Energy management of hybrid renewable energy system with fractional order PI controller based STATCOM

PANGA AKHILA[1] |S NAGANNA[2]B.SHIVAJI [3]

[1]Pg Scholar, Dept of EPS, Kodada Institute of Technology & Science for Women-Kodad, Telangana.

[2] Assistant Professor, Dept of EEE, Kodada Institute of Technology & Science for Women-Kodad,Telangana.

[3]Assoc Professor& HOD,Dept of EEE, Kodada Institute of Technology & Science for Women-Kodad,Telangana.

ABSTRACT: This article delineates energy co-ordination among hybrid renewable energy (HRE) sources and enhanced quality of power with a fractional order PI (FOPI) controller incorporated STATCOM. Solar and wind energy power generations are interfaced for deliver power to non-linear loads. Due environmental factors, intermittence nature the power produced by HRE sources is in unbalanced nature. These unbalanced voltage and currents impact the damage critical or sensitive loads. In this view, for the energy management of HRE sources and improves its quality of power, a static compensator (STATCOM) with integration of quasi-Z-Source Inverter (qZSI) is evolved in this work. For well operating STATCOM, FOPI controller modeled in this work. The power produced by PV system connected to qZSI converter to maximize its power. An adaptive frequency fixed-SOGI is employed to estimate the fundamental component of three phase currents, which can be utilizes for precise control of the STATCOM. However, the FOPI controller pose optimizes the controller parameters (K_p, K_i and fractional parameters) for achieve improved performance. To check the effectiveness of the proposed FOPI based STATCOM for HRE system, simulation study carried out for various mode of hybrid RE source operating conditions.

KEYWORDS: THD, PV, ENERGY MANAGEMENT, STATCOM, FLC.

I.INTRODUCTION: A essential test within the improvement of economically sound non-compulsory techniques for the technology of power is the fast expansion of herbal depletion worldwide. Thus, a number of exam is being completed all around the international with an give up goal to music

down an answer for executing a protracted haul and obviously pleasant strength age framework. Photovoltaic (PV), wind ranches, electricity additives, and biomass are the primary players within the sustainable power age industry [1]. A dependable strength plan, wind-driven unfastened designs have proven their capacity to meet the electrical necessities of an widespread number of everyday customers internationally, mainly in areas with a medium to excessive capability for wind power. Despite the reality that that is real, clients are discouraged from enforcing a sustainable electricity supply in areas with less favorable local conditions because of the requirement for a big amount of electricity stockpiling restriction and the oversizing of wind generators. At the factor while wind strength with a medium or excessive capacity is joined with daylight based totally power, there are a ton of puts on our planet [2]. This diminishes the need for electricity limit in regular free systems. When doubtful, the free use of wind and daytime power cannot meet the corporation's changing needs due to the fact their availability varies drastically with the course of the day.

To meet the strength needs of some distance off customers, free solar managed and wind strength structures must have over the top setting away cutoff [3]. It is viable to diminish how plenty strength stockpiling predicted by a framework by the use of the correlative idea of wind and daylight based strength. There are multiple everyday kinds of coursed energy age utilized in microgrid applications. In any case, the affiliation point strength converter is vital for the microgrid's consistency. Consequently, a steady and dependable circulated strength age framework can be ensured via the relationship factor strength converter's powerful electricity control [4]. Consequently, the number one consciousness of this examine is the enhancement of an off-community semi-Z-source inverter—a further sort of interacting inverter [5]. Depending on whether or not a transformer is used or no longer, in addition to whether a two-degree or staggered inverter is utilized, a variety of force converter regions are utilized in PV structures. Each of these regions has its personal set of benefits and drawbacks. Single-degree inverters are dislodging more wellknown -level models resulting from their little length, negligible value, and excessive getting through high-quality [6].

