PERFORMANCE ANALYSIS OF FUZZY AND ANFIS CONTROLLED Z-SOURCE VIRTUAL SYNCHRONOUS GENERATOR FOR PHOTOVOLTAIC SYSTEMS

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Abstract:
In photovoltaic (PV) systems, this paper suggests an improved multi-mode control solution for a Z-source virtual synchronous generator (ZVSG) utilizing a fuzzy logic controller (FLC) and Adaptive Neuro- Fuzzy Inference System (ANFIS). With its consistent and adaptable power output, the ZVSG shows promise as a grid integration option for PV systems. A steady voltage and frequency output may be maintained by the ZVSG while operating in various modes, including grid- connected, standalone, and islanding, according to the suggested control strategies. The FLC and ANFIS controllers are used to control the ZVSG's switching frequency and the DC-link voltage. By lowering the steady-state error and providing a quick dynamic response, the suggested control techniques increases the ZVSG's performance. Across a range of operating modes and load circumstances, the simulation results demonstrate that the suggested control methods enhances the ZVSG's performance.

Key words: Z-source virtual synchronous generator (ZVSG), Fuzzy Logic Controller (FLC), Adaptive Neuro Fuzzy Inference System (ANFIS), Total harmonic distortion (THD), Standalone.

1. Introduction:

Demand for electricity is rising. Thermal and other energy sources face a major dilemma with limited reserves that might run dry in the coming decades. Traditional power plant carbon emissions harm the environment. Nuclear energy is another dangerous energysource. Experts have concentrated on renewable energy sources to solve the above challenges lately. Since solar energy is abundant and free, it is the most widely used renewable energy source. Photovoltaic (PV) technology converts solar energy into electricity. Solar photovoltaic (PV) cells, power electronics converters, and a control unit for regulating PV-generated electricity comprise the solar energy conversion system. PV solar cells don't operate linearly. It produces DC electricity at poor efficiency and depends on ambient temperature and solar radiation.

This correspondence presents a useful secondary frequency control (SFC) technique for virtual synchronous generators (VSGs) that makes rotor frequency response predictable and hence simplifies parameter design by illustrating the relationship between rotor inertia, damping factor, integral coefficient, and low-pass filter time constant. The results of the simulation back up the proposed theory [1]. Here we take a look at the short-term efficiency of microgrids that combine SG and VSG. Crucially, a one-of-a-kind pre-synchronization control technique satisfies generating unit closure and re-closure requirements while also doing away with phase jumps. Itis possible to generate VSG inertia and damping using a small-signal dynamic model by using the proportion of VSG to SG unit capacity. The power angle stability research also proposes an active power supply technique to prevent transient power oscillation brought on by inertia differences [2]. When considering converter and line dynamics, this analysis shows that stability limits virtual inertia and damping parameters. Using a simple transfer function method, the stability conditions are examined. In order for a second-order system to approximate and stabilize the VSG, the damping-to-virtual inertia ratio is critical [3]. Stable operation, especially in fault conditions, might be compromised due to differences in paralleled systems' effects concerning temporary stability. This paper compares the transient angle stability of a paralleled VSG system and an SG-VSG system with paralleled synchronous and virtual synchronous generators. Speed governor mismatches lead to increased transient instability in paralleled SG-VSG systems [4]. Examined include the enhanced VSG control's decay time constant, voltage, current limiting control, and parameter modification. Evidence from both simulations and experiments under both typical and fault grid scenarios attest to the efficacy of the VSG control mechanism [5]. The lack of dampening characteristics and spinning mass distinguishes distributed generator (DG) units from conventional bulk power plants. Low inertia and damping have a greater impact on grid stability and dynamic performance as the penetration of DG increases [6]. Future research is discussed in this article, which also evaluates the literature on ways for implementing virtual inertia. Some of the most important virtual inertia topologies are reviewed and classified. Theoretical studies and numerical simulations of selected topologies show that coupling their parameters with time and inertia constants may provide similar inertial response, however with different frequency dynamics [7]. In order to improve VSG management, this study suggests modifying the virtual stator reactance using state-space research; this will share transient active power and reduce oscillations. The ability to accurately share reactive power without the need for communication is made possible by inverse voltage calculation for the common ac bus and control of voltage droop. Simulations and studies demonstrate the superiority of the increased VSG control method [8]. On the other hand, when voltage drops, the three-phase inverter's current amplitude limitation control can provide the reactive/rated current ratio needed to satisfy many LVRT standards and provide the most reactive power possible while staying within the rated current amplitude [9]. This study implements a one-stage, three-phase grid-connected photovoltaic system. The suggested control may achieve the control objectives while greatly enhancing the MPPT method's stability by altering the incremental conductance MPPT technique. It is possible to do reactive power adjustment for local load in order to lower grid consumption [10]. A power electronics interface (PEI) with many ancillary services is introduced in this work for use in photovoltaic (PV) applications. Renewable energy PEIs should include auxiliary services like Reactive power compensation along with low-voltage ride-through (LVRT) are utilised to adapt to the growing number of distributed producing systems. This research suggests a robust model predictive-based control strategy for grid-tied Z-source inverters (ZSIs) in PV systems with LVRT capabilities [11]. Incorporating the defective grid's power imbalance with renewable producers, this control technique will make advantage of the maximum energy inertia of HRES. Maximizing the collection of renewable energy while keeping operational and environmental restrictions in mind is an optimization problem [12]. Under LVRT circumstances, this work presents a feedback linearization based on sliding-mode control that increases the response PV system speed. To construct the control system more resistant to changes in the parameters, this article employs feedback linearization and sliding-mode control. Further, the PV system may be linearized across its operating range [13]. Expanded A steady state and a dynamic setting are both used to study PV installation capacity in Taiwan. Using a charged system search (CSS) method, the ideal PV installed capacity at selected buses is first determined in order to reduce gearbox loss and voltage volatility [14]. In the case of grid-connected three-phase solar systems, the inverter is responsible for managing the output current and ensuring it stays below the maximum current limit even when grid disruptions occur, as well as for meeting the needs of low-voltage ride-through technology. Thus, the suggested intelligent controller modifies reactive power to a new reference value satisfying the LVRT grid failure criteria [15].

