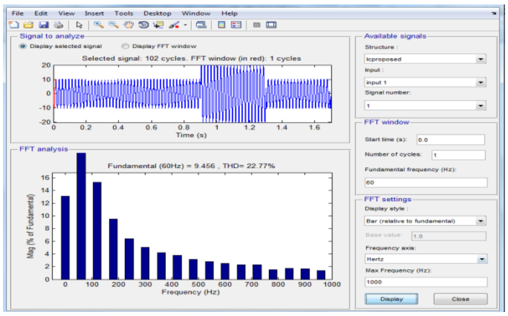


IR THD Under proposed=29.56

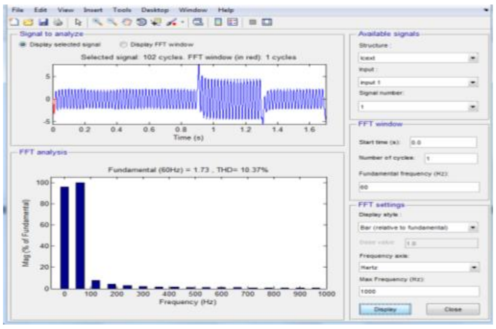
Figure 7. Dynamic Response of the Proposed WECS for Step Change in Wind Velocity



IR THD Under Extension=11.40%



Ic THD Under Proposed=22.72%



Ic THD Under Extension=10.32%

Figure 7. Dynamic Response of the Proposed WECS for Step Change in Wind Velocity

6. CONCLUSION

As of late, numerous nations energize the customers for creating electrical power from exchange energy sources, which prompts the arrangement of microgrids. In such manner, 120 V dc microgrid systems draw substantially more consideration for low power applications supplied from renewable vitality sources. Especially, this voltage reach is most appropriate for family unit machines, home inverters and capacity frameworks. A straightforward circuit setup and control calculation is crucial for simple operation and upkeep of such dc microgrid frameworks by buyers. Subsequently, this paper has displayed a straightforward MPPT calculation and circuit topology for dc microgrid applications supplied from a little scale WECS. The rationale for diminishing the obligation proportion with expanding estimation of dc network current for the MPPT has been appeared with illustration. Without the requirement for the estimation of wind speed or turbine rotor speed i.e., with no mechanical sensors, the MPPT calculation proposed in this paper is easy to actualize.Further, the whole system has been created utilizing MATLAB/Simulink environment along with the WT model for surveying the unfaltering state and dynamic execution of the proposed WECS. Different foreordained and reenacted results outfitted in this paper exhibit the best possible following of the MP point utilizing the proposed single variable detecting calculation.

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