ISSN: 0974-5823 Vol. 7 No. 5 May, 2022

International Journal of Mechanical Engineering

WEAK GRID INTERLINK WEGS WITH HYBRID COMPREHENSIVE INTEGRATOR FOR ENHANCMENT OF POWER QUALITY WITH ANFIS CONTTROLLER

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Abstract: In this article, the WEGS (wind energy generating system) seeks to supply the necessary active peak power under changeable wind speed conditions, even when there are large frequency fluctuations. In this manner, the machine-side VSC (MSVSC) and utility grid-side VSC (UGVSC) are connected to back-to-back, serving to increase or decrease the generator speed when the wind speed fluctuates via a dc link capacitor. A hybrid generalized integrator control is developed in this study, with the goal of replacing the UGVSC for supplying more successful at blocking DC offset errors, and better able to resist oscillatory errors from subharmonics (PQ). An adaptive neuro fuzzy inference system (ANFIS) controller is employed to regulate the speed of the salient pole synchronous generator (SG) that is connected to the wind turbine. The ANFIS improves in tracking the reference speed in conditions with excessive overshoot transients and narrow bandwidth. Switching MSVSC is used to control MSVSC switching from the field. In this context, "weak grid" refers to situations in which the grid voltage is out of balance, sagging, inflated, or otherwise warped due to a variety of factors. To test the system's performance, a prototype is built in a laboratory. Test results demonstrate how well the system works when the wind blows harder & when the power grid has less stability. Also, PQ improvement results in a reduction in overall grid current harmonics & is determined to be less than 5 percent.

Keywords: Wind Energy Generating System (WEGS) Adaptive neuro fuzzy inference system (ANFIS), synchronous generator (SG)

I.INTRODUCTION

The use planning for the unending guide assets is the stunning area of concern, where wind power sources are a serious concern for trained professionals, monetary experts & also the designers of corporations. In any event, with no hyperlinks to the grid, low force packages were genuinely arranged and, in addition, supply management has now seen crucial endowments to interface WEGS with the item network [1].[2] - This detail includes requests for garage electricity contractions which are more unmistakably recorded to fuse batteries, condensers, gas cells & many more [3]. The opposite effects for the item system while associated with any of the energy change gadgets are music implantation, a decomposition of the weakest stream, in spite of non-ideal intersect oral conditions with voltage lights, abrupt voltage worsening, tension hanging & also swelling. [4] [5] these tongues could be reversed through introducing much higher power transducer control structures, i.e., returned to the returned related voltage resource converter (VSCs), which is linked between the maker result & the grid. This would reduce the load in the cross section & involve the guide to gain its main cost in the wind speed of the producer. [6] Despite UGVSC, in particular, the system-side VSC & VSC strength grid viewpoint are dubbed MSVSC. The unconnected control of two VSCs is performed using a transient condenser that gives disproportionate admission to each VSC, but the opposite side is not affected by the VSC. [7] The UGVSC has the aim of blending illogical, fantastic cross-sectional energy summit (PQ) streams into the structure. The control plans using low avoidance filters for fundamental data collection include a sizeable part of various supervisory structures for UGVSC. There was really a problem of huge fear about the downside of lacking groundbreaking execution. To stop the snares, bendy canals, of which the unbelievably fewer short squares & their redesigns, as the fourth least assume, are actually vital, are genuinely recommended [8] In view of the bargain to the right change, the security worries are raised. The key detail of the organizational voltages wishes to be thought out in order to implement the sensitive sinusoidal ideal progression straight into the utility grid under the susceptible cross part burdens of varied voltages or the structure voltage bending. The machine entry symbol (SOGI), which was filtered by the bandpass, is an approach for basic extraction evaluated packages. The dc balance presents all aspects of the filtered signal analogous to that of the subharmonics. In the event of a powerless organization, SOGI cannot be needed [9] these criteria prevent the mistakes of the polluted alerting strategies. Better estimates have indeed been proposed with better machine insulation limits. For the exemption of dc counter, the low-avoid system filter is displayed in [10], at any rate the high repeated symphonic isolation limit of SOGI has without a doubt been influenced. SOGI-familiar integrator was called for in [11] the high potential of the filtering machine really took the chance of eliminating the slip-ups that the dc balance had attained. 1/3-demand summary directives were conveyed in [12] for obstacles to higher-demand excessive repetition of music. SOGI found its network sync item to fill in as a section-dart circular (PLL) profiler under odd grid conditions [13] Streamlined SOGI with FLL has been pushed Repeating Shoot Circle Despite a reduction in computer weight, the FLL has modified the PLL standard. It is green to further distinguish the abundance, the level, notwithstanding the consistency of the indication from the filtered contradiction point of view. Finally, due to oscillatory fluxes inside the approximation pointers the isolating machine potential is restricted. A few SOGI [15] & multi-faceted forward (ANF) [16] have just been proposed in order to illuminate the general. They offer a few symphonic departures the character of troubling influence. Moreover, the ideal conditions, the complex design plan, the standards, identical to the concession, in spite of symphonic filtration, are the contradictory accusation. In this research, a combination of a summary integrator (HGI) with a FLL is proposed to help redundant repeat consonant lower limits & more grounded execution in weak grid situations. The planned HGI of the UGVSC is like a wholly synthesized integrate based on FLL (GI). The profiler is a filter that alters in the typical assortment as it lifts the compromise of accuracy & also values the normal GI meeting. Nevertheless, it improves the potential for interferences by redesigning the immunity instead of dc counterbalance & interharmonic channels despite subharmonic elements. The HGI features a higher-demand business characteristic that guarantees remarkable filtering capacity. Higher demand phrases really have a shared array of consequences that add up to the trouble of changing the advantages. A linear variation that carries the expense of smooth adjustment of advantages is therefore followed. The UGVSC trading beats are obtained for the current network control from the HGI control elements. Similarly, the dubious wind appreciation idea causes a necessity for control strategies to remedy cross-sectional shortcomings of music shots for the UGVSC in relation to the MSVSC. Du et al. examined the effects of varying wind generator approaches associated to the organization, whereas Atari et al. [20] requested a methodology to deal with customized energy adequacy conditions by solving grid dissatisfaction problems in the light of doubtful breeze speed conditions. Domain-arranged control (FOC) is used to control snapshot power from the concurrent breeze-turbine (SG) generator. High performance with negligible power swell & in addition to amazing stream commentaries are some of FOC's possible gains. This strategy is easy to use & easily preferred in his office. For the co-ordination of generator cost, conventional FOC uses necessary (PI) controls. Taking into account everything, the PI controller reports the drawbacks of exceptional overview & thin documents switch to short timeframes. This can give a standard country or dynamic remarks which do not pay very little attention to the fact that a number of examiners have clearly come to this constraint and, moreover, a few present compositions have probably been considered by using the advantages of the PI controller constantly change [22]. However, these approaches improve unusually, calculating weight, just as a mixed expansion difference can also improve contraction instability. For this purpose, sophisticated control mechanisms are being studied. Similar to nonlinear adaptable control, the ANFIS is a type of insightful that is really interesting in the same way as the alternative PI Charging Controller.