While prior studies did address the effectiveness of ZSIs in providing grid ancillary services, they failed to take virtual inertia emulation into account. This research delves into the Z-source virtual synchronous generator (ZVSG) performance and operation, a kind of ZSI that may mimic inertia and provide grid ancillary services.

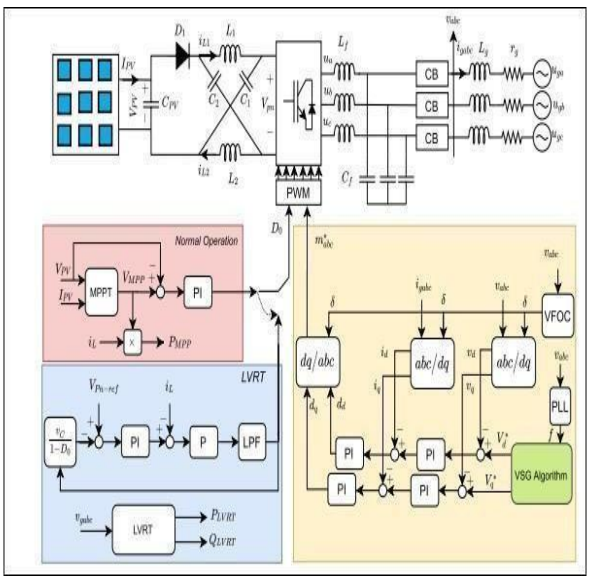

Fig.1 Block diagram of Z-source virtual synchronous generator

2. METHODOLOGY:

In addition to providing accurate results, Fuzzy logic controllers are simple, resilient, making them ideal for solving difficult situations. Hence, the system's responsiveness will be enhanced. Matlab/Simulink is used to assess the outcomes of this system's simulations. While FLC's installation is simple to plan, its application is more challenging to the need for qualitative understanding. As seen in the images below, it primarily comprises of one output and two inputs: error and change in error. The FLC is used in this paper and shown below.