The popular inverter, then again, must be greater noteworthy to exchange in

accordance with the incredible swings in PV bunch voltage which might be welcomed on by way of the low result voltage of the PV sheets as well as the huge series of range that relies upon upon irradiance and temperature, automatically at a degree of one: 2. Although it's far predicted that huge low-recurrence transformers will connect an inverter's low voltage output to the network, these transformers have some disadvantages, including larger dimensions, lower efficiency, more acoustic commotion, and improved average fees. By utilizing a lift DC/DC converter to supply the information voltage from a extensive range to the suitable predictable price, the 2-degree inverter eliminates the want for a transformer [7]. Due to a defective transfer, the DC/DC converter becomes the framework's most luxurious and efficient element. For the reason of improving protection, some sun-primarily based managed strength age frameworks consist of galvanic confinement, which may be implemented both within the DC/DC guide converter that makes use of a excessive-recurrence transformer or at the air conditioner yield facet of a line recurrence transformer [8]. The normal length and value of the framework as an entire are accelerated as a result of this more galvanic separation, as is its general adequacy, and so forth. Transformerless topographies advantage in addition research because of their unrivaled capability, smaller size, and decrease PV gadget fee [9].

The qZSI has been applied in PV frameworks as a result of its unmarried-degree strength converter to push in advance and step-down capacities [10], [11]. In addition, the inverter shouldn't even ought to fear about being too effective to address a wide range of PV DC voltage stages. This lessens the overall expense of the framework and diminishes element matter and fees at the same time as furthermore expanding constancy and security. PV frameworks may additionally gain from qZSIs' particular and interesting blessings. By drawing a consistent current from the PV board and discarding the want for extra filtering capacitors, the qZSI decreases trading waves and deals with the PV system. Additionally, it simplifies the PV device and has a decrease factor (capacitor) rating. For the pulled out load situation, this examine utilized qZSI to crew up the PV-conveying shape. The creators of this survey understand the foundation of an AFF-SOGI manage assume up associated with a PV show and a Breeze Energy Change Construction (WECS)- kept up with qZSI-

STATCOM to redesign the electricity concept of the development framework. A mixture of the two is used to perform this. These are the primary targets that this assessment manner to accomplish. By dealing with the qZSI-STATCOM with a control algorithm primarily based on AFF-SOGI, it's miles viable to improve the power satisfactory inside the distribution device when there may be a DC offset within the load currents in addition to distorted and unbalanced voltages. This is probably completed interior seeing the 2 instances with the helper of the multi-mode well worth of the qZSI-STATCOM.

II.SYSTEM CONFIGARATION: QZSIs offer some specific and intriguing advantages that PV frameworks may additionally benefit from. By drawing a constant cutting-edge from the PV board and removing the need for extra sifting capacitors, the qZSI diminishes replacing waves and works on the PV framework. Additionally, it has a decrease factor (capacitor) rating and simplifies the PV gadget. For the withdrew load condition, this take a look at used qZSI to collaborate the PV-handing over structure. The makers of this assessment get a handle on the muse of an AFF-SOGI manage contrive linked with a PV display and a Breeze Energy Change Structure (WECS)- maintained qZSI-STATCOM to overhaul the electricity concept of the motion system. This is executed by using a mix of the two. These are the fundamental goals that this assessment intends to attain. When there may be a DC offset in the load currents as well as distorted and unbalanced voltages, it's miles feasible to improve the energy first-class in the distribution device by coping with the qZSI-STATCOM with a manipulate set of rules primarily based on AFF-SOGI. This can be achieved in either state of affairs through utilising the multi-mode capabilities of the qZSI-STATCOM.

Considering their negligible value and versatile movement, energy turbines, for instance, wind mills and PV are used to serve the load more simply than some different strength supply. As a result, direct and non-straight loads are both expected from the breeze turbine. The organisation's power fine is in addition progressed via the usage of pay circuits. To settle the strength first-class issues on the source, a STATCOM compensator thinking about a qZSI is built agreed with the scattering affiliation. The qZSI and PV device have been mixed right into a unmarried unit in the deliberate compensator circuit, which makes use of STATCOM for switching. The qZSI

primarily based STATCOM version that has been supplied can be visible in Fig.1. The AFF-SOGI manipulate approach arranges the compensator to keep the breeze strength device's voltage and repeat internal okay degrees. Moreover, this adds to the decrease of the 3P4W dispersion framework's sounds. The recurrence regulator's barriers are advanced with the assistance of the fluffy tuned PI regulator. By disposing of track and making up for the receptive strength present within the electricity assets, this strategy manages the development of ability to the heap.