II.PORPOSED SYSTEM CONFIGURATION

The proposed configuration system is shown in Fig.1. The function at a changeable wind speed is guaranteed by the MSVSC cascade & UGVSC by an intermediate dc link condenser. UGVSC connects to the power grid whereas the MSVSC connects to an SG powered wind turbine. The dc engine is constructed & connected to the SG like a wind turbine. The HGI control method removes UGVC pulses & the MS’s retrieves the pulses from the FOC system. P&O algorithm monitor the winds from the MPP & supply the reference generator with a rotor speed (HGR). The SG speed & rotor position are approximated with a BEMF sensor less technique. Additionally, UGVSC's control system maintains the dc connection voltage at its function. Interface inducers linked to UGVSC in series & the grid increase the gap between instantaneous grid tension & the broad tension UGVSC pulse. A ripple filter is employed parallel to the grid to filter out the harmonics.

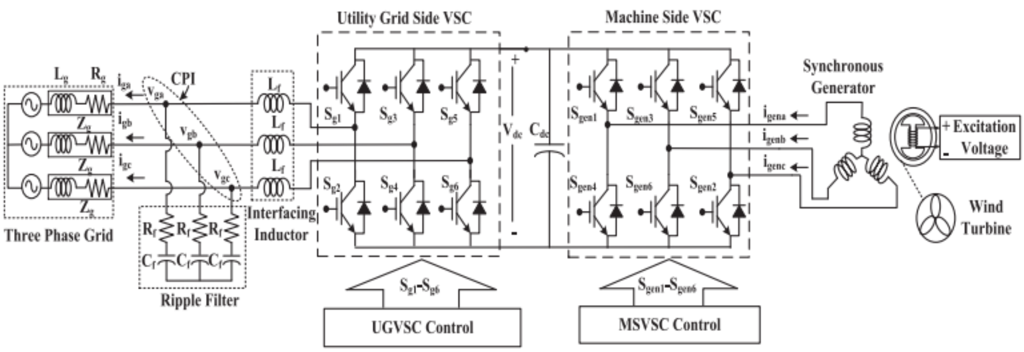


Fig. 1. Proposed system configuration

III.PROPOSED ANFIS CONTROLLER FOR MSVSC

The MSVSC control method is illustrated in Fig.2. The wind generator controls the immediate torque by applying the FOC. SG sensor-less speed and position assessment is done using the P&O MPP tracking technique, and the BEMF is employed for wind MPP. The MSVSC control consists of three sections. First of all is the generation of the axis reference (iqref), the generation of the direct axis reference current (idref) & the generation for MSVSC of switching signals.

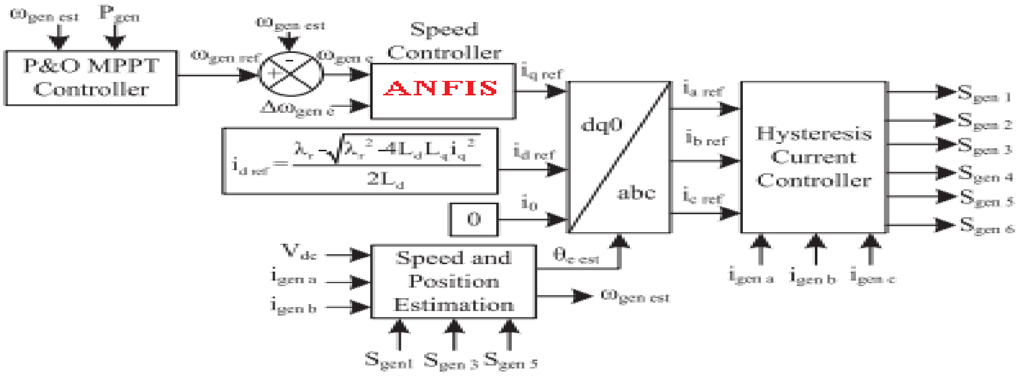


Fig.2. MSVSC control with ANFIS.

1) Generation of iq ref*:* A wind P&O algorithm is used for the reference speed (SG) to the direction of the genref. The system tracks the MPP by disturbing the estimated speed (along est) of the generator & the power generated from SG (Pgen). The wind P&O algorithm is defined as governing equations

$$\omega_{\text{gen ref}}(k) = \omega_{\text{gen ref}}(k-1) + \Delta\omega_{\text{gen}}; \quad \text{if} \begin{Bmatrix} \Delta P_{\text{gen}} > 0 \text{ and } \Delta\omega_{\text{gen est}} > 0 \\ \Delta P_{\text{gen}} < 0 \text{ and } \Delta\omega_{\text{gen est}} < 0 \end{Bmatrix} \tag{1}$$

$$\omega_{\text{gen ref}}(k) = \omega_{\text{gen ref}}(k-1) - \Delta\omega_{\text{gen}}; \quad \text{if} \begin{Bmatrix} \Delta P_{\text{gen}} > 0 \text{ and } \Delta\omega_{\text{gen est}} < 0 \\ \Delta P_{\text{gen}} < 0 \text{ and } \Delta\omega_{\text{gen est}} > 0 \end{Bmatrix}. \tag{2}$$