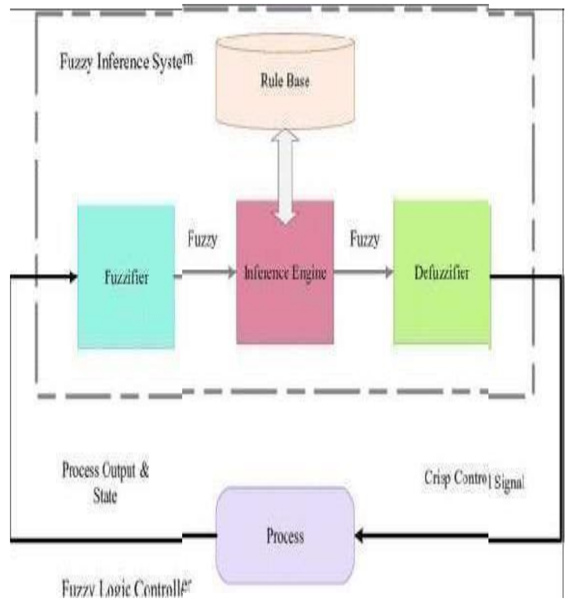

Fig. 2 Fuzzy Logic Controller

ANFIS (Adaptive Neuro-Fuzzy Inference System) is a kind of intelligent system hybrid that blends fuzzy logic and neural networks to provide a potent controller. Applications where traditional control techniques are challenging to implement, like complex systems with nonlinear or uncertain dynamics, are common uses for ANFIS controllers. Fuzzy rules and a neural network trained to understand the fuzzy rule base comprise the ANFIS controller. Linguistic variables and fuzzy sets are used to express the fuzzy rule base, which specifies the mapping between input and output variables. An algorithm for hybrid learning, which combines least squares and backpropagation techniques, is used to train neural networks.

The ANFIS controller is an effective tool for managing complex systems because of its capacity to learn from and adjust to changing surroundings. It has proven effective in a number of domains, including as industrial control, robotics, and financial forecasting.

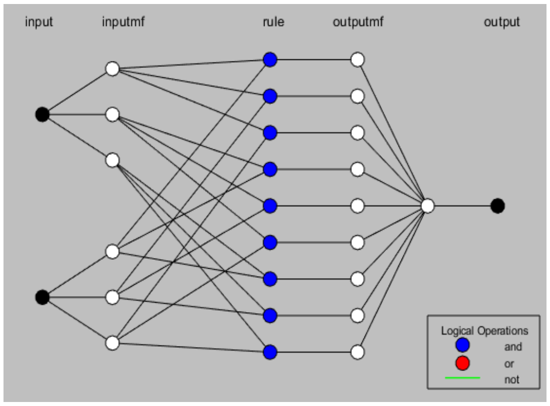

Fig. 3 Structure of ANFIS Controller

3. Simulation Results:

3.1 Using Fuzzy logic controller:

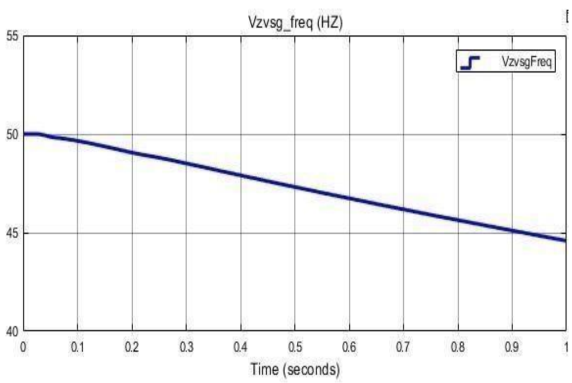

Fig .4 Frequency at ZVSG side

The above figure shows the RoCoF plots of the converter, which the Fuzzy Logic Controller produced when the ZVSG was operating in MPPT mode.