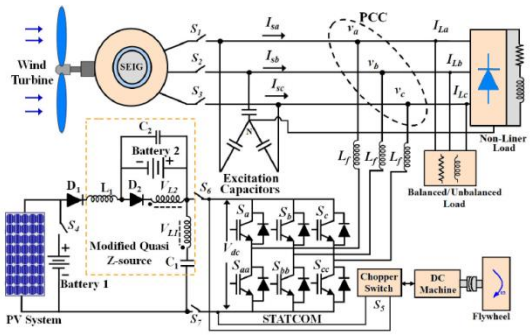


FIGURE 1. qZSI-STATCOM integrated with the wind energy conversion system.

Fig. 2 shows the flowchart for PV-qZSI-STATCOM working mode decision. Utilizing facilitated control, this PV-helped qZSI-STATCOM comprises of four unmistakable modes. The shut or open conditions of the power electronic switches (S1-S7) are portrayed in Modes 1 (Creation of PV power), 2 (Battery reinforcement), 3 (Nonstop stock), and 4 (Flywheel energy capacity). The control structure enters mode:

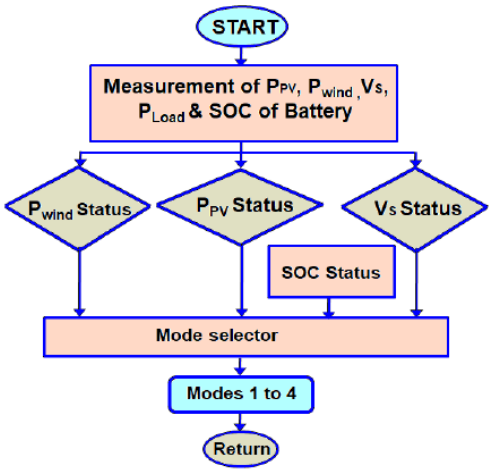


FIGURE 2. Flowchart for PV-qZSI-STATCOM operating mode selection.

1 when how much power made by the PV power conveying system is more than how much power that is related with the store (PLoad). The switches are situated as continues in this mode: S1, S2, S3, S4 (in the event that the battery's Territory of Charge (SOC) is under half), S5 (off), and S6 (on) are on. Right when the PV power conveyed by the PV structure drops to PPV < 10%, the control system changes to mode: 2. The mode: At the point when Vsabc approaches zero. 3 setting is started, and the switch positions are set as follows: (S1, S2, S3 = On, S4 = On (If PPV < 10%), S5 = Off, S6, S7 = On). The control system will enter mode 4 after it has affirmed that the power conveyed by the breeze energy structure Pwind is more than the power made by the store PLoad. Fig. The mode-to-mode transition condition is shown in Figure 3.

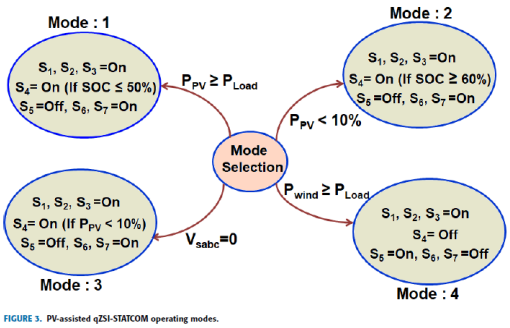


FIGURE 3. PV-assisted qZSI-STATCOM operating modes.

Sounds may be feeling better and open power usage from related weights can be compensated for with the help of the qZSI-STATCOM control, which endeavors to totally work on the reliability of the power network. Additionally, the goal is to produce pure sinusoidal grid currents even at distorted load currents and unbalanced voltages. Thus, the AFF-SOGI can be utilized to assess sinusoidal reference matrix flows even with lopsided network voltages and contorted load flows. Fig. The AFF-SOGI qZSI-STATCOM control conspire is displayed in Figure 4. AFF-SOGI ponders solely the key repeat streams. Where ZCD tends to Zero Convergence Identifier, S/H tends to Test and Hold circuit and Abs addresses Through and through. To achieve this, it denies authorization to the next recurrence part to create the tricky flows. This keeps those flows from entering the framework and just allows those produced by different recurrence part. Thus, the framework just gets dynamic power from the source. The regulator additionally utilizes unit voltage vectors that are determined utilizing the positive grouping voltages of the framework. Grid voltage imbalances and distortions cannot affect the reference currents as a result of this. By supplanting the damping factor and the thunderous recurrence with fragmentary request forms, this technique, which was created from a SOGI calculation in view of a steady recurrence, makes it conceivable to remove the basic current. The DC offset dismissal circle's fuse has largely worked on the AFF-SOGI. Because of this loop, DC offsets in the load current will no longer have any effect on estimating the fundamental current. Fig. 5 depicts the AFF-SOGI schematic, which reveals the relationship between its interior components. The articulation that follows can be utilized to characterize the AFF-SOGI's in-quadrature move capability:

$$\frac{v'}{v} = \frac{m\omega_n s^2}{s^3 + (k_1 + m\omega_n)s^2 + (\omega_n)^2 s + k_1(\omega_n)^2} \quad (1)$$

$$\frac{q'}{v} = \frac{m(\omega_n)^2 s}{s^3 + (k_1 + m\omega_n)s^2 + (\omega_n)^2 s + k_1(\omega_n)^2} \quad (2)$$

v′ and q′ are the in-quadrature principal recurrence signals, while m′ and n′ specifically address the thunderous recurrence and partial request damping

factor. The signs at the fundamental repeat are tended to by v′ and q′ documentation, independently. The full recurrence and the fragmentary request damping component can both be addressed by m′. n′.

$$m' = -2cos\left(\frac{\mu}{x}\right) \tag{3}$$

$$\omega_n' = \omega_n^{\frac{1}{x}} \tag{4}$$

$$\frac{\mu}{x} = \begin{cases} \pi - tan^{-1}\dfrac{\sqrt{4-m^2}}{m} & 0 < m < 2 \\ \pi & m \geq 2 \end{cases} \tag{5}$$

Even though the AFF-SOGI is based on the recurrence fixed (FF)- SOGI, the final option is limited by the boundaries m and n. However, if m′ and n′ are replaced with x, the AFF-SOGI may become flexible enough to handle fluctuations in framework recurrence. By and by, the system can likewise be used to work out principal load flows. Holding an example of the approximated central flows at each no intersection of the quadrature unit vectors is utilized to compute the dynamic current. A ZCD is used to choose if a sign has crossed zero. Unit vectors convey the voltage stage and recurrence of the network, facilitating synchronization through these vectors. Since curving and imbalanced voltages could distort vectors, they should be pure sinusoids of unit abundancy. The unit vectors are delivered including positive gathering voltages thus. Coming up next is a once-over of the stage voltages of the structure, as shown by the most recent evaluations that anybody could expect to find:

$$v_{sa} = \frac{1}{3}(2v_{sabp} + v_{sabp}) \tag{6}$$

$$v_{sb} = \frac{1}{3}(-v_{sabp} + v_{sbcp}) \tag{7}$$

$$v_{sc} = \frac{1}{3}(-v_{sabp} - 2v_{sbcp}) \tag{8}$$

$$V_T = \sqrt{\frac{2}{3}(v_{sa}^2 + v_{sb}^2 + v_{sc}^2)} \tag{9}$$

$$U_a = \frac{v_{sa}}{V_T},\ U_b = \frac{v_{sb}}{V_T},\ U_c = \frac{v_{sc}}{V_T} \tag{10}$$

$$q_a = \frac{U_a}{\sqrt{3}} + \frac{U_c}{\sqrt{3}} \tag{11}$$

$$q_b = \frac{\sqrt{3}U_a}{2} + \frac{(U_b - U_c)}{2\sqrt{3}} \tag{12}$$

$$q_c = -\frac{\sqrt{3}U_a}{2} + \frac{(U_b - U_c)}{2\sqrt{3}} \tag{13}$$

$$I_{p\,avg} = \frac{I_{pa} + I_{pb} + I_{pc}}{3} \tag{14}$$

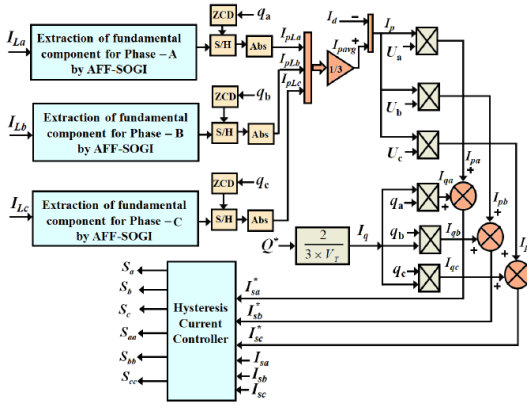


FIGURE 4. AFF-SOGI control scheme for qZSI-STATCOM.

