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Performance Enhancement of Microgrid Stability and Quality with ANN regulated UPFC

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ABSTRACT: this paper aims to utilize a UPFC (Unified-Power Flow-Controller) with an Artificial Neural Network (UPFCANN) to enhance power quality within a microgrid setup. The microgrid comprises various renewable source based on solar PV arrays, wind turbines and a synchronous generator, along with a