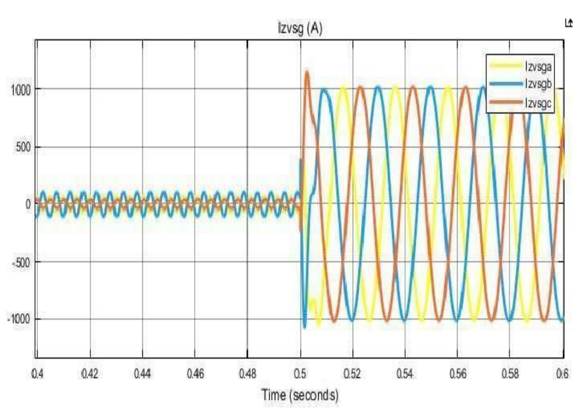

Fig .5 Izvsg

When the ZVSG is connected to the grid using a Fuzzy logic controller, the inrush current is shown above

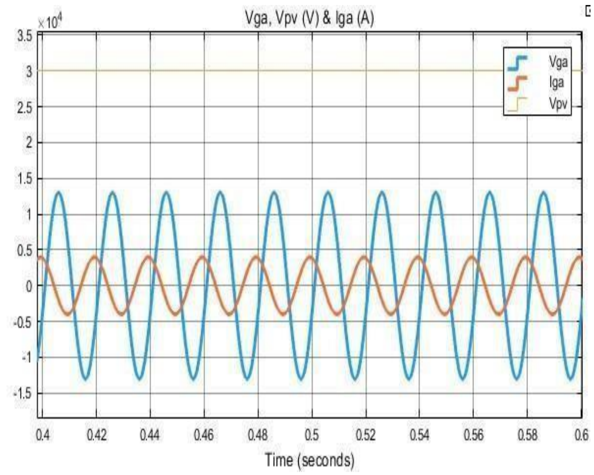

Fig .6 Vga, Vpv Iga

The Figure depicts the total system performance before and after the failure, as measured by theFuzzy Logic controller.

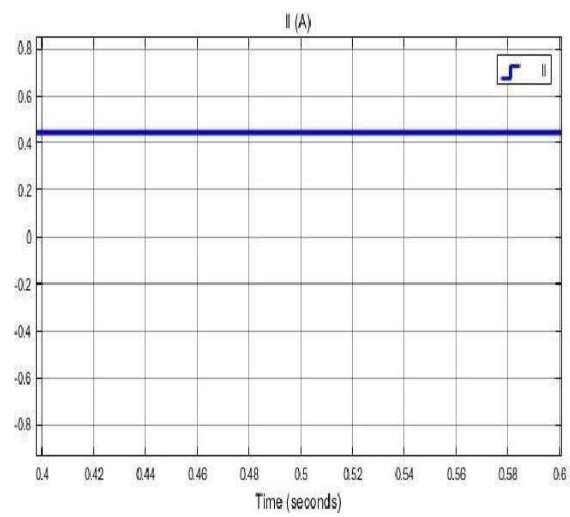

Fig . 7 IL (A)

The above figure depicts current value of load by using fuzzy logic controller.

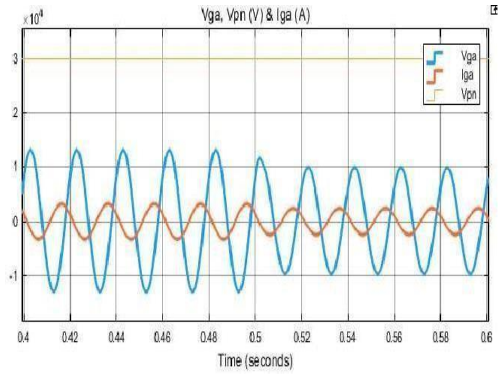

Fig. 8 Vga, Vpn & Iga

The Figure shows the results of the fuzzy logic controller's working in relation to the grid voltage, inductor current, and dc link voltage.

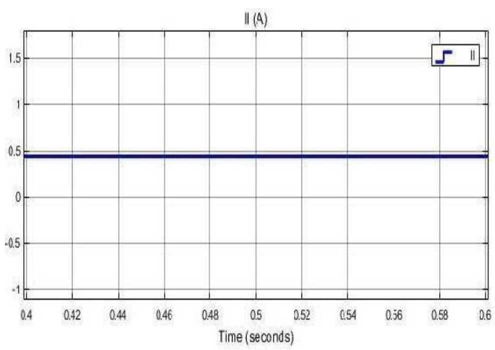

Fig . 9 IiL (A)

The above figure depicts current value of load by using fuzzy logic controller.