The repeat of the not completely permanently established by utilizing a Phase Locked Circle (PLL) including three-stage terminal voltages as data. To control the

recurrence error and compare the assessed and reference recurrence, a fuzzy tuned PI regulator is used. The unique current that is drawn by the compensator equipment is the consequence of the repeat PI controller.

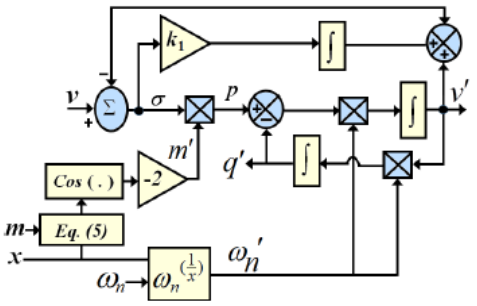


FIGURE 5. Internal structure of AFF-SOGI.

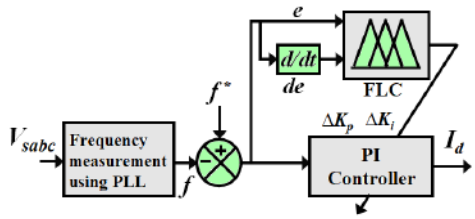


FIGURE 6. Fuzzy-tuned PI frequency controller.

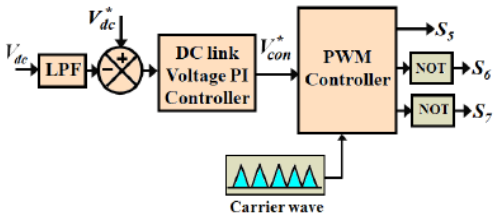
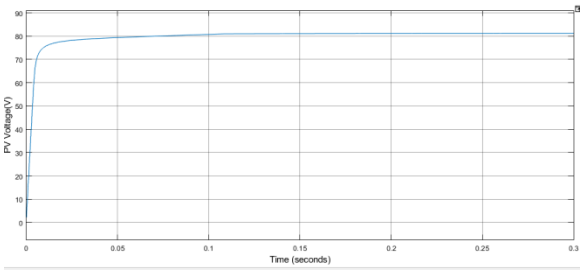


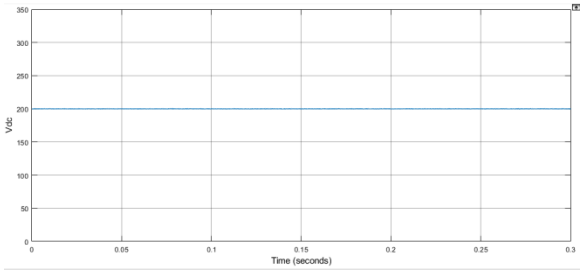
FIGURE 7. DC link voltage controller.

III.SIMULATION RESULTS: CASE_1

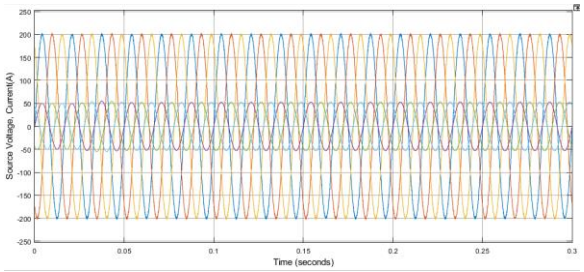
When the wind speed is held constant and the non-linear loads are balanced, PV-STATCOM is evaluated. As may be seen in below figures the present compensation simulation findings for Case 1 compensation are shown. Whereas the non-linear balanced load has an effect, the compensator circuit may be utilized to maintain a constant voltage and current.



