International Journal of Advances in Applied Sciences (IJAAS)
Vol. 15, No. 3, September 2026, pp. 1050~1058
ISSN: 2252-8814, DOI: 10.11591/ijaas.v15.i3.pp1050-1058

Low-switch count based excitation of induction generator in wind power generation

Nijam Uddin Molla[1], Shilpi Bhattacharya[1], Debashis Chatterjee[2], Arabinda Das[2]
[1]Department of Electrical Engineering, RCC Institute of Information Technology, Kolkata, India
[2]Department of Electrical Engineering, Faculty of Engineering and Technology, Jadavpur University, Kolkata, India

Article Info

Article history:

Received Sep 30, 2024
Revised Jun 19, 2026
Accepted Aug 13, 2026

Keywords:

Induction generator
Self-excitation
Split phase induction motor
Standalone power system
Wind energy conversion system

ABSTRACT

The power sector is undergoing sea changes from conventional forms of power generation towards renewable energy due to diminishing resources of conventional sources of energy and also to deal with environmental issues. Three-phase self-excited induction generators (IGs) are popular in power generation from renewable sources in grid-connected as well as standalone systems. The single-phase induction generators (SPIG) with self-excitation capacitors are used in domestic applications. This paper proposes a novel reduced switch-based converter excitation system for an asymmetrical split-phase induction generators (ASPIG) application in a standalone wind energy-based power generation system. Instead of the normal six-switch inverter, the excitation scheme proposed here comprises of four numbers of power switches and four capacitors. Proper control shows that variable excitation can be effectively provided to the ASPIG using only four switches with reasonably good performance on sufficient loading and wide speed range. The proposed system is implemented and tested on load and at varied speeds in MATLAB/Simulink. This paper presents a novel excitation scheme, modeling, control, simulation, and analysis. The results obtained are reported to be effective and satisfactory in wide speed range in the standalone system.

Corresponding Author:

Shilpi Bhattacharya
Department of Electrical Engineering, RCC Institute of Information Technology
Beleghata, Kolkata 700015, India
Email: shilpibhatt2013@gmail.com

1. INTRODUCTION

The energy demand is on the rise worldwide at a continuous pace. Hence, the world is steadily moving towards renewable energy sources mainly for emission of toxic pollutants and threat of exhausting fossil fuel reserves [1]. In view of this, several forms of renewable resources such as solar (photovoltaic), wind, geothermal, and tidal have been in vogue among researchers and power engineers [2]–[4]. An extensive study on the role of renewable energy in the changing world energy scenario is detailed in recent research [5]. The tremendous growth of power electronic devices and power converter technology, renewable energy power generation is expanding at a fast pace [6]–[8].

Among these, wind energy has generated a lot of interest among energy providers and academia people for its eco-friendly power generation [9]–[13]. Wind energy is popular for power generation in grid-connected schemes. Wind energy conversion systems (WECS) are also gaining momentum in isolated grids in regions where electrification through grid is not viable due to geographical constraints, higher transmission costs and associated losses. Variable wind speeds and their intermittent nature dictate proper design and control of WECS. Standalone power sources are becoming popular to deliver remote and grid inaccessible areas. Wind energy harnessing for the generation of electricity with the use of induction generators (IGs) is a well-explored domain. IGs, both with constant and variable wind speeds, are often chosen in wind energy applications for power generation. In most cases, the preferred choice is three-phase IGs for their superiority in terms of robustness and minimal maintenance. Also, in large-scale wind energy power systems, three-phase IGs are able to meet the energy demand. Capacitors in star or delta are connected across the three-phase IG terminals for self-excitation [14]–[18]. The techniques of using three-phase IGs for generation of power for single-phase applications are presented [19], [20].

Single-phase induction generators (SPIG) are used in small-scale wind turbines. The split-phase induction machines are very common and widely used for their simplicity, rugged construction, and cost-effectiveness in single-phase applications. These machines are of low horsepower (HP) rating, aptly suited for single-phase domestic loads. SPIG consists of two asymmetrical main and auxiliary windings on the stator, which are spatially displaced from each other by 90°. These machines, coupled to the wind turbine, may effectively be operated as a generator in standalone domestic applications [21]–[30]. In off-grid power systems, maintaining voltage regulation for self-excited induction generators (SEIG) is a tough task owing to the fluctuations in wind speed and varying loads. In SPIG, excitation capacitors are connected across the main and/or auxiliary windings for excitation. As there is increase in load or as the wind speed changes, the variable reactive power demand cannot be supplied any longer; in that case, variable excitation schemes are proposed in various literature, detailed in literature survey. To achieve better voltage regulation, variable excitation is provided through switching control of inverter-assisted SPIG schemes.