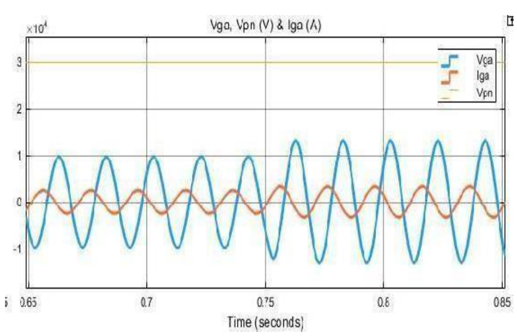

Fig . 10 Vga, Vpn, & Iga (A)

The figure depicts performance of dc link voltage, inductor current and grid voltage by usingfuzzy logic controller.

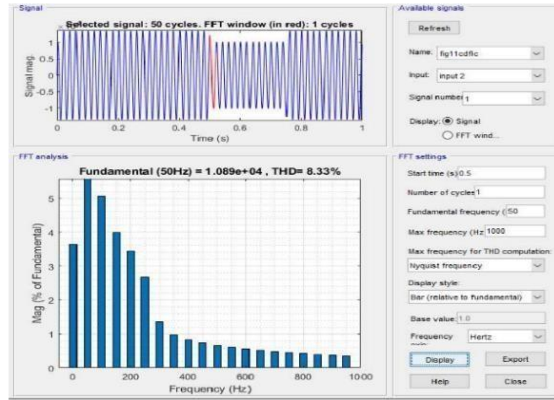

Fig. 11(a)

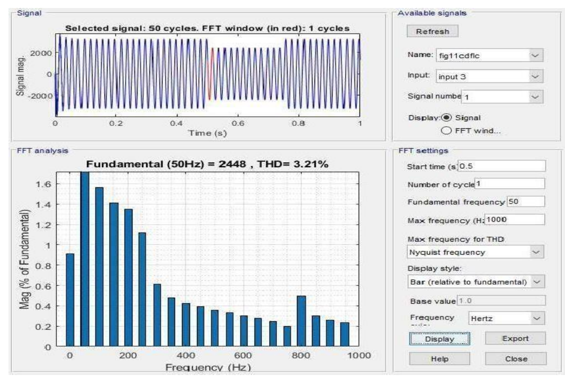

Fig. 11(b)

The figure 11 a) & b) depicts the THD comparison by using fuzzy logic controller.

3.2 Using ANFIS controller:

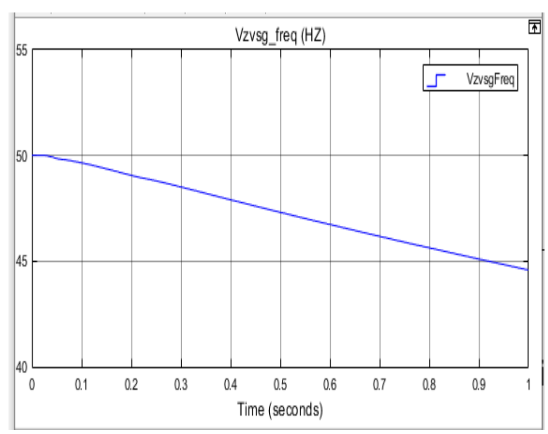

Fig . 12 Frequency at ZVSG side

Figure 12 shows the RoCoF plots of the converter , which were generated by the anfis controller when the ZVSG was operating in MPPT mode.

