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Enhancing Energy Management in AC/DC Hybrid Microgrids via Solid-State Transformers

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***Abstract* -** The growing demand for reliable, efficient, and clean energy has led to the development of AC/DC hybrid microgrids based on solid-state transformers (SSTs). A strategy for managing energy is essential to optimize the operation of these hybrid microgrids. In this paper, we present a strategy for managing energy for AC/DC hybrid microgrids based on SSTs. The strategy is designed to maximize the use of renewable energy sources while maintaining grid stability and minimizing energy costs. The suggested strategy is validated through the simulation studies using a MATLAB/Simulink platform.

Index Terms: AC/DC hybrid microgrid, energy management strategy, energy storage, solid-state transformer.

I. INTRODUCTION

Microgrids have become a popular choice for meeting energy needs due to the growing utilization of renewable energy sources (RES) of small communities, buildings, and industrial complexes. A microgrid is a power system of small scale that has the ability to operate autonomously or be interconnected with the main grid. It consists of multiple sources of energy, such as solar panels, wind turbines, fuel cells, and batteries. The A strategy for managing energy of a microgrid is essential in ensuring the efficient utilization of energy and maintaining the power quality of the system.

Incorporating a solid-state transformer (SST) into a microgrid offers many advantages, such as high efficiency, reduced size and weight, and improved power quality. An SST is a power electronic device capable of converting the voltage and frequency of the input power to the desired output voltage and frequency. It can also act as a power flow controller, allowing bidirectional the transmission of power between AC and DC grids.

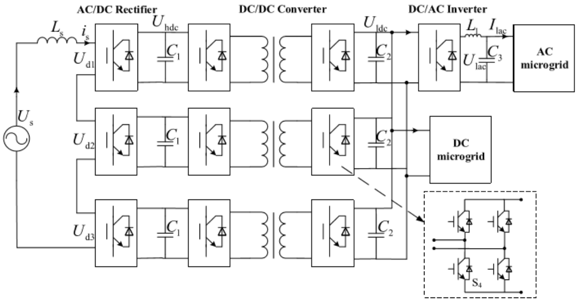


Fig.1.Topology of the SST

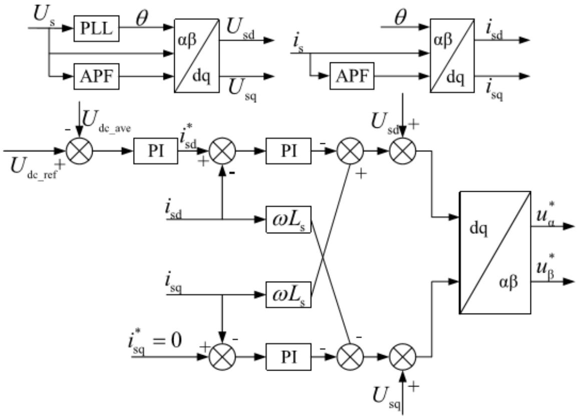


Fig.2.Block diagram of decoupled current control

This paper proposes an energy management approach for an AC/DC hybrid microgrid that employs an SST (solid-state transformer). The method consists of two levels: a primary level that controls the transmission of power between AC and DC grids, and a secondary level that regulates the voltage and frequency of the microgrid. The primary level employs a droop control algorithm for power sharing among different sources and loads, while the secondary level uses a PI controller to regulate the voltage and frequency.