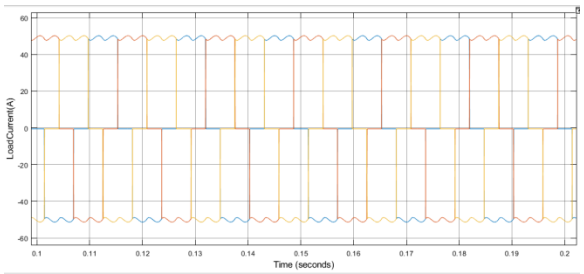
PV Voltage



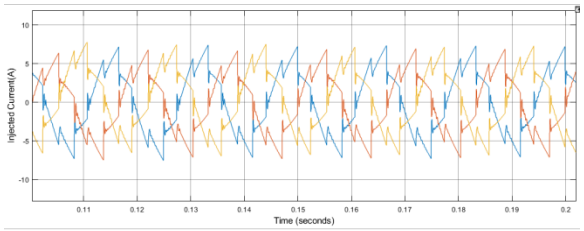
DC Link Voltage



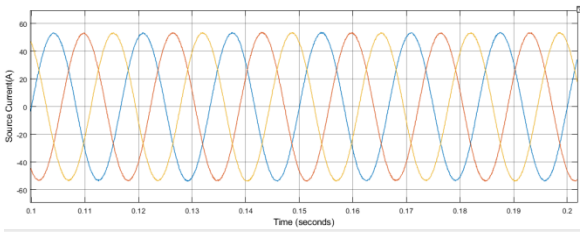
Source Voltage,Current



Load Current



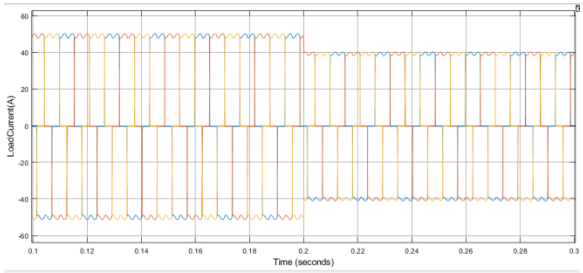
Injected Current



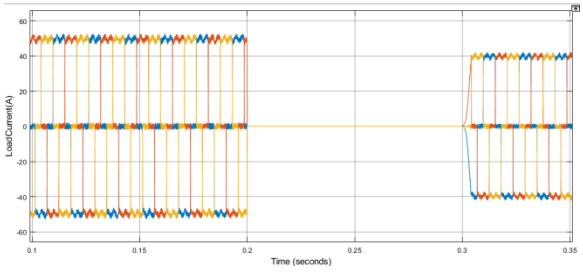
Source Current

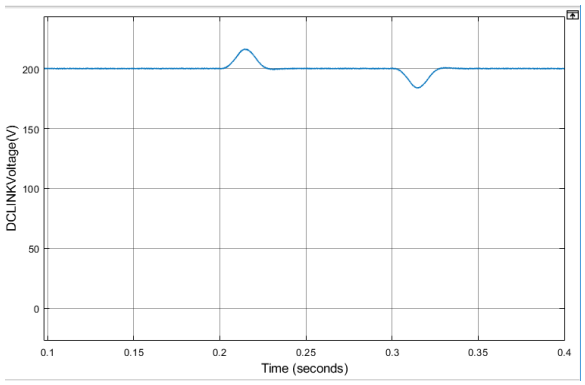
CASE_2

It demonstrates that as soon as the qZSI-STATCOM is started, the grid current not only becomes sinusoidal but also continues to stay in phase with the phase voltage, which typically results in an operation with a power factor of unity. Below figures displays uncompensated Load current and Compensated source current with the incorporation of compensator circuitry.