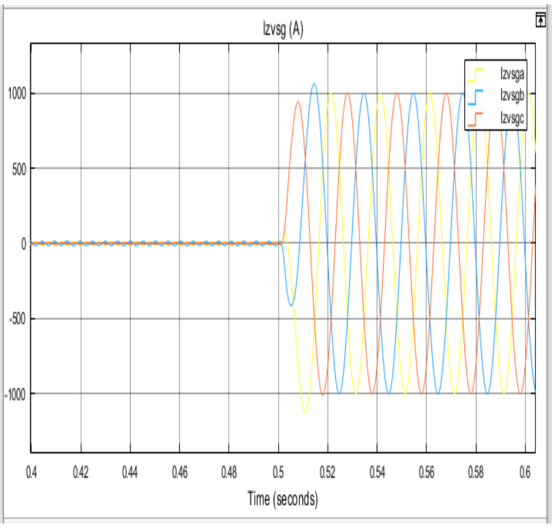

Fig .13 Izvsg

when the ZVSG is connected to the grid using anfis controller, the inrush current is shown in the above figure

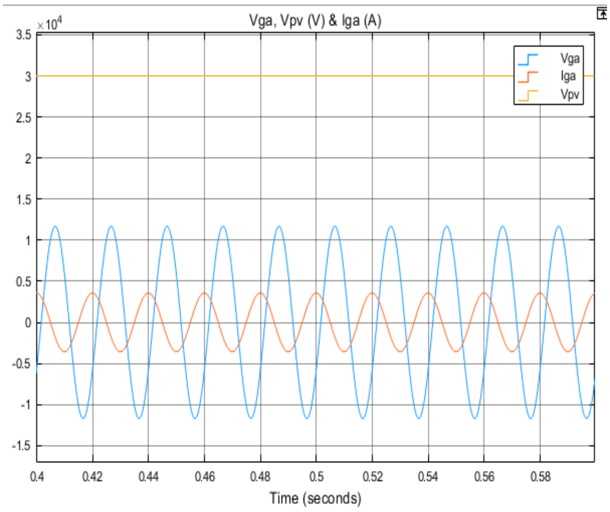

Fig .14 Vga, Vpv, Iga

Figure 14 depicts the total performance before and after the failure, as measured by the anfis controller.

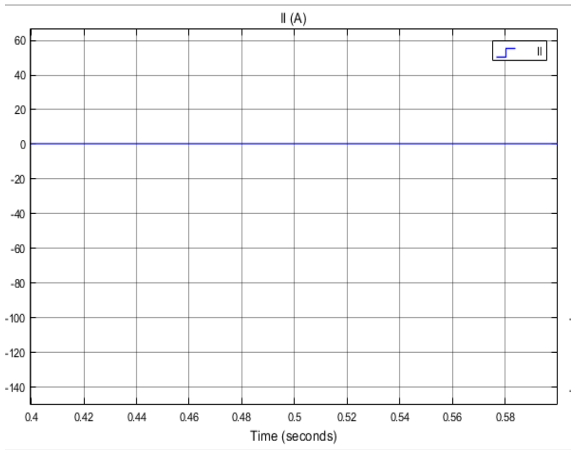

Fig . 15 IL (A)

The above figure 15 depicts the current value of the load by using anfis controller.

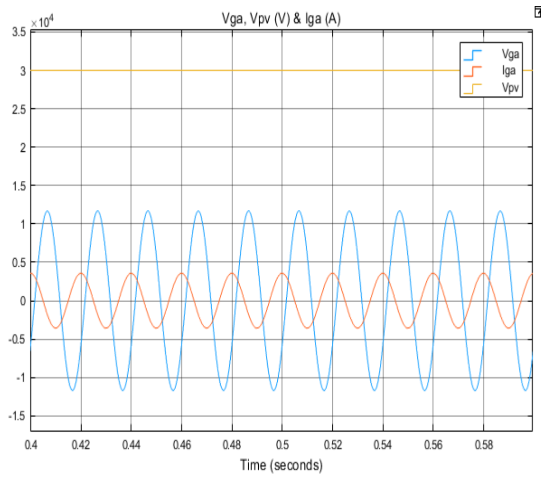

Fig. 16 Vga, Vpv, Iga

Figure 16 shows the results of anfis controller's functioning in relation to the grid voltage, inductor current, and dc link voltage.