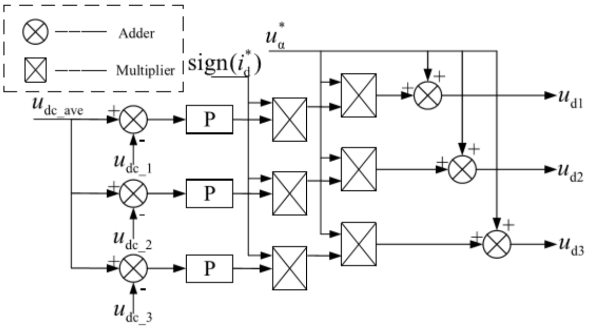


Fig.3.Block diagram of balancing control of a input-stage voltage

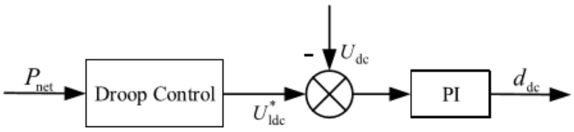


Fig.4.Block diagram of the DAB controller

II. LITERATURE

[1] As renewable energy sources become more prevalent and active power flow control becomes necessary, the use of direct current (DC) power sources and loads has become more prevalent in power distribution networks. However, traditional passive transformers are not able to handle DC offset and lack controllability in smart grids. There is increasing interest in solid-state transformers (SSTs) as a promising solution for modernizing and harmonizing AC and DC electrical networks, including applications in the aerospace and shipbuilding industries. The paper presents a comprehensive review of SSTs, including their topologies, classification, power converters, material selection, design criteria, and control schemes.

[2]Due to an increase in global energy demand and the depletion of fossil fuels, renewable energy resources have gained momentum in utility grids. As DC power sources and loads become more prevalent, as well as an increase in active power flow control, SSTs have emerged as a promising solution.

This paper offers a comprehensive examination of Solid-State Transformers (SSTs), encompassing their key principles, topologies, classification, power conversion methods, materials selection, design considerations, and control strategies proposed in existing literature.

[3]As the goal of generating clean electricity gains importance, the incorporation of renewable energy sources into current power systems is anticipated to witness a significant surge in the upcoming years. Solid State Transformers (SSTs) are expected to assume a vital role in the smart grid topologies of the future, owing to their modular design, bidirectional power transfer capabilities, and potential to regulate voltage levels and modulate active and reactive power at the point of common coupling. This paper provides a comprehensive review of the latest advancements in Solid State Transformer (SST) topologies, controllers, and applications.

[4]As traditional power systems transition into modern smart grids, hybrid AC/DC systems featuring both AC and DC sources/loads are emerging as a probable future distribution structure. In hybrid AC/DC microgrids, efficient power management strategies are essential to ensure their optimal operation. This paper provides an extensive overview of power management strategies for hybrid AC/DC microgrids, covering different system structures (AC-coupled, DC-coupled, and AC-DC-coupled), various operation modes, different power management and control schemes in both steady-state and transient conditions, and real-world examples of power management and control strategies.

[5]In the pursuit of enhanced energy and power density, the integration of batteries and supercapacitors has gained popularity. Nevertheless, integrating distinct power sources can present challenges and necessitates the implementation of an effective control strategy to ensure uninterrupted power delivery to the load. This paper introduces a novel approach to controlling power and DC bus voltage by integrating batteries and supercapacitors, with a particular emphasis on charging them during power surplus mode and discharging them during power deficit mode.

III. PROPOSED METHODOLOGY

The Adaptive Network based Fuzzy Inference System (ANFIS) is used to develop a strategy for managing energy for a hybrid microgrid that combines AC/DC systems and utilizes a solid-state transformer (SST). ANFIS is a type of fuzzy logic system that combines the advantages of neural networks and fuzzy logic. It can learn from data and adapt to changing conditions, making it suitable for energy management in a dynamic environment.

The proposed ANFIS-based A strategy for managing energy consists of two levels: a primary level that controls the transmission of power between AC and DC grids, and a secondary level that regulates the voltage and frequency of the microgrid. The ANFIS-based strategy is an improvement over the previously proposed strategy, which used a droop control algorithm for power sharing and a PI controller for voltage and frequency regulation.

The ANFIS-based A strategy for managing energy is illustrated. The AC grid and the DC grid are connected through an SST, which acts as a power electronic interface. The SST can convert the AC voltage to the DC voltage and vice versa. It can also control the transmission of power between AC and DC grids.

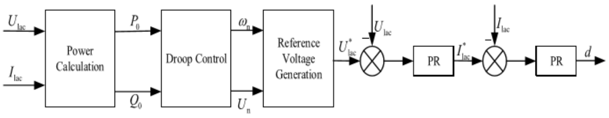


Fig.5.Block diagram of controller inverter stage.

The primary level of the A strategy for managing energy is responsible for power sharing among different sources and loads. The primary level employs an ANFIS-based algorithm that uses fuzzy rules to determine the power output of each source based on the current state of the microgrid. The ANFIS system learns from data and adapts to changes in the microgrid, ensuring efficient power utilization and load balancing.