CASE_3





IV.CONCLUSION

A pioneering approach for control of HRE system with FOPI based STATCOM presented in this current work. The FOPI-based STATCOMs offer a promising solution for enhancing energy management in HRES. Their superior control performance, flexibility, and robustness make them well-suited for addressing the challenges associated with integrating intermittent RE into the grid and non-linear loads. Future research should focus on developing advanced optimization techniques for FOPI controller tuning and investigating the application of this technology in real-world HRES deployments. STATCOMs are voltage-sourced converters that can inject or absorb reactive power into the grid. Maintaining grid voltage within acceptable limits, improving power factor and grid stability, managing power flow between the HRES and the grid can be achieved with FOPI based STATCOM. From the simulation

results it is evident that with proposed control scheme for various operating conditions of RE sources maintained constant DC link voltage and load current..

V.REFERENCES: [1] L. de Oliveira-Assis, P. García-Triviño, E. P. P. Soares-Ramos, R. Sarrias-Mena, C. A. García-Vázquez, C. E. Ugalde-Loo, and L. M. Fernández-Ramírez, ‘‘Optimal energy management system using biogeography based optimization for grid-connected MVDC microgrid with photovoltaic, hydrogen system, electric vehicles and Z-source converters,’’ Energy Convers. Manage., vol. 248, Nov. 2021, Art. no. 114808, doi: 10.1016/j.enconman.2021.114808.

[2] S. Ouchen, A. Betka, S. Abdeddaim, and A. Menadi, ‘‘Fuzzy-predictive direct power control implementation of a grid connected photovoltaic system, associated with an active power filter,’’ Energy Convers. Manage., vol. 122, pp. 515–525, Aug. 2016, doi: 10.1016/j.enconman.2016.06.018.

[3] P. Aree, ‘‘Dynamic performance of self-excited induction generator with electronic load controller under starting of induction motor load,’’ in Proc. 5th Int. Conf. Electr., Electron. Inf. Eng. (ICEEIE), Malang, Indonesia, Oct. 2017, pp. 21–24, doi: 10.1109/ICEEIE.2017.8328756.

[4] A. B. Shitole, H. M. Suryawanshi, G. G. Talapur, S. Sathyan, M. S. Ballal, V. B. Borghate, M. R. Ramteke, and M. A. Chaudhari, ‘‘Grid interfaced distributed generation system with modified current control loop using adaptive synchronization technique,’’ IEEE Trans. Ind. Informat., vol. 13, no. 5, pp. 2634–2644, Oct. 2017, doi: 10.1109/TII.2017.2665477.

[5] H. Abu-Rub, A. Iqbal, S. M. Ahmed, F. Z. Peng, Y. Li, and G. Baoming, ‘‘Quasi-Z-source inverter-based photovoltaic generation system with maximum power tracking control using ANFIS,’’ IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 11–20, Jan. 2013, doi: 10.1109/TSTE.2012.2196059.

[6] J. Zhang, ‘‘Unified control of Z-source grid-connected photovoltaic system with reactive power compensation and harmonics restraint: Design and application,’’ IET Renew. Power Gener., vol. 12, no. 4, pp. 422–429, Mar. 2018, doi: 10.1049/iet-rpg.2016.0478.

[7] J. G. Cintron-Rivera, Y. Li, S. Jiang, and F. Z. Peng, ‘‘Quasi-Zsource inverter with energy storage for photovoltaic power generation systems,’’ in Proc. 26th Annu. IEEE Appl. Power Electron. Conf. Expo. (APEC), Fort Worth, TX, USA, Mar. 2011, pp. 401–406, doi: 10.1109/APEC.2011.5744628.

[8] N. Cheraghi Shirazi, A. Jannesari, and P. Torkzadeh, ‘‘Self-start-up fully integrated DC–DC step-up converter using body biasing technique for energy harvesting applications,’’ AEU-Int. J. Electron. Commun., vol. 95, pp. 24–35, Oct. 2018, doi: 10.1016/j.aeue.2018.07.033.

[9] S. Parthiban and V. Madhaiyan, ‘‘Experimental validation of solar PV sustained ZSI based unified active power filter for enrichment of power quality,’’ Automatika, vol. 62, no. 1, pp. 137–153, Jan. 2021, doi: 10.1080/00051144.2021.1908013.

[10] M. Vijayakumar and S. Vijayan, ‘‘PV based three-level NPC shunt active power filter with extended reference current generation method,’’ Int. J. Electr. Energy, vol. 2, no. 4, pp. 258–267, 2014, doi: 10.12720/ijoee.2.4.258-267.