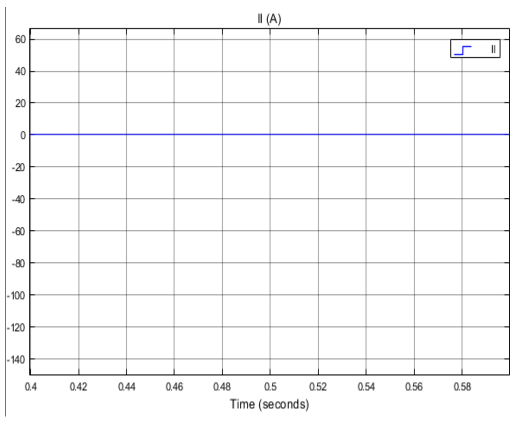

Fig . 17 IiL (A)

The figure 17 depicts current value of load using anfis controller.

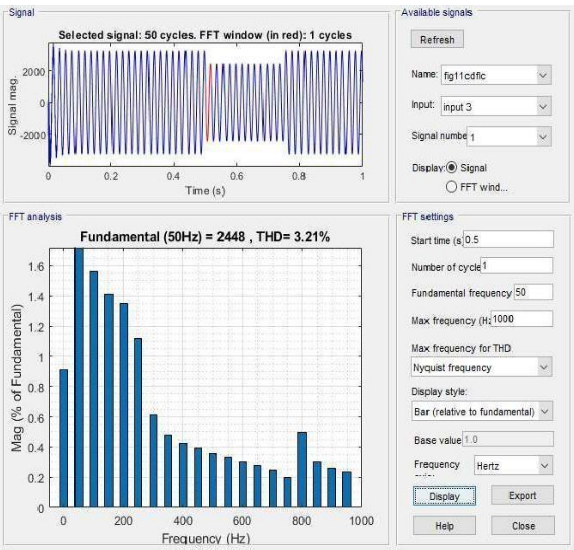

Fig. 18 (a)Iga

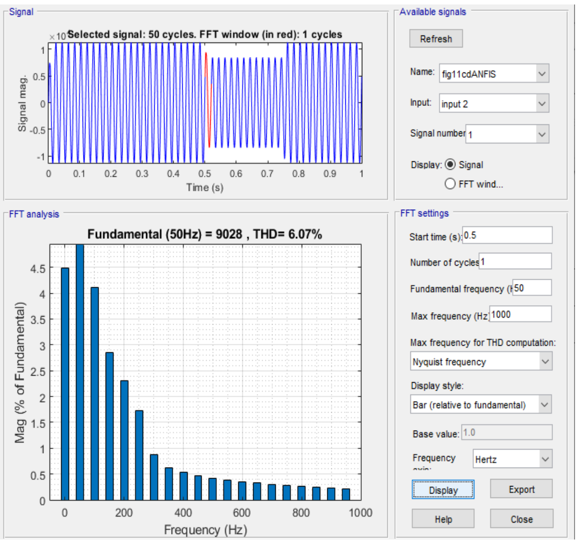

Fig. 18 (b)

The Figure 18 a) & b) depicts the THD comparision using ANFIS controller.

CONCLUSION

Finally, a potential strategy for improving the multi-mode management of photovoltaic (PV) systems' Z-Source Virtual Synchronous Generator (ZVSG) is to use a flc and anfis controller. When it comes to controlling the DC-link voltage and making sure the system is stable, the suggested control methods takes use of both ZVSG and VSG. To enhance the system's dynamic reaction under varying operating circumstances, the flc and anfis controller are used to real-time change the PI controller's gain. Results from the simulations demonstrate that the suggested control method is capable of achieving adequate performance in synchronising the grid, rejecting disruptions, and controlling the DC- link voltage. As the flc and anfis controllers are superior than the conventional PI control approach in several respects, including its ability to lessen the system's sensitivity to load and irradiance fluctuations, as well as its overshoot and settling times. In addition, the suggested control methods are more resistant to disturbances and has more flexibility in responding to unknown parameters. In conclusion, the suggested fuzzy logic controller-based and anfis controller based improved multi-mode control of ZVSG for PV systems shows promising results in termsof the stability, effectiveness, and dependability of PV systems and could have abig influence on the production and management of renewable energy.

REFERENCES

[1] K. Jiang, H. Su, H. Lin, K. He, H. Zeng, and Y. Che, ‘‘A practical secondary frequency control strategy for virtual synchronous generator,’’ IEEE Trans. Smart Grid, vol. 11, no. 3, pp. 2734–2736, May 2020.