In this paper, a novel variable excitation system is proposed for an asymmetrical split-phase induction generators (ASPIG) with reduced number of power switches in a standalone wind energy-based power generation system suitable for domestic applications. In most cases, the switching circuit is a six-switch-based inverter topology in conjunction with capacitors for self-excitation, which suffers from disadvantages of low reliability, high switching losses, and complicated control strategies. A single-phase induction machine is utilized as an asymmetrical two-phase IG in this work. The proposed excitation system consists of two sets of dual capacitors placed across a half-bridge configuration formed with two insulated-gate bipolar transistors (IGBT's). Two such units are connected across the main and auxiliary winding accordingly, with the midpoints of IGBT's connected to one terminal of main and auxiliary winding respectively. Whereas the mid-points of capacitors are connected to other terminal of main and auxiliary winding respectively forming a common point. The proposed structure is tested under single-phase variable electrical load with different power factors. The ASPIG is found to operate successfully and generate steady voltages and currents with acceptable distortion limits for varying power factor loads. This wind energy power system based on ASPIG with the novel variable self-excitation system is also observed to operate effectively under wide variations in wind speed. The dynamic model, control, simulation, results, and discussion are presented in this work.

2. DYNAMIC MODEL OF PROPOSED ASPIG

Model of asymmetrical split-phase induction machines: the two-phase induction machine has two stator windings, namely the main winding and the auxiliary winding, which are 90° in space apart and a squirrel-cage rotor winding. Auxiliary winding resistance is generally greater than the main winding, and main winding inductance is greater than the auxiliary winding inductance. The dynamic model of the SPIG is as shown in Figure 1, where Figure 1(a) presents the q-axis model and Figure 1(b) presents the d-axis model.

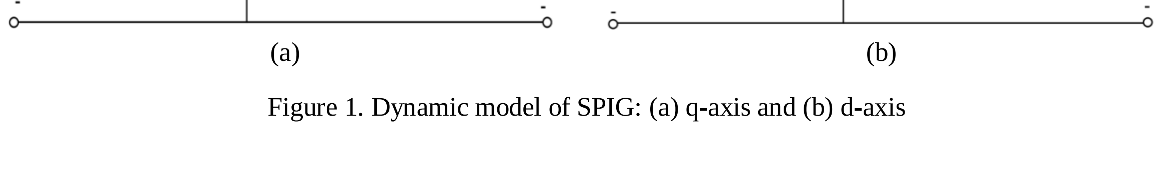


Figure 1. Dynamic model of SPIG: (a) q-axis and (b) d-axis

The dynamic model equations of SPIG are given in (1) to (9).

$$V_{qs} = R_{ms} i_{qs} + \frac{d\varphi_{qs}}{dt} \tag{1}$$

$$V_{ds} = R_{as} i_{ds} + \frac{d\varphi_{ds}}{dt} \tag{2}$$

$$V_{qr} = R_{mr}i_{qr} + \frac{d\varphi_{qr}}{dt} - \alpha\varphi_{dr}\omega_r \quad (3)$$

$$V_{dr} = R_{ar}i_{dr} + \frac{d\varphi_{dr}}{dt} - \frac{1}{\alpha}\varphi_{qr}\omega_r \quad (4)$$

$$\varphi_{ds} = L_{asr}i_{ds} + L_{as}i_{dr} \quad (5)$$

$$\varphi_{qs} = L_{msr}i_{qs} + L_{ms}i_{qr} \quad (6)$$

$$\varphi_{dr} = L_r i_{dr} + L_{as}i_{ds} \quad (7)$$

$$\varphi_{qr} = L_r i_{qr} + L_{ms}i_{qs} \quad (8)$$

$$T_e = \frac{1}{\propto}\varphi_{qr}i_{dr} - \alpha\varphi_{dr}i_{qr} \quad (9)$$

Where V_{ds}, V_{qs}, V_{dr}, V_{qr}, i_{ds}, i_{qs}, i_{dr}, i_{qr}, φ_{ds}, φ_{qs}, φ_{dr}, and φ_{qr} are the d-q axis voltages, currents, and flux of stator and rotor in the stator reference frame. R_{ms}, R_{as}, R_{mr}, and R_{ar} are the main and auxiliary winding stator and rotor reactances. L_{ms} and L_{as} are the main winding and auxiliary winding magnetizing inductances. L_{msr} and L_{asr} are the total stator and rotor leakage inductances of main and auxiliary windings, respectively. $\omega r$is the rotor speed in rad/s.

3. COMPARATIVE STUDY WITH STANDARD TOPOLOGIES

A single-phase load is supplied from a three-phase IG proposed in [25], where two phases are excited with variable capacitors. Sardyoung *et al*. [26] used a single-phase AC/DC/AC converter system for microhydel and wind energy in a grid-connected system where the SPIG is equipped with two specially designed stator windings placed in quadrature. A photovoltaic panel is connected at the DC link of the inverter to supplement power generation. To ensure sustained voltage during periods of low solar insolation, nighttime, or under high load conditions, an intermediate battery storage unit is incorporated. In this scheme, a DC–DC converter is used to control the generated voltage, which is first rectified using a diode-based rectifier connected across the main winding of the SPIG. Furthermore, Ojo *et al*. [27] proposed an alternative variable excitation method, wherein excitation is provided through a single-phase inverter–battery system connected across the auxiliary winding, along with a capacitor and filter circuit for voltage regulation. The single-phase load is connected across the main winding in this configuration. However, the requirement of an additional battery in this scheme increases both the overall system cost and maintenance requirements. In proposed system, variable excitation of main winding and auxiliary windings are done by self-induced voltage and controlled by respective inverter circuits. Moreover, the proposed system does not require any extra battery in contrast to the above systems thus reducing the cost and low in maintenance.