In order to find the speed mistake (ωgen e), a ωgenref is compared with a ωgenest.

$$\omega_{\text{gen}\,e}(k) = \omega_{\text{gen ref}}(k) - \omega_{\text{gen est}}(k). \tag{3}$$

The ANFIS-based speed controller is fed with the appropriate ωgen e & Δωgen e & the controller's output is considered as iqref. When it comes to calculating the average weight of all outputs, we use the variance of the integral gains.

$$G = \sum_{i=1}^{N} \Psi_i c_i \Big/ \sum_{i=1}^{N} \Psi_i . \tag{4}$$

2) Generation of idref : The proposed technique retains the UPF at the SG stator terminals by keeping the stator power factor angle (s) at zero. Phase angle and SG stator voltage are calculated as a function of the voltage.

$$\begin{Bmatrix} \theta_v = \tan^{-1}\left(\frac{v_q}{v_d}\right) = \tan^{-1}\frac{\omega_r \lambda_r - \omega_r L_d i_d}{\omega_r L_q i_q} \\ \theta_i = \tan^{-1}\left(\frac{i_q}{i_d}\right) \end{Bmatrix}. \tag{5}$$

To produce UPF, idref is estimated to be such that

$$\theta_s = \theta_v - \theta_i = 0. \qquad \textbf{(6)}$$

The value of *id*ref is given as

$$i_{d\,\mathrm{ref}} = \frac{\lambda_r - \sqrt{\lambda_r{}^2 - 4L_d L_q i_q{}^2}}{2L_d} \qquad \textbf{(7)}$$

The rotor flux linkage, d-axis inductance, & q-axis inductance are linked via λr, Ld, & Lq..

3) MSVSC offers three possibilities for Switching Signals:

Inverse Park's transform is used to generate the three-phase reference stator currents (iaref, ibref, icref). IGV & REF currents are sent to the hysteresis current controller to control SG stator currents. In this experiment, current & switching signals are compared in order to produce the MSVSC switching signals.

IV.ANFIS CONTROLLER

Neuro-fuzzy adaptive inference system is the abbreviation for ANFIS. fuzzy logic and neural networks form an ANFIS controller. Depending on the inputs of the neural network, several inputs are transmitted through the neural network. Neural network is trained according to the performance & inputs. The performance is added to the fuzzy logic after training the neural network. The rules (IF & THEN) & (MF) membership functions are generated by Fuzzy logic. The below figure.4 shows the ANFIS architecture.

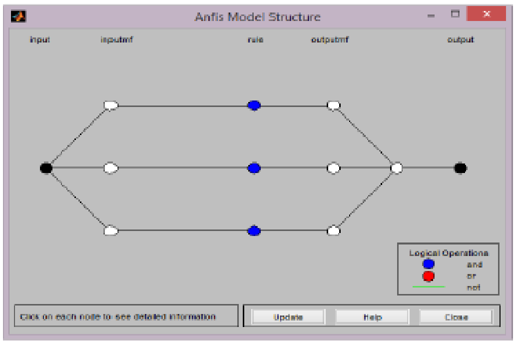


Fig. 3. ANFIS architecture

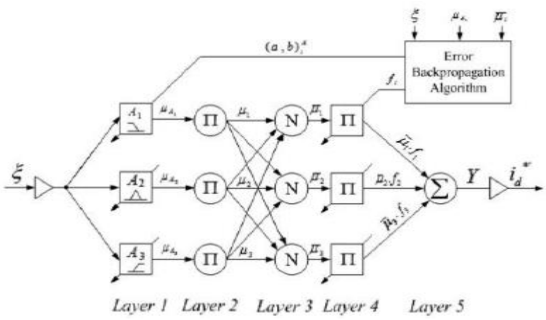


Fig.4 Schematic of the proposed ANFIS

A Neurofuzzy controller will be error between reference voltage of dc-link & the exact dc-link voltage (ξ = Vdc*-Vdc), & the precondition & the following parameters will also be set by a similar error. The dc-link voltage controller provides the active current (id *') section that is further adapted to calculate the active current injected into RES (iRen).

Layer 1: This is a layer of fuzzification. Membership degrees for each input variable are determined in this layer. ANFIS input variables are selected as error (e) & error change (Δe). In order to reduce the error of measurement as shown in Figure 5, trapezoidal & triangular registration abilities.as described below the node conditions are,

$$O_i^1 = \mu_{Ai}(x) = \frac{1}{1+\left[\left(\frac{x-c_i}{a_i}\right)^2\right]^{bi}} \qquad (6)$$

Where x is the node-i entry, Ai is the linguistic variable associated with it, & {ai, bi, ci} is the premise parameter set.

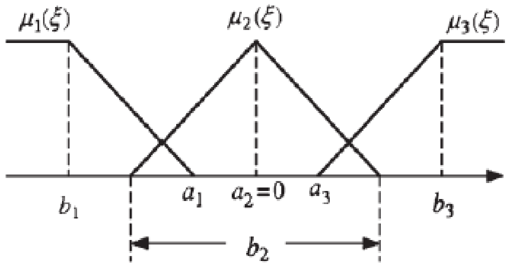


Fig.5 Fuzzy membership functions.

Layer 2: This layer is the inferior layer of the rule. Each node in this layer is a fixed node labelled as a $\prod$ the input node multiplies & the product sends out. Each node output is the firing strength of a fuzzy rule.

$$O_i^2 = \mu_i = \mu(x)\mu(y) \qquad i = 1,2,3 \text{ i=1,2,3(7)}$$

Layer 3: It is the normalization layer. Each layer node is an N-labeled circle node. The i-th node computes the relation of firing force of the rules to amount of the firing force of all rules.

$$O_i^3 = \overline{\mu_i} = \frac{\mu_i}{\mu_1+\mu_2+\mu_3} \qquad i = 1,2,3 \qquad (8)$$

Layer 4: It is the resulting layer. All nodes have network functionality & adaptive mode

$$O_i^4 = \overline{\mu_i}.f_i = \overline{\mu_1}(a_0^i + a_1^i\epsilon) \;\; i = 1,2,3 \qquad (9)$$

The resulting parameter set where the output of Layer 3 is wi (a0, a1).

Layer 5: It is the output layer. The only node within this layer is a fixed node labelled as $\sum$ a combination of all incoming signals that calculates the total output.

$$O_i^5 = \mu_i = \sum_i \overline{\mu_i}\, f_i \qquad i = 1,2,3 \qquad (10)$$

The ANFIS parameters are modified with the following back propagation error:

$$\frac{\partial E}{\partial O^5} = k_1.e + k_2.\Delta e \qquad (11)$$

Signals error (e) & the change of error (Δe) multiplied by the k1 & K2 coefficients.

$$\alpha_{k+1} = \alpha_k - n\frac{\partial E}{\partial \alpha_k} \qquad (12)$$

Where α is one ANFIS parameter and¨the study rate is η. The next training iteration will be reduced by the error.

V.SIMULATION RESULTS

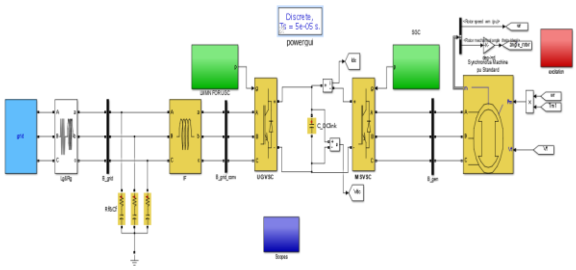


Fig.6 MATLAB/SIMULINK configuration of the recommended grid tied WEGS

A) EXISITNG RESULTS WITH FUZZY CONTROLLER

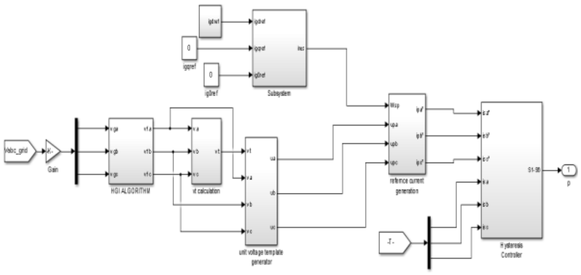


Fig.7 Subsystem of UGVSC controller

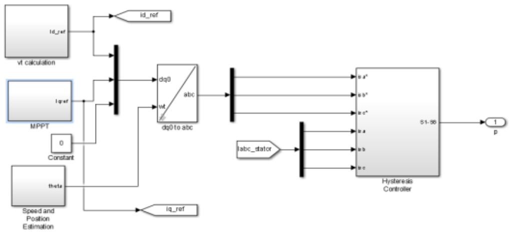


Fig.8 Subsystem for MSVSC with fuzzy controller

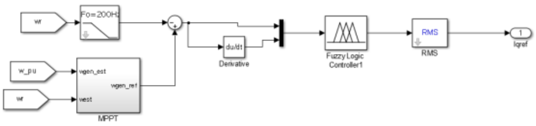
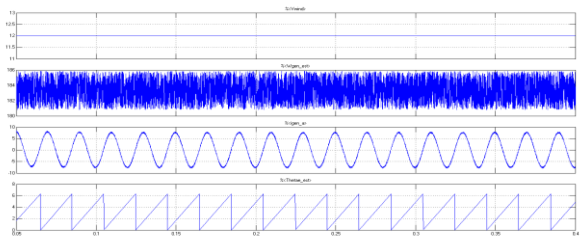
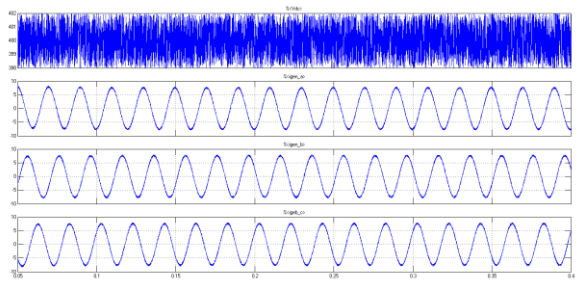


Fig.9 Subsystem of MPPT with fuzzy logic control

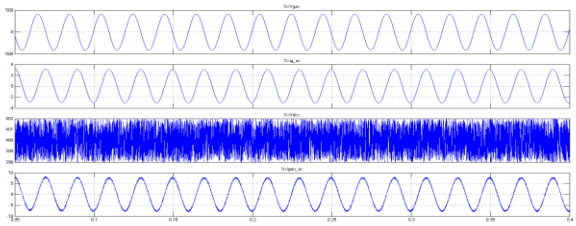
Case1: Steady-State Performance



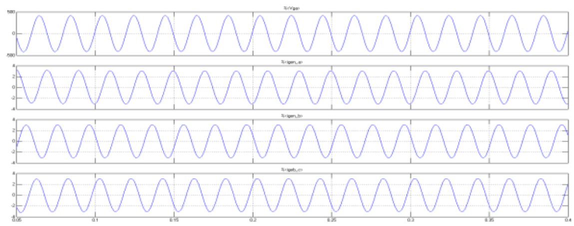
(a)



(b)

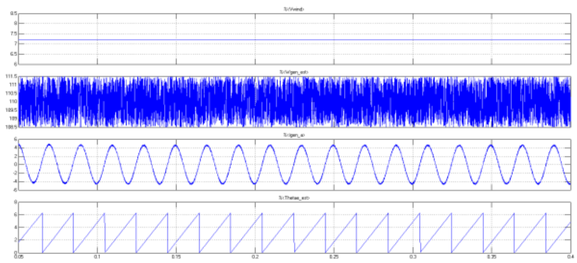


(c)

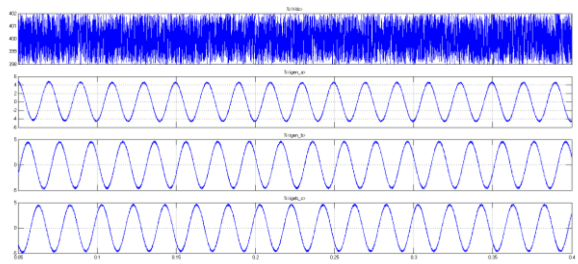


(d)

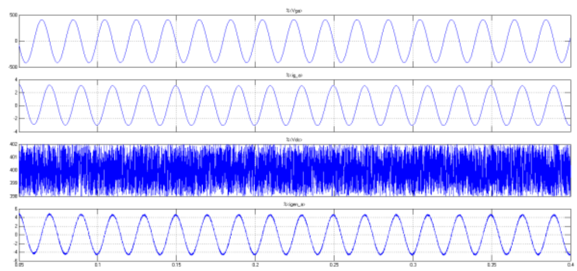
Fig.10 (a-d) Response of WEGS at 12 m/s wind speed in steady state



(a)



(b)



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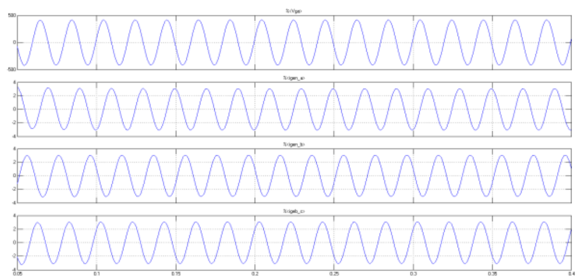
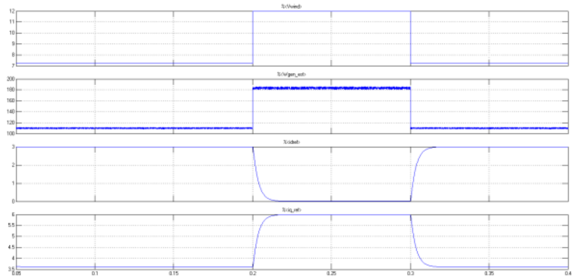


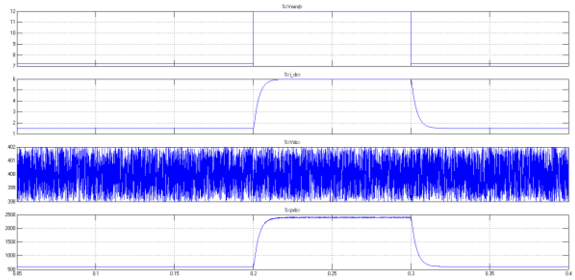
(d)

Figs. 11 (a-d) At 7.2 m/s wind speed, the WEGS has a steady state response.

Case 2: Variable Wind Speed Operation



(a)



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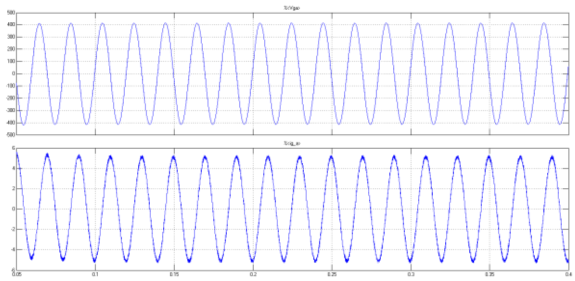

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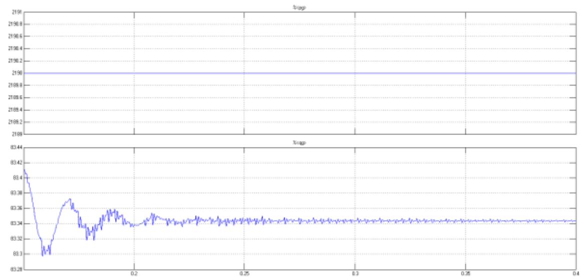

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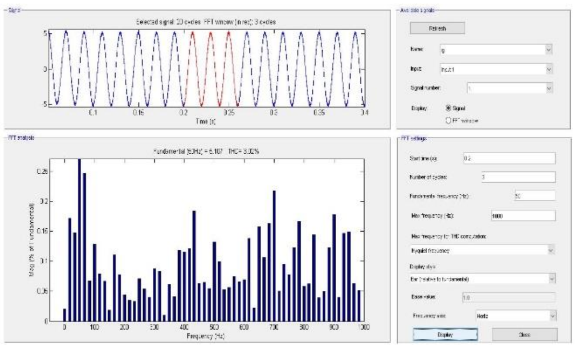
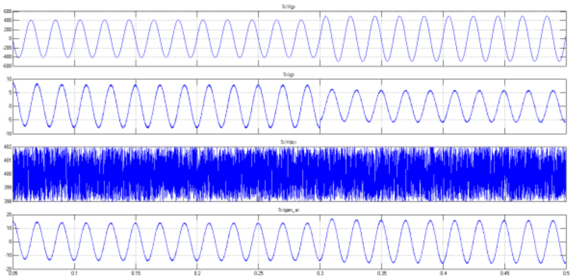


(e)

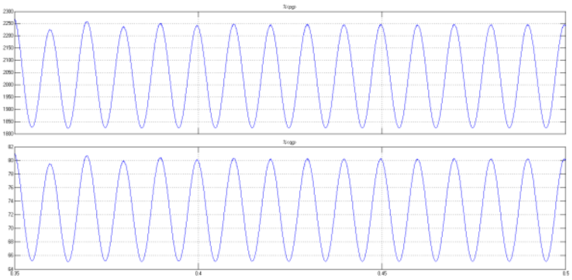
Fig. 12 (a-b) The system's dynamic performance when wind speed increases (c) vga and iga at 12 m/s (d) The grid was supplied with electricity (e) iga's harmonic spectrum

Case 3: The System's Performance in a Weak Grid Environment

1) Voltage Swell Condition:



(A)



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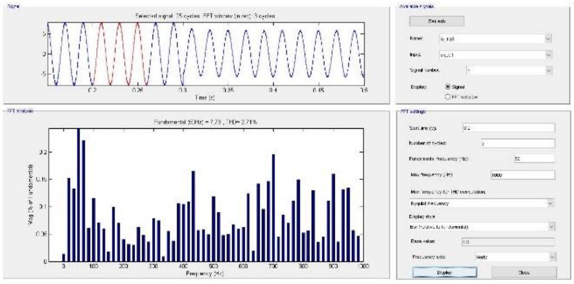
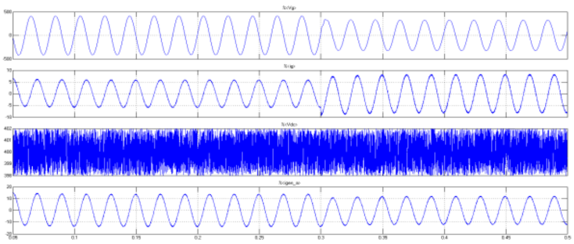


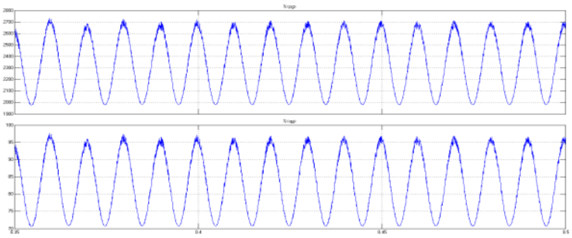
(C)

Fig.13 (A) WEGS response to voltage swell, (B) power delivered into the grid (C) iga harmonic spectrums are all shown in this figure.

2) Voltage Sag Condition:



(A)



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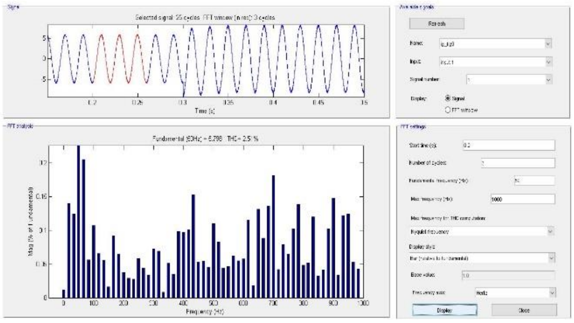
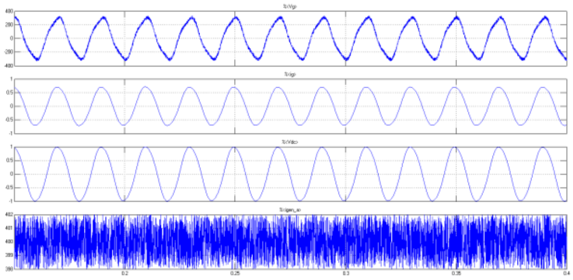


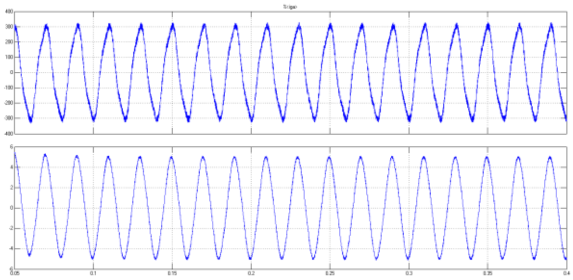
(C)

Fig.14 (A) WEGS response to voltage sag, (B) power delivered into the grid (C) iga harmonic spectrums are all shown in this figure.

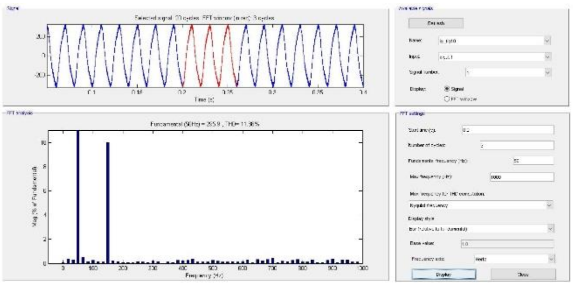
3) Grid Voltage Distortion:



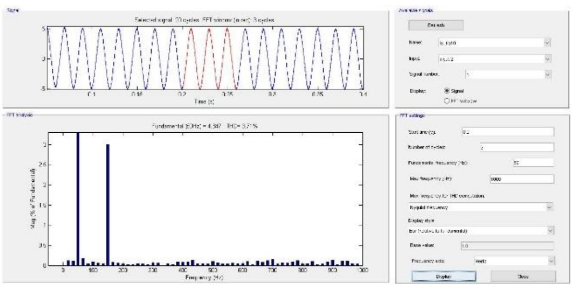
(A)



(B)



(C)



(D)

Fig.15 HGI control (A) and vga and iga (B) performance under grid voltage distortion grid current harmonic spectra (C) and grid voltage harmonic spectra (iga) (D).

4) Grid Voltage Unbalance:

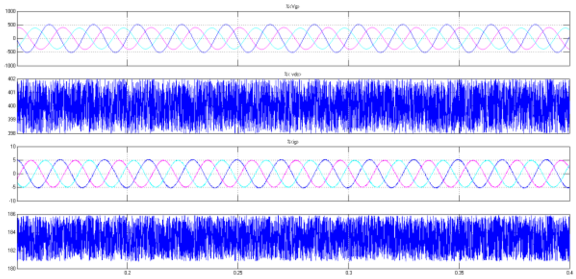


Fig.16 (A) Grid voltage imbalance and DC link voltage, (B) balanced grid currents under voltage imbalance and predicted generator speed,

B) EXTENSION RESULTS WITH ANFIS CONTROLLER

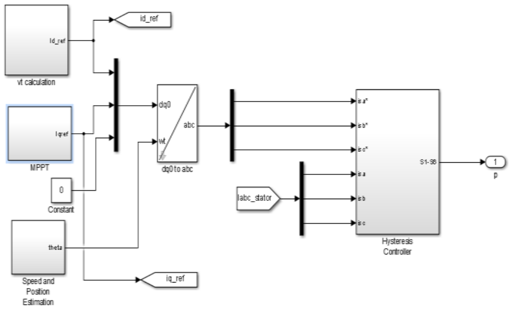


Fig.17 control system for MSVSC with ANFIS controller

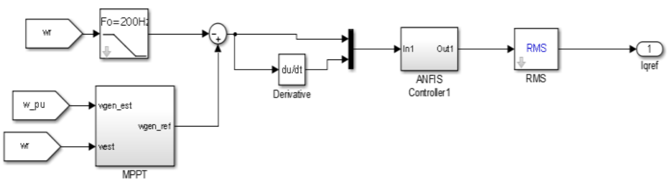
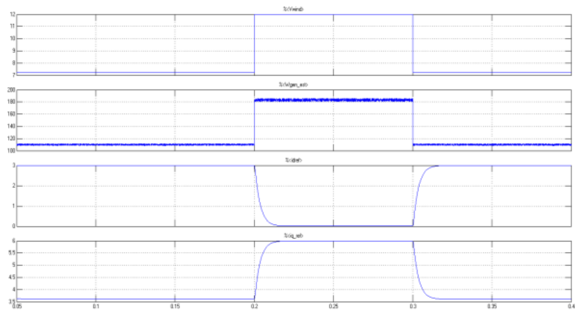
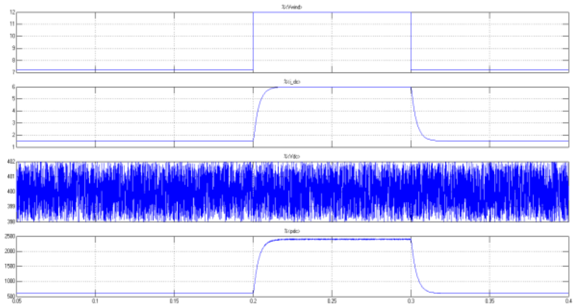


Fig.18 Subsystem of MPPT with fuzzy logic control

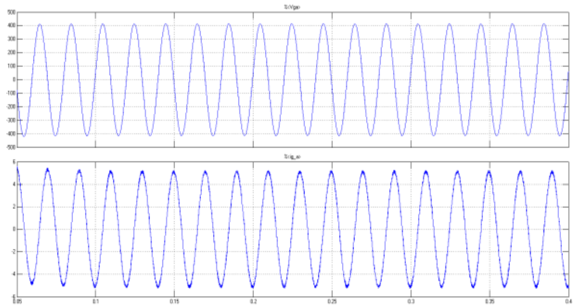
Case 2: Variable Wind Speed Operation



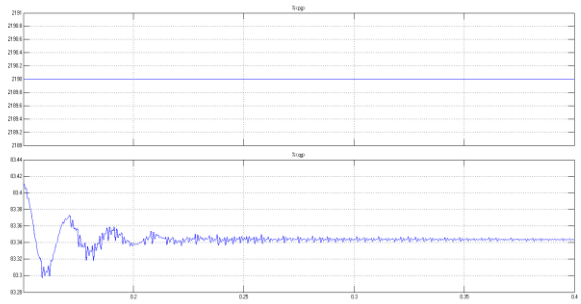
(A)



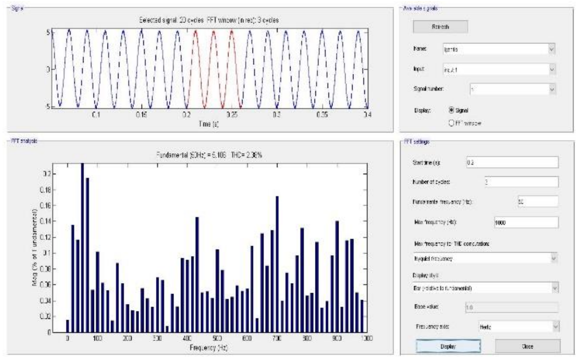
(B)



(C)



(D)

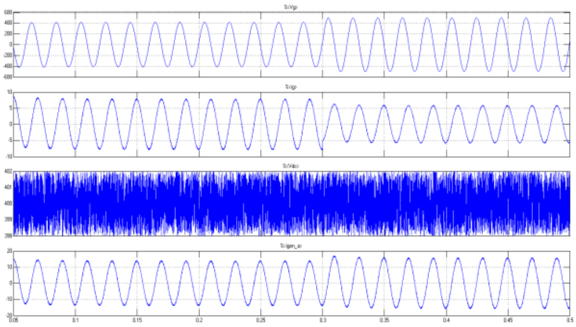


(e)

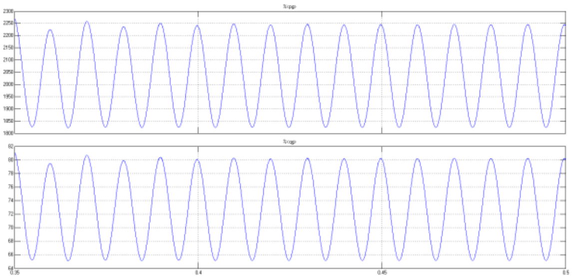
Fig. 19 Dynamics of the system under increasing wind speed (A-B), (C) vga/iga under wind speed of 12m/s (D) Grid power (E) iga harmonic spectram

Case3. Performance of System under Weak Grid Condition

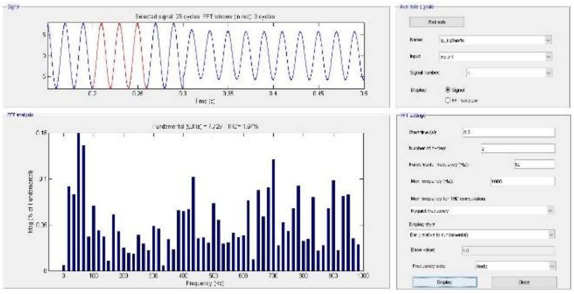
1) Voltage Swell Condition:



(A)



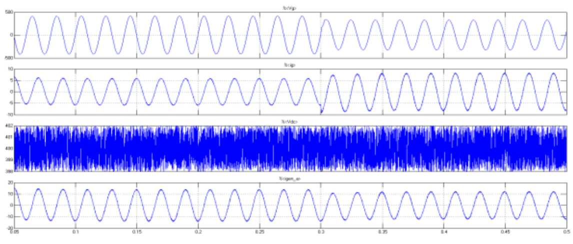
(B)



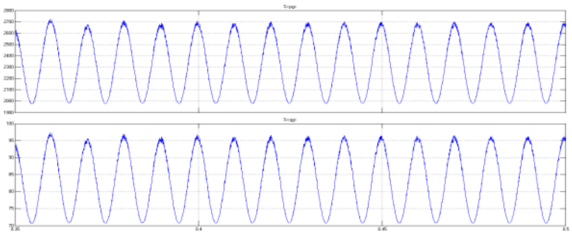
(C)

Fig.20 (A) WEGS response to voltage swell, (B) power delivered into the grid (C) iga harmonic spectrums are all shown in this figure.

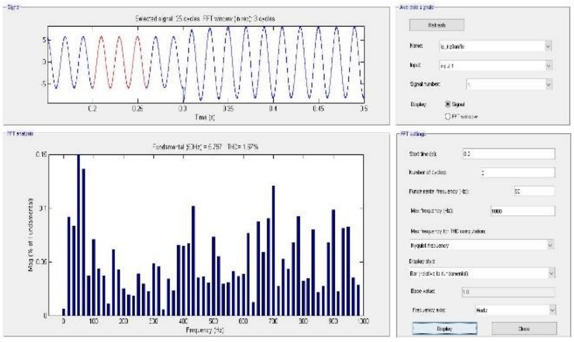
2) Voltage Sag Condition:



(A)



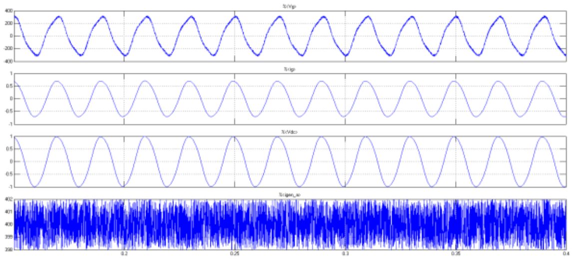
(B)



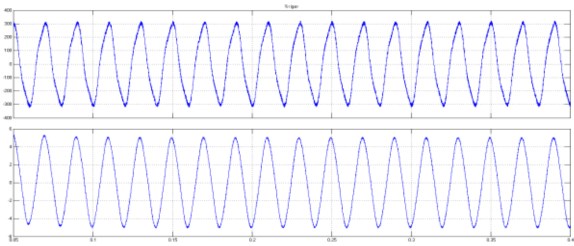
(C)

Fig. 21 (A) WEGS response to voltage sag, (B) power delivered into the grid (C) iga harmonic spectrums are all shown in this figure.

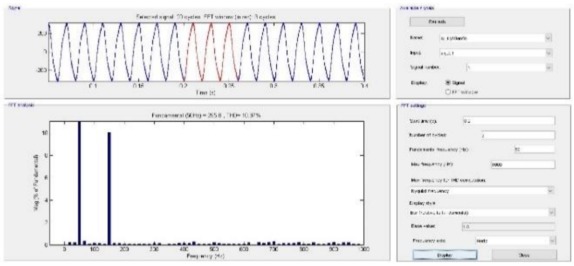
3) Grid Voltage Distortion:



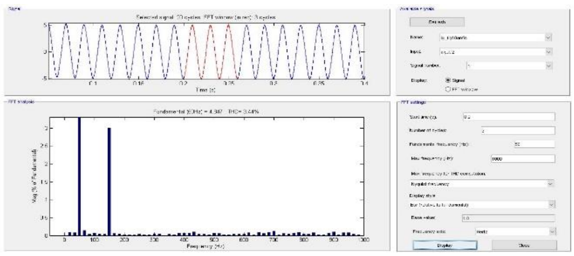
(A)



(B)



(C)



(D)

Fig. 22 performance of HGI control (A) and vga and iga (B) performance under grid voltage distortion grid current harmonic spectra (C) and grid voltage harmonic spectra (iga) (D).

4) Grid Voltage Unbalance:

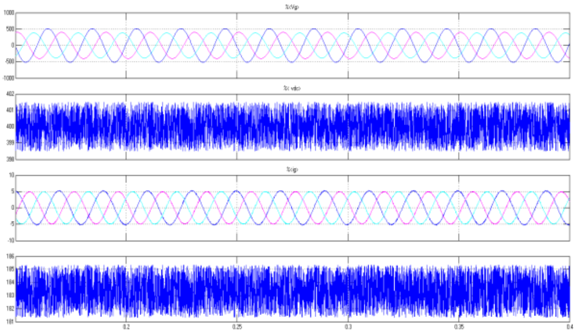


Fig.23 (A) Grid voltage imbalance and DC link voltage, (B) balanced grid currents under voltage imbalance and predicted generator speed

THD COMPARISION TABLE

Variable Wind Speed Operation

	FLC	PROPOSED ANFIS
THD % of grid current	3.02%	2.38%

Under Weak Grid Condition

1) Voltage Swell Condition:	FLC	ANFIS
THD% of Ig	2.71%	1.67%

2) Voltage Sag Condition:	FLC	ANFIS
THD% of Ig	2.51%	1.67%

2) Voltage Sag Condition:	FLC	ANFIS
THD% of Ig	3.71%	3.44%
THD% of Vg	11.86%	10.87%

CONCLUSION

The authors carried out a detailed study on the recommended system using SG-based WEGS in standard & weak grid settings to evaluate its capabilities. Satisfactory rejection of harmonics, subharmonics, & dc offset in the input signal was obtained with the HGI adaptive control. PQ was likewise significantly boosted in the extraction rate, albeit with a pure sinusoidal wavelength. Tensile distortion, voltage imbalances, strong harmonic immunity, & good frequency responsiveness were added advantages of HGI. When using an ANFIS-based speed control, the speed is set to converge with the reference generator as quickly as possible. Speed control was improved by using ANFIS. The system performance was demonstrated to be effective as grid circumstances continued to weaken. The testing results for a produced prototype have proven the usefulness of controlling processes. This feature ensures compliance with IEEE-519, & also has less than 5% THD under enforced anomalies.

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