[2] K. Shi, W. Song, H. Ge, P. Xu, Y. Yang, and F. Blaabjerg, ‘‘Transient analysis of microgrids with parallel synchronous generators and virtual synchronous generators,’’ IEEE Trans. Energy Convers., vol. 35, no. 1, pp. 95–105, Mar. 2020.

[3] J. Chen and T. O'Donnell, ‘‘Parameter constraints for virtual synchronous generator considering stability,’’ IEEE Trans. Power Syst., vol. 34, no. 3, pp. 2479–2481, May 2019.

[4] H. Cheng, Z. Shuai, C. Shen, X. Liu, Z. Li, and Z. J. Shen, ‘‘Transient angle stability of paralleled synchronous and virtual synchronous generators in islanded microgrids,’’ IEEE Trans. Power Electron.,

vol. 35, no. 8, pp. 8751–8765, Aug. 2020.

[5] H. Nian and Y. Jiao, ‘‘Improved virtual synchronous generator control of DFIG to ride- through symmetrical voltage fault,’’ IEEE Trans. Energy Convers., vol. 35, no. 2, pp. 672–683, Jun. 2020.

[6] H. Bevrani, T. Ise, and Y. Miura, ‘‘Virtual synchronous generators: A survey and new perspectives,’’ Int. J. Electr. Power Energy Syst., vol. 54, pp. 244–254, Jan. 2014.

[7] U. Tamrakar, D. Shrestha, M. Maharjan, B. Bhattarai, T. Hansen, and R. Tonkoski, ‘‘Virtual inertia: Current trends and future directions,’’ Appl. Sci., vol. 7, no. 7, p. 654, Jun. 2017.

[8] J. Liu, Y. Miura, H. Bevrani, and T. Ise, ‘‘Enhanced virtual synchronous generator control for parallel inverters in microgrids,’’ IEEE Trans. Smart Grid, vol. 8, no. 5, pp. 2268–2277, Sep. 2017.

[9] C.-Y. Tang, Y.-T. Chen, and Y.-M. Chen, ‘‘PV power system with multi-mode operation and low-voltage ride-through capability,’’ IEEE Trans. Ind. Electron., vol. 62, no. 12, pp. 7524– 7533, Dec. 2015.

[10] W. Libo, Z. Zhengming, and L. Jianzheng, ‘‘A single-stage three-phase grid-connected photovoltaic system with modified MPPT method and reactive power compensation,’’ IEEE Trans. Energy Convers., vol. 22, no. 4, pp. 881–886, Dec. 2007.

[11] S. Sajadian and R. Ahmadi, ‘‘ZSI for PV systems with LVRT capability,’’ IET Renew. Power Gener., vol. 12, no. 11, pp. 1286–1294, Aug. 2018.

[12] Y. He, M. Wang, and Z. Xu, ‘‘Coordinative low-voltage-ride-through control for the wind- photovoltaic hybrid generation system,’’ IEEE J. Emerg. Sel. Topics Power Electron., vol. 8, no. 2, pp. 1503–1514, Jun. 2020.

[13] Y. Zhang, J. Wang, H. Li, T. Q. Zheng, J.-S. Lai, J. Li, J. Wang, and Q. Chen, ‘‘Dynamic performance improving sliding-mode control-based feedback linearization for PV system under LVRT condition,’’ IEEE Trans. Power Electron., vol. 35, no. 11, pp. 11745–11757, Nov. 2020.

[14] Y.-K. Wu, G.-T. Ye, and M. Shaaban, ‘‘Analysis of impact of integration of large PV generation capacity and optimization of PV capacity: Case studies in taiwan,’’ IEEE Trans. Ind. Appl., vol. 52, no. 6, pp. 4535–4548, Nov. 2016.

[15] F.-J. Lin, K.-C. Lu, T.-H. Ke, B.-H. Yang, and Y.-R. Chang, ‘‘Reactive power control of three-phase grid-connected PV system during grid faults using Takagi–Sugeno–Kang probabilistic fuzzy neural network control,’’ IEEE Trans. Ind. Electron., vol. 62, no. 9, pp. 5516–5528, Sep. 2015.