In another study, the control of SPIG was proposed for supplying domestic loads connected across the main winding, while variable excitation was provided through the auxiliary winding [28]. To enhance system reliability, an additional photovoltaic panel, integrated through an inverter system and supported by a storage battery, was connected across the auxiliary winding. Mossad *et al*. [29] proposed an SPIG-based isolated power generation system to regulate the load voltage. In this WECS configuration, voltage regulation is achieved by using a switched capacitor connected across the auxiliary winding of the generator, while the load is directly connected to the main winding. Furthermore, Choorak and Kinnares [30] presented a modified two-phase IG with separate main and auxiliary windings. An silicon-controlled rectifier SCR-based soft-starting mechanism and a shunt active filter-based grid-connected SPIG generation system are proposed in [31]. However, in this scheme, the total harmonic distortion (THD) for load current is quite high. In the proposed system, both windings are excited and connected in a manner so that the impressed voltage across the load is phasor addition of individual voltages. Hence, the load voltage is comparatively higher than in all existing topologies where the load is connected across any one winding.

4. PROPOSED SYSTEM STRUCTURE AND CONTROL

Figure 2 shows the reduced switch-based excitation circuit for the ASPIG. The circuit comprises of two half-bridge inverter circuits with respective center-tapped capacitors. The main winding terminals are connected to center point of inverter leg of T1 and T2 and center point of CM1 and CM2. The auxiliary winding terminals are connected to center point of inverter leg of T3 and T4 and center point of CA1 and

CA2. The load is connected across terminals as shown. Main winding excitation is provided and controlled by the half-bridge inverter made by T1, T2, CM1, and CM2. For excitation control, the triggering of T1 and T2 is implemented where gate pulses are 1,800 shifted. The other half-bridge inverter formed by T3, T4, CA1, and CA2 are controlled to provide excitation to the auxiliary winding. The triggering of T3 and T4 is implemented where both gate pulses are 1,800 shifted. Also, the gate pulses of auxiliary inverter and main inverter is again 900 shifted from each other according to the ASPIG structure. The important features of the proposed scheme are: i) the proposed two-winding ASPIG scheme reduces switch count to 2/3rd of the six-switch configuration, hence more cost-effective, reliable, with low switching losses and ease of control; ii) it can utilize extended ranges of wind speeds for power generation; and iii) stable voltage for varying loads. The system parameters with specifications are enlisted in Table 1.

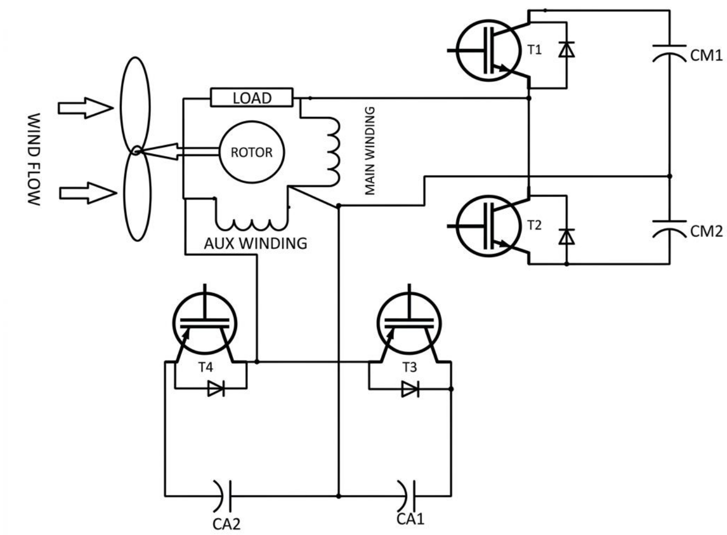


Figure 2. Proposed reduced switch excitation system

Table 1. System parameters

Type of machine	Split phase induction machine	Inertia	0.0146 kg m^2
Power	1,000 VA	No of poles	4
Voltage	220 V	Main winding rotor resistance	7.14 Ω
Frequency	50 Hz	Main winding rotor inductance	8.5 mH
Main winding stator resistance	2.02 Ω	Turn ratio: auxiliary/main	1.18
Main winding stator inductance	10 mH		
Auxiliary winding stator resistance	7.14 Ω	IGBTs (4 nos)	600 V, 10 A
Auxiliary winding stator inductance	8.5 mH		
Main winding mutual inductance	0.1772 H	Capacitors (4 nos)	400V, 40 µF

5. SIMULATION RESULTS AND DISCUSSION

The proposed reduced switch variable excitation system for ASPIG is simulated in MATLAB/Simulink. The ASPIG is rated at 1 kVA, 220 V, 50 Hz, and it is subjected to loading conditions as in Table 2. The simulation diagram is shown in Figure 3. The following cases were reported. Case I: wind speed 10 m/s and load power factor 0.7 lagging: the peak load voltage is 300 V and peak load current is 3 A, as in Figure 4. The fast Fourier transform (FFT) analysis of load voltage is shown in Figure 5; its THD is 0.13%.

Table 2. Load parameters

Z (Ω)	Power factor (lagging)	Current (A)
135	0.7	2
122	0.83	3
160	0.7	1.6
54	0.7	3.9

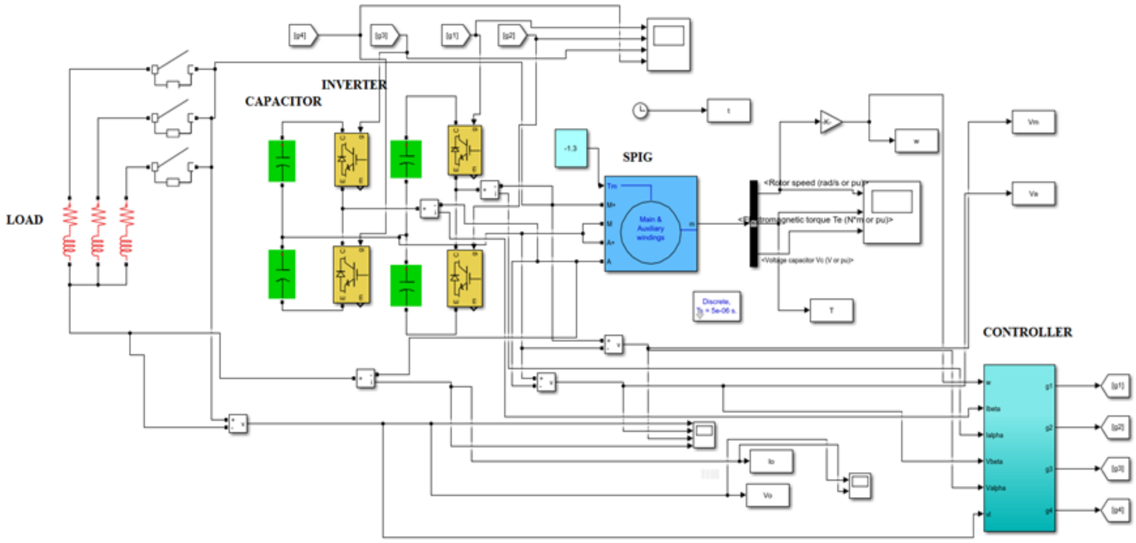


Figure 3. Simulation diagram of proposed system

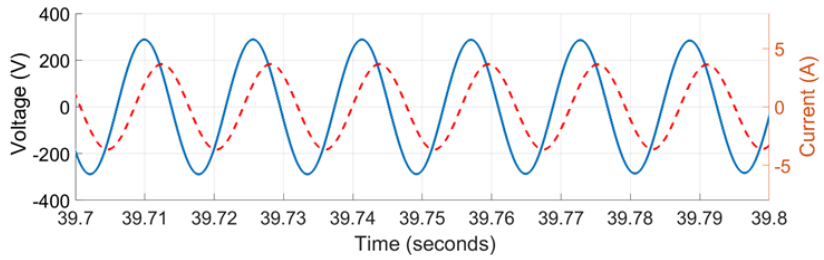


Figure 4. Load voltage and load current at wind speed (10 m/s) of load power factor of 0.7 (lagging)

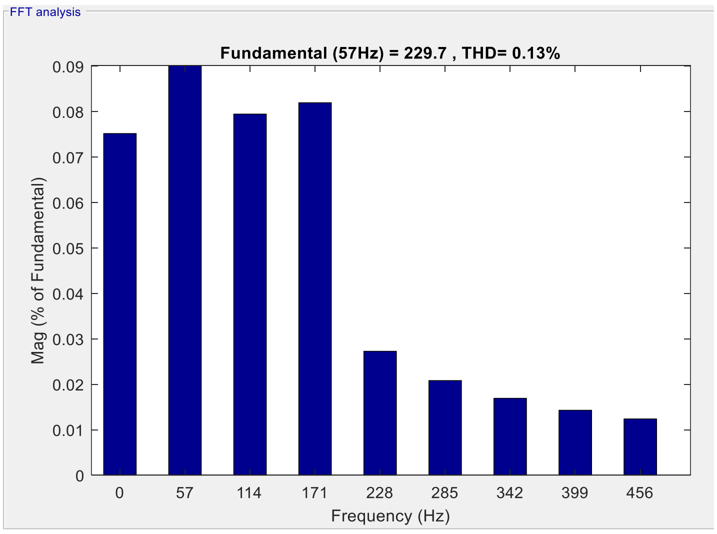


Figure 5. FFT analysis of load voltage at wind speed 10 m/s and 0.7 power factor (lagging)

Figure 6 shows FFT analysis of the load current; the THD of current obtained is 0.15%. The load current THD is shown to be obtained as 3.7% in [28]. In [31], THD of non-linear load current is at 55.5%.

The load voltage and load current profile for different loads connected at 10 seconds and 25 seconds respectively is shown in Figure 7. First the system is started without load. At 10 seconds first load is connected, and second load is connected at 25 seconds. Under these conditions, it is seen that the system retains stability within few seconds. The transition of rotor speed for the above loading conditions is plotted in Figure 8. Case II: wind speed 8 m/s and load power factor 0.7 lagging: the peak voltage across load is 230 V, and peak load current is 2.2 A, as depicted in Figure 9. Case III: wind speed 13 m/s and load power factor 0.83 lagging: peak value of main winding, auxiliary winding, load voltage, and load current are shown in Figure 10. The load current is also plotted in Figure 11. Case IV: wind speed 10 m/s and load power factor 0.83 lagging: when peak load current is 2.2 A, both waveforms of load current and load voltage are shown in Figure 11(a). Also, at a changed load current of 3 A, the load voltage and current are plotted in Figure 11(b). The voltage regulation curve is plotted for varied load currents is shown in Figure 12. It is observed that the voltage variation is low during changes in load current. The voltage regulation is within the acceptable limits.

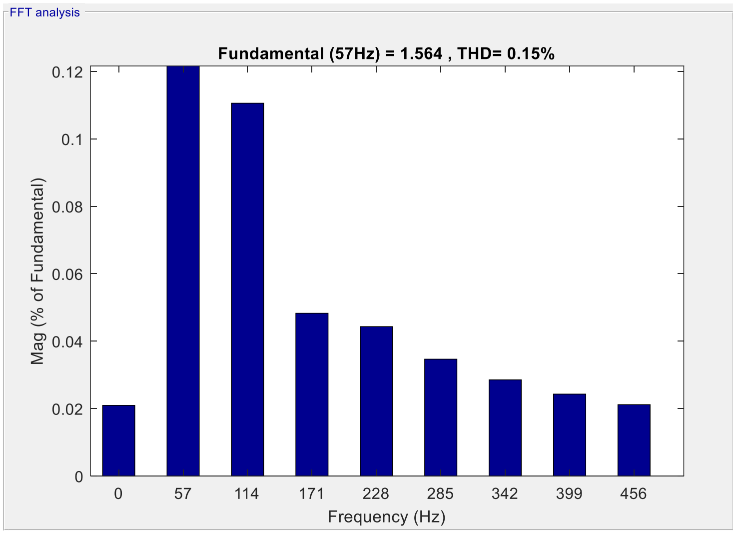


Figure 6. FFT analysis of load current at wind speed 10 m/s and 0.7 power factor (lagging)

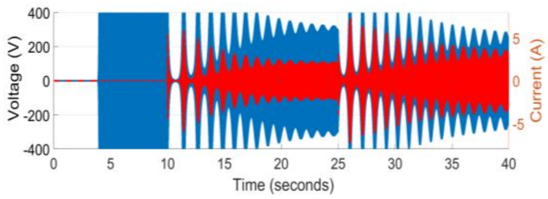


Figure 7. Load voltage and load current profile for load changes at 10 sec and 25 sec

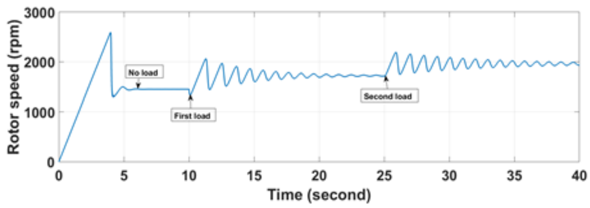


Figure 8. Rotor speed transition from no load to different loads when the wind speed is 10 m/s

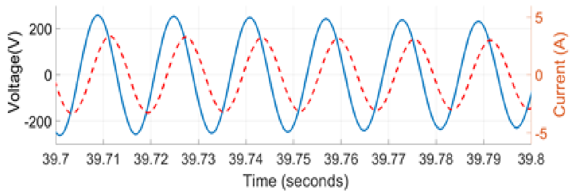


Figure 9. Load voltage and load current at wind speed (8 m/s) and load power factor 0.7 (lagging)

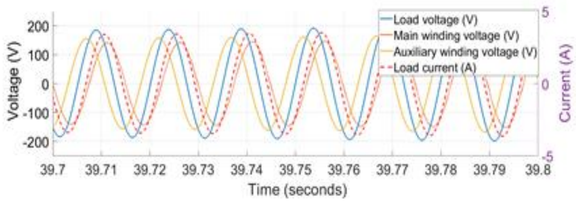
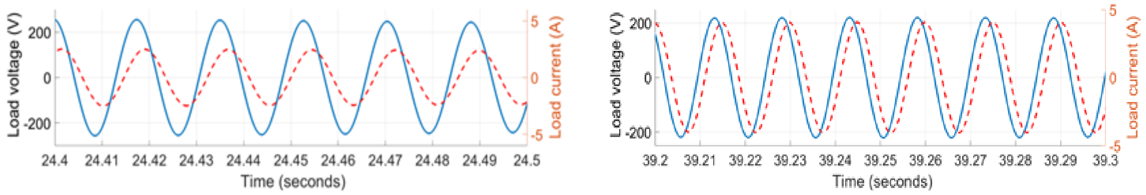


Figure 10. Main winding voltage, auxiliary winding voltage, load voltage, and load current at wind speed (13 m/s) with load power factor 0.83 (lagging)



(a) (b)

Figure 11. Load voltage and load current at (a) wind speed (10 m/s), load current 1.7 A, power factor 0.83 (lagging) and (b) wind speed (10 m/s), load current of 2.7 A, load power factor 0.83 (lagging)

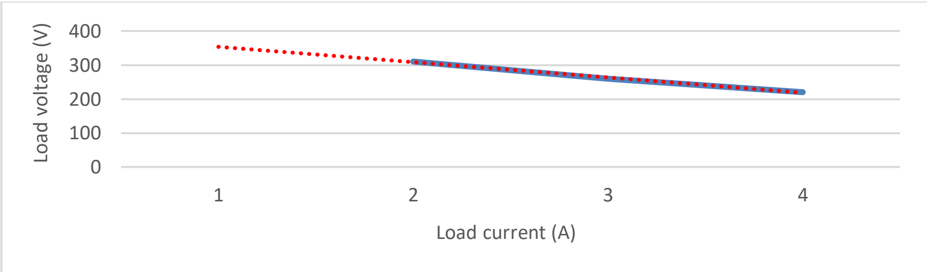


Figure 12. Voltage regulation at wind speed 13 m/s

6. CONCLUSION

In this paper, an ASPIG is used for power generation in a standalone single-phase application in a wind energy-based power generation scheme. Here, a reduced switch-based converter system is proposed for excitation of the system. The novelty of the excitation scheme lies in using lesser number of power devices to generate appreciably higher voltage. The proposed two-phase IG system has been observed and reported to maintain steady voltages across a wide range of loads, effectively utilizing varying wind speeds. The results are promising, demonstrating that despite having fewer power switches, the system can meet the output requirements for small-scale, standalone domestic applications, particularly in remote areas. This ASPIG configuration is expected to be more cost-effective and reliable than other alternatives. Additionally, the control complexity is reduced, as two switches are eliminated in this setup, unlike the conventional three-leg voltage source inverter that requires six switches.

FUNDING INFORMATION

The authors hereby declare that no financial grants or funding of any kind were received for the conduct of this research, and the work was carried out independently without any external support.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Nijam Uddin Molla	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Shilpi Bhattacharya	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Debashis Chatterjee	✓	✓			✓	✓				✓		✓	✓	
Arabinda Das		✓				✓				✓		✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial or non-financial interest that could have appeared to influence the work reported in this paper submitted to this journal.

DATA AVAILABILITY

All the data presented in this work were obtained through simulation in the MATLAB/Simulink platform. The work was performed on the proposed system and tested on a simulation model.

REFERENCES

[1] R. M. Elavarasan *et al.*, "A comprehensive review on renewable energy development, challenges, and policies of leading Indian states with an international perspective," *IEEE Access*, vol. 8, pp. 74432–74457, 2020, doi: 10.1109/ACCESS.2020.2988011.

[2] M. R. Patel, *Wind and solar power systems: design, analysis and operation*, 2nd Ed. Boca Raton, Florida: CRC Press, 2005.

[3] W. Alnatsha, F. Zaro, I. Khatib, and M. Jawadeh, "Techno-economic feasibility analysis of solar-wind energy conversion system utilizing genetic algorithm," in *2019 6th International Conference on Electrical and Electronics Engineering*, Apr. 2019, pp. 349–353, doi: 10.1109/ICEEE2019.2019.00074.

[4] K. V. B. Reddy, A. Murali, A. P. Rao, P. Laxma, D. S. Siddhartha, and J. V. Bhargav, "Analysis of a grid-connected photovoltaic/wind hybrid power system's performance," in *2025 IEEE International Conference on Interdisciplinary Approaches in Technology and Management for Social Innovation*, Mar. 2025, pp. 1–6, doi: 10.1109/IATMSI64286.2025.10985623.

[5] B. Mendi, M. Pattnaik, and G. Srungavarapu, "A single current sensor based adaptive step size MPPT control of a small scale variable speed wind energy conversion system," *Applied Energy*, vol. 357, Mar. 2024, doi: 10.1016/j.apenergy.2023.122492.

[6] R. Melício, V. M. F. Mendes, and J. P. S. Catalão, "Power converter topologies for wind energy conversion systems: integrated modeling, control strategy and performance simulation," *Renewable Energy*, vol. 35, no. 10, pp. 2165–2174, Oct. 2010, doi: 10.1016/j.renene.2010.03.009.

[7] M. Liserre, T. Sauter, and J. Hung, "Future energy systems: integrating renewable energy sources into the smart power grid through industrial electronics," *IEEE Industrial Electronics Magazine*, vol. 4, no. 1, pp. 18–37, Mar. 2010, doi: 10.1109/MIE.2010.935861.

[8] F. Blaabjerg and K. Ma, "Future on power electronics for wind turbine systems," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 1, no. 3, pp. 139–152, Sep. 2013, doi: 10.1109/JESTPE.2013.2275978.

[9] Q. Hassan *et al.*, "The renewable energy role in the global energy transformations," *Renewable Energy Focus*, vol. 48, Mar. 2024, doi: 10.1016/j.ref.2024.100545.

[10] S. Rizvi, S. P. Singh, and R. Tyagi, "Advances in offshore wind turbine systems: a technical review," in *2024 International BIT Conference*, Dec. 2024, pp. 1–5, doi: 10.1109/BITCON63716.2024.10985379.

[11] E. S. Abdin and W. Xu, "Control design and dynamic performance analysis of a wind turbine-induction generator unit," *IEEE Transactions on Energy Conversion*, vol. 15, no. 1, pp. 91–96, Mar. 2000, doi: 10.1109/60.849122.

[12] Y. Ma, J. Xu, G. Li, and K. Wang, "Stability and dynamic analysis of PMSG-based wind generation system considering torsional oscillation and virtual inertia control," *Journal of Modern Power Systems and Clean Energy*, vol. 13, no. 3, pp. 852–864, 2024, doi: 10.35833/MPCE.2024.000573.

[13] C. Du, X. Du, C. Tong, Y. Li, and P. Zhou, "Stability analysis for DFIG-based wind farm grid-connected system under all wind speed conditions," *IEEE Transactions on Industry Applications*, vol. 59, no. 2, pp. 2430–2445, Mar. 2023, doi: 10.1109/TIA.2022.3218022.

[14] M. E. Moursi, K. Goweily, and E. A. Badran, "Enhanced fault ride through performance of self-excited induction generator-based wind park during unbalanced grid operation," *IET Power Electronics*, vol. 6, no. 8, pp. 1683–1695, Sep. 2013, doi: 10.1049/iet-pel.2012.0528.

[15] R. C. Bansal, "Three-phase self-excited induction generators: an overview," *IEEE Transactions on Energy Conversion*, vol. 20, no. 2, pp. 292–299, Jun. 2005, doi: 10.1109/TEC.2004.842395.

[16] B. M. Mohan, M. P. P. Reddy, and M. Lakshminarayana, "A fuzzy logic based MPPT controller for wind-driven three-phase self-excited induction generators supplying DC microgrid," *International Journal of Advances in Applied Sciences*, vol. 6, no. 4, pp. 325–334, Dec. 2017, doi: 10.11591/ijaas.v6.i4.pp325-334.

[17] Z. Wang, Q. Li, S. Kong, W. Li, J. Luo, and T. Huang, "Analysis of renewable energy consumption and economy considering the joint optimal allocation of 'renewable energy + energy storage + synchronous condenser,'" *Scientific Reports*, vol. 13, no. 1, Nov. 2023, doi: 10.1038/s41598-023-47401-4.

[18] A. S. Satpathy, D. Kastha, and N. K. Kishore, "Optimization of the excitation capacitor of a STATCOM assisted self excited induction generator based wind energy conversion system," in *IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society*, Oct. 2018, pp. 1904–1909, doi: 10.1109/IECON.2018.8591406.

[19] A. Krishnan and K. Natarajan, "An efficient power conversion scheme for a three-phase wind-driven induction generator feeding a single-phase grid," in *2021 National Power Electronics Conference*, Dec. 2021, pp. 1–6, doi: 10.1109/NPEC52100.2021.9672528.

[20] C. P. Ion and C. Marinescu, "Three-phase induction generators for single-phase power generation: an overview," *Renewable and Sustainable Energy Reviews*, vol. 22, pp. 73–80, Jun. 2013, doi: 10.1016/j.rser.2013.01.031.

[21] S. S. Murthy, "A novel self-induced self-regulated single phase induction generator. I. Basic system and theory," *IEEE Transactions on Energy Conversion*, vol. 8, no. 3, pp. 377–382, 1993, doi: 10.1109/60.257048.

[22] Y. H. A. Rahim, A. I. Alolah, and R. I. Al-Mudaiheem, "Performance of single phase induction generators," *IEEE Transactions on Energy Conversion*, vol. 8, no. 3, pp. 389–395, 1993, doi: 10.1109/60.257050.

[23] O. Ojo and I. Bhat, "An analysis of single-phase self-excited induction generators: model development and steady-state calculations," *IEEE Transactions on Energy Conversion*, vol. 10, no. 2, pp. 254–260, Jun. 1995, doi: 10.1109/60.391890.

[24] O. Ojo, "The transient and qualitative performance of a self-excited single-phase induction generator," *IEEE Transactions on Energy Conversion*, vol. 10, no. 3, pp. 493–501, 1995, doi: 10.1109/60.464873.

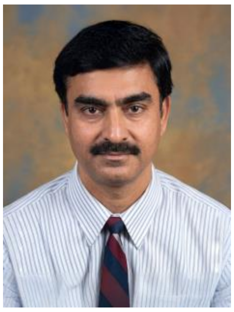
[25] S. Chakraborty, J. Samanta, and R. Pudur, "Experimental analysis of a modified scheme for supplying single-phase remote loads from micro-hydro based three-phase self-excited induction generator," *Measurement: Sensors*, vol. 33, Jun. 2024, doi: 10.1016/j.measen.2024.101166.

[26] P. Sardyoung, W. Promkhun, and V. Kinnares, "Single-phase AC/DC/AC converter system for a grid-connected asymmetrical parameter type two-phase induction generator," in *TENCON 2014 - 2014 IEEE Region 10 Conference*, Oct. 2014, pp. 1–6, doi: 10.1109/TENCON.2014.7022410.
[27] O. Ojo, O. Omozusi, and A. A. Jimoh, "The operation of an inverter-assisted single-phase induction generator," *IEEE Transactions on Industrial Electronics*, vol. 47, no. 3, pp. 632–640, Jun. 2000, doi: 10.1109/41.847904.
[28] A. Chatterjee and D. Chatterjee, "An improved current balancing technique of two-winding IG suitable for wind-PV-based grid-isolated hybrid generation system," *IEEE Systems Journal*, vol. 14, no. 4, pp. 4874–4882, Dec. 2020, doi: 10.1109/JSYST.2019.2960151.
[29] M. I. Mossad, F. A. Banakhr, S. S. M. Ghoneim, T. A. AbdulFattah, and M. M. Samy, "Self-regulated single-phase induction generator for variable speed stand-alone WECS," *Intelligent Automation & Soft Computing*, vol. 28, no. 3, pp. 715–727, 2021, doi: 10.32604/iasc.2021.017534.
[30] C. Choorak and V. Kinnares, "Performance evaluation of vector controlled asymmetrical two-phase induction generator using three-leg voltage source inverter," in *2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, Jun. 2016, pp. 1–5, doi: 10.1109/ECTICon.2016.7561445.
[31] N. Prapurt and V. Kinnares, "Single-phase grid connected induction generator with soft starting and power quality improvement," in *2022 25th International Conference on Electrical Machines and Systems*, Nov. 2022, pp. 1–5, doi: 10.1109/ICEMS56177.2022.9983045.

BIOGRAPHIES OF AUTHORS

Nijam Uddin Molla obtained his B.E. (Electrical) and M.E. from Jadavpur University. Now he works as an assistant professor in the Department of Electrical Engineering at RCC Institute of Information Technology, Kolkata. His research interests are in the areas of electrical machines, power systems, and renewable energies. He can be contacted at email: nuzjubee@gmail.com.

Shilpi Bhattacharya is an associate professor in Department of Electrical Engineering at RCC Institute of Information Technology, Kolkata, since 2011. She received her B.Tech. degree from National Institute of Technology, Agartala; M.Tech. from University of Calcutta; and Ph.D. degree from Jadavpur University. Her research interests include power electronics, electric drives, and renewable energies. She can be contacted at email: shilpibhatt2013@gmail.com or shilpi.bhattacharya@rcciit.org.in.



Debashis Chatterjee received the Ph.D. degree in Department of Electrical Engineering, Faculty of Engineering and Technology, from Jadavpur University, Kolkata, India, in 2005. He is currently a professor in the Department of Electrical Engineering, Faculty of Engineering and Technology, Jadavpur University. His research interests include electrical machines, variable-speed drives, electric vehicles, renewable-energy generation, and power quality studies. He can be contacted at email: debashisju@yahoo.com.

Arabinda Das is a professor in the Department of Electrical Engineering, Faculty of Engineering and Technology, Jadavpur University. Before joining in Jadavpur University in 1999, he worked as a lecturer at Regional Engineering College, Durgapur (presently National Institute of Technology, Durgapur) since 1996. He obtained his B.Tech., M.Tech., and Ph.D. degrees in 1990, 1992, and 2000, respectively, in Electrical Machines and Power Systems from the University of Calcutta. His field of interest is electrical machines and drives, application of microprocessor/microcontroller in electrical engineering and modeling, and simulation of electrical systems. He can be contacted at email: adas_ee_ju@yahoo.com.