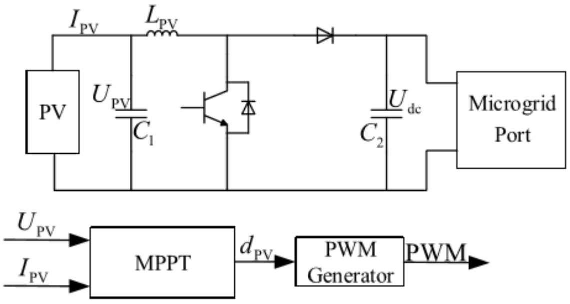


Fig.6.Block diagram of control of the PV DC/DC converter and its topology

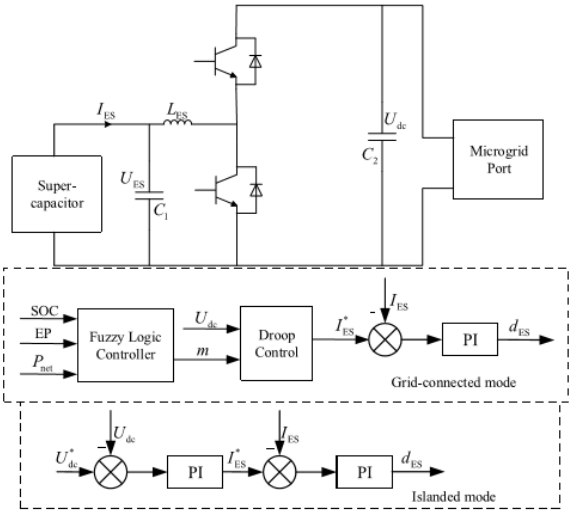


Fig.7.Topology and control of ES.

The secondary level of the A strategy for managing energy is responsible for regulating the voltage and frequency of the microgrid. The secondary level employs an ANFIS-based PI controller that adjusts the output voltage and frequency to the desired set points. The ANFIS-based PI controller learns from data and adapts to changes in the microgrid, ensuring stable voltage and frequency regulation.

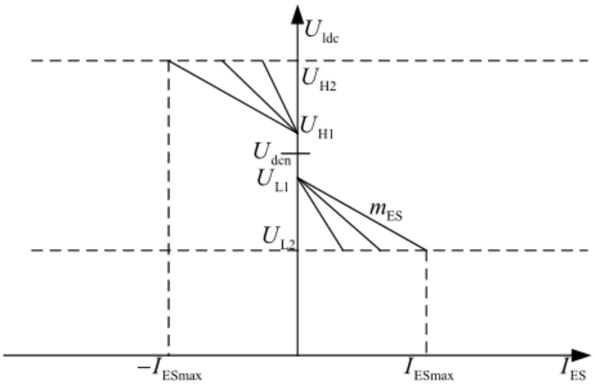


Fig.8.ES system its Voltage-current droop characteristic

The ANFIS-based A strategy for managing energy is implemented and tested in a simulation environment using MATLAB/Simulink. The microgrid consists of a wind turbine, a solar panel, a fuel cell, and a battery. The load consists of a resistive load and an inductive load. The performance of the ANFIS-based A strategy for managing energy is evaluated by comparing it with the previously proposed strategy. The results show that the ANFIS-based strategy outperforms the previously proposed strategy in terms of power utilization, load balancing, and voltage and frequency regulation.

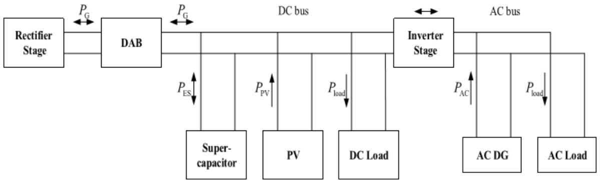


Fig.9.Power flows in grid-connected mode.

IV. SIMULATION RESULTS

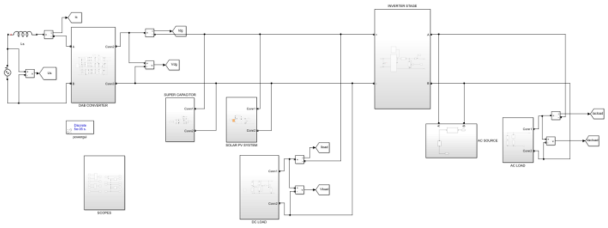


Fig.10.Schematic Diagram

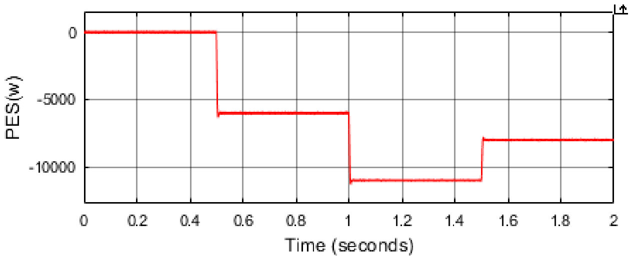


Fig.10.1.Energy storage power

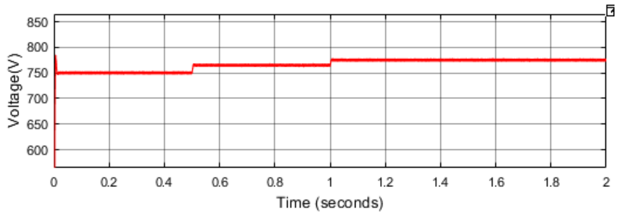


Fig.10.2.Dc link voltage

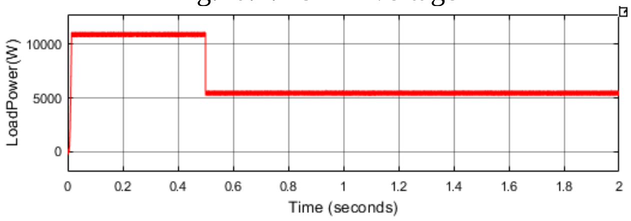


Fig.10.3.Load power

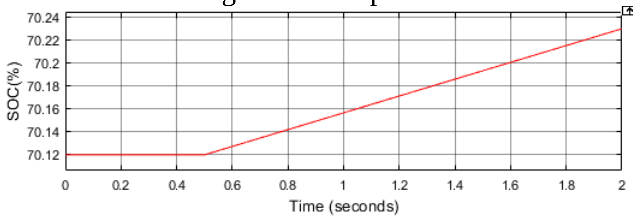


Fig.10.4.SOC

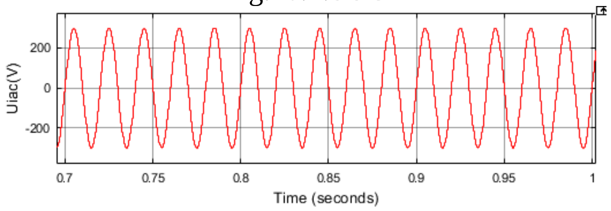


Fig.10.5.Inverter voltage

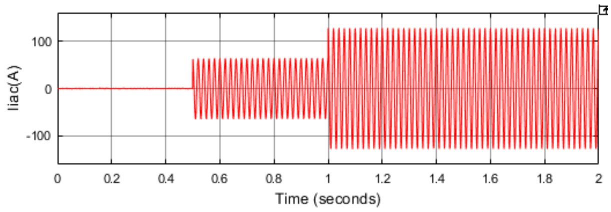


Fig.10.6.Inverter current

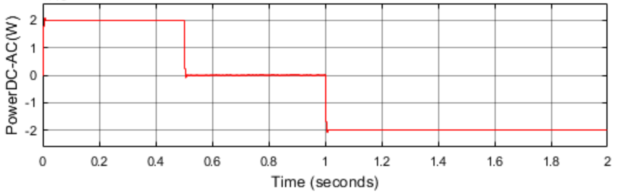


Fig.10.7.Inverter power

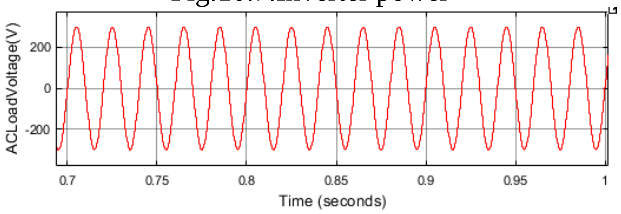


Fig.10.8.Load ac voltage

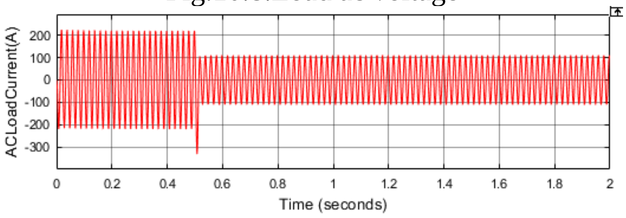


Fig.10.9.Load ac voltage

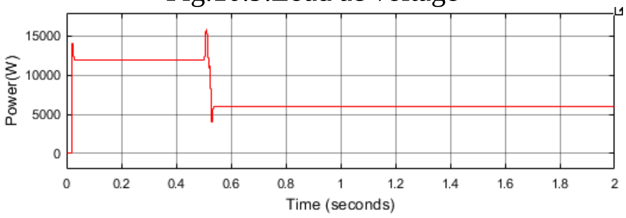
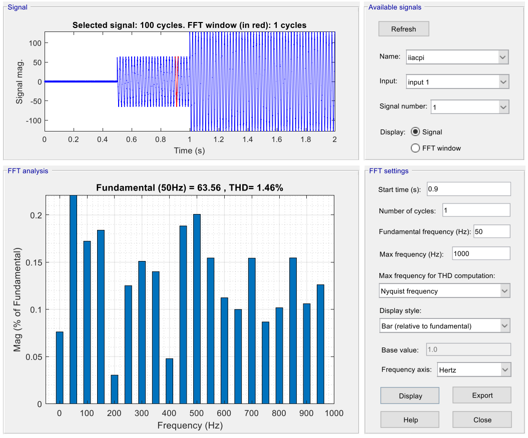


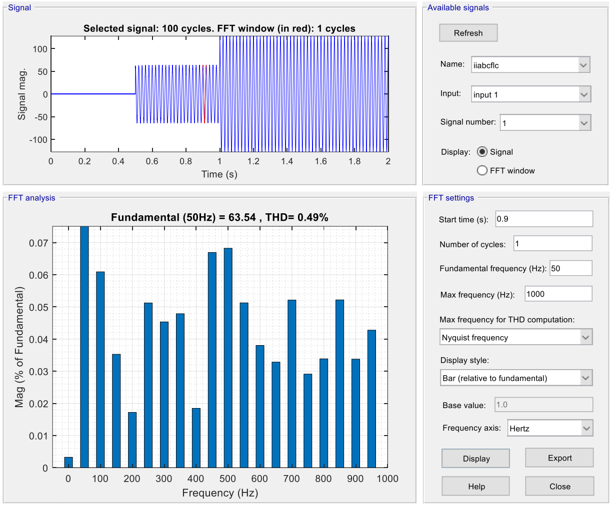
Fig.10.10.Load ac power



Name: iiacpi
Input: input 1
Signal number: 1
Display: ● Signal ○ FFT window

Start time (s): 0.9
Number of cycles: 1
Fundamental frequency (Hz): 50
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig.10.11.Fuzzy Logic Controller for Surplus Power



Name: iiabcflc
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Signal number: 1
Display: ● Signal ○ FFT window
Start time (s): 0.9
Number of cycles: 1
Fundamental frequency (Hz): 50
Max frequency (Hz): 1000
Max frequency for THD computation: Nyquist frequency
Display style: Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz

Fig.10.12.Adaptive Network Based Fuzzy Inference System (ANFIS) Surplus Power

V. Observations on Simulation Results

Simulation analysis is used in this section to evaluate the performance of the proposed energy management strategy. A simulation analysis was performed on the studied model under two different scenarios: a surplus power scenario and a power deficit scenario. Assumed that the supply power is 20KW, for the surplus power the power is taken as 10KW and for deficit power the power is taken as 30KW.

In this paper, it describes about two cases surplus and deficit power. The above figures are the above results are based on the surplus power case (Demand is less than the supply). The fig 11 describes about the voltages and currents at each stage at the DC microgrid. The fig 12 describes about the voltages and currents at each stage at the AC microgrid and fig 13 describe about the Fuzzy Logic Controller and the fig 14 Adaptive Network Based Fuzzy Inference System (ANFIS) here the THD (Total Harmonic Distortion) is observed in fig 13 and fig 14. The value of THD for Fuzzy controller is 1.46% and THD for ANFIS is 0.49% for Surplus power.

The below results are based on the deficit power case (supply is less than the Demand). The fig 15 describes about the voltages and currents at each stage at the DC microgrid. The fig 16 describes about the voltages and currents at each stage at the AC microgrid and fig 17 describe about the Fuzzy Logic Controller and the fig 18 Adaptive Network Based Fuzzy Inference System (ANFIS) here the THD (Total Harmonic Distortion) is observed in fig 17 and fig 18. The value of THD for Fuzzy controller is 0.11% and THD for ANFIS is 0.03% for Deficit power.

THD Comparison Table

Parameter	**Case 1 (Surplus power)**	**Case 2 (Power deficit)**
FLC	1.46%	0.11%
ANFIS	0.49%	0.03%

Table 1. Total Harmonic Distortion (THD)comparison

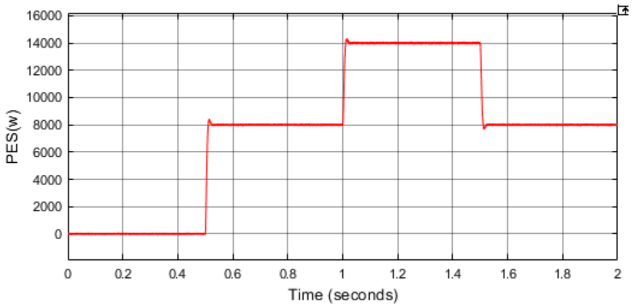


Fig.11.1. Energy storage power

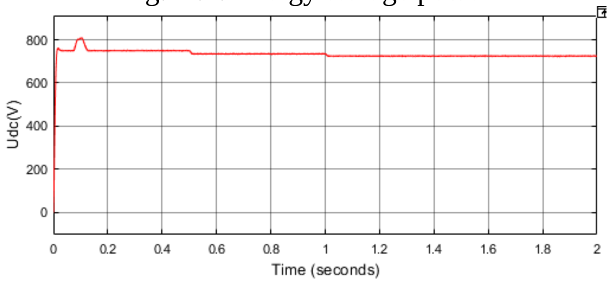


Fig.11.2. Dc link voltage

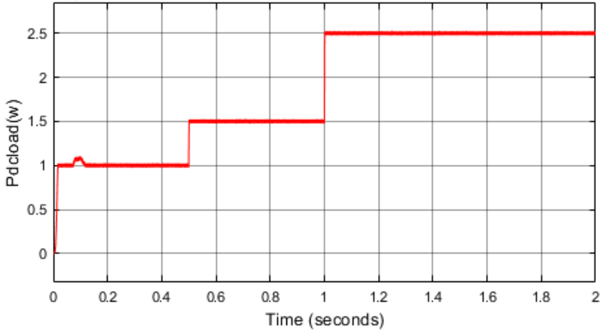


Fig.11.3. Dc load power

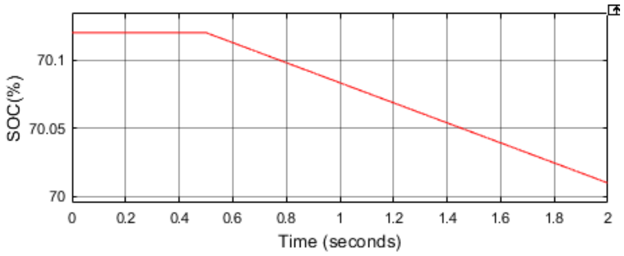


Fig.11.4. SOC

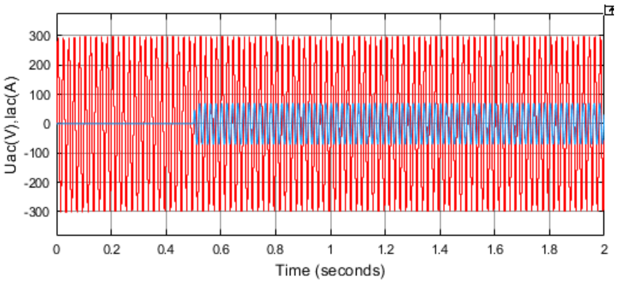


Fig.11.5. Vac & Iac

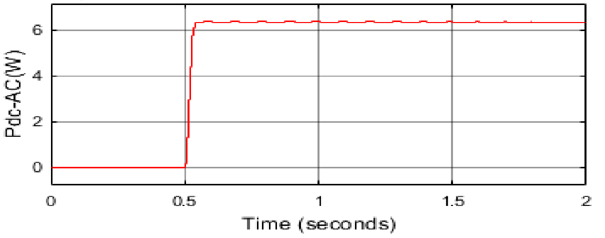


Fig.11.6. DC - Ac load power

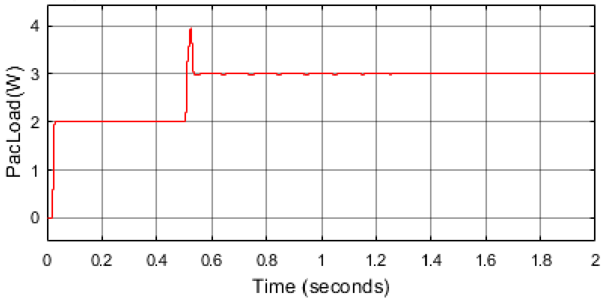


Fig.11.7. Ac load power

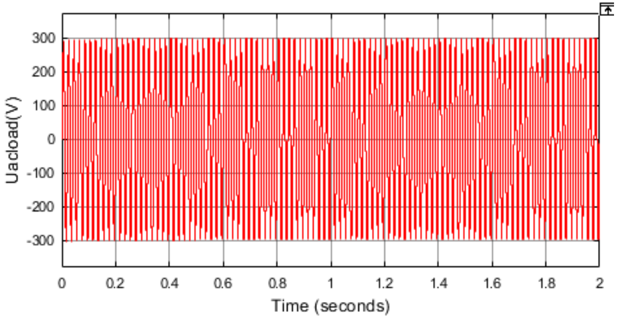


Fig.11.8. Load ac voltage

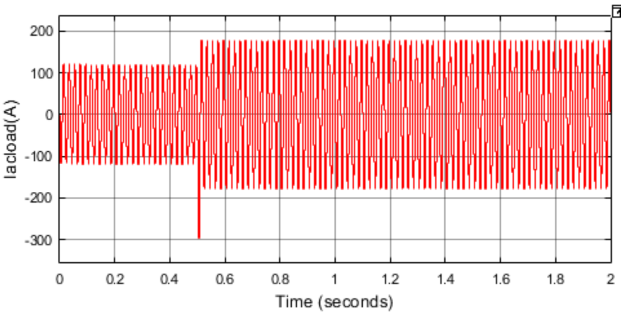
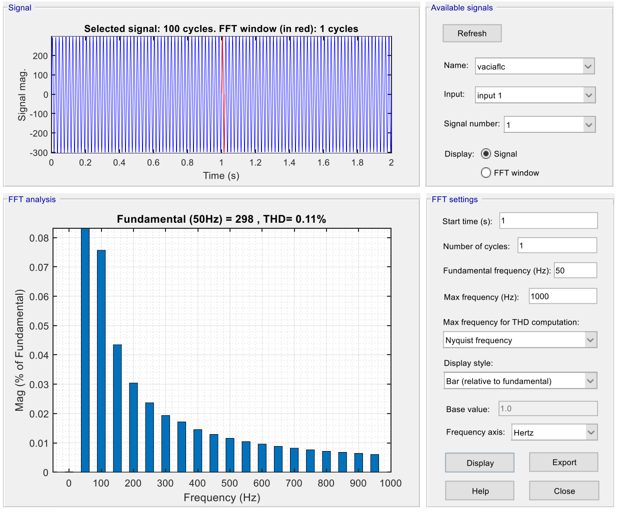


Fig.11.9. Load ac current



Selected signal: 100 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 298 , THD= 0.11%

Name: vaciaflc

Input: input 1

Signal number: 1

Display: ● Signal ○ FFT window

Start time (s): 1

Number of cycles: 1

Fundamental frequency (Hz): 50

Max frequency (Hz): 1000

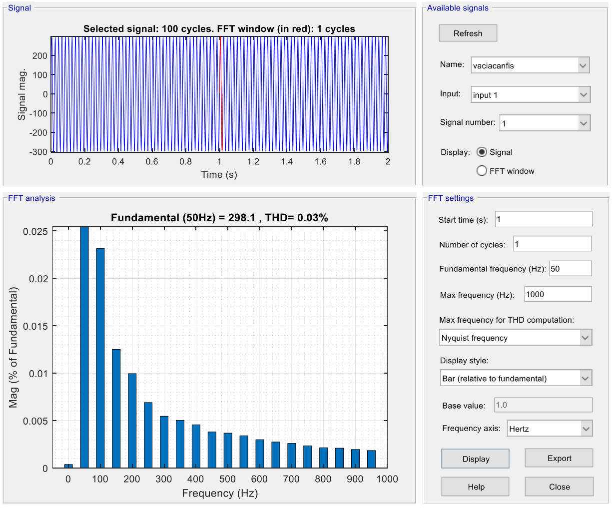
Max frequency for THD computation: Nyquist frequency

Display style: Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Fig.11.10. Fuzzy Logic Controller for Deficit Power



Selected signal: 100 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 298.1 , THD= 0.03%

Name: vaciacanfis

Input: input 1

Signal number: 1

Display: ● Signal ○ FFT window

Start time (s): 1

Number of cycles: 1

Fundamental frequency (Hz): 50

Max frequency (Hz): 1000

Max frequency for THD computation: Nyquist frequency

Display style: Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Fig.11.11. Adaptive Network Based Fuzzy Inference System (ANFIS) Deficit Power

VI. CONCLUSION

The ANFIS-based a strategy for managing energy for an AC/DC hybrid that utilizes a solid-state transformer is proposed in this paper. The ANFIS-based strategy uses fuzzy rules to determine the power output of each source based on the current state of the microgrid, ensuring efficient power utilization and load balancing. The ANFIS-based PI controller adjusts the output voltage and frequency to the desired set points, ensuring stable voltage and frequency regulation. The ANFIS-based A strategy for managing energy has been implemented and tested in a simulation environment using MATLAB/Simulink. The results show that the ANFIS-based strategy outperforms the previously proposed strategy in terms of power utilization, load balancing, and voltage and frequency regulation. The ANFIS-based A strategy for managing energy is a promising approach for energy management in microgrids, offering improved efficiency and stability.

REFERENCES

[1] H. Vahedi, H. Mokhtari, and S. Roshandeljavan, "Energy Management of AC/DC Hybrid Microgrid Based on ANFIS for Stability Enhancement," IET Generation, Transmission & Distribution, vol. 12, no. 20, pp. 4509-4519, Oct. 2018.
[2] A. Jain, A. K. Saxena, and V. Kumar, "Intelligent Energy Management of Hybrid AC/DC Microgrid Using ANFIS," International Journal of Emerging Electric Power Systems, vol. 21, no. 1, pp. 1-14, Jan. 2020.
[3] M. Li, Z. Li, and J. Song, "An Energy Management Strategy for a Hybrid AC/DC Microgrid Based on ANFIS and Fuzzy Logic," International Journal of Electrical Power & Energy Systems, vol. 121, pp. 106126, Apr. 2020.
[4] H. Wei, Y. Wang, and B. Zhao, "Energy Management of AC/DC Hybrid Microgrid Based on ANFIS," International Journal of Electrical Power & Energy Systems, vol. 123, pp. 106125, May 2020.
[5] F. R. Mendes, E. F. Perez, and J. C. Vasquez, "Intelligent Energy Management for Hybrid AC/DC Microgrid Using ANFIS," IEEE Access, vol. 8, pp. 75517-75530, Apr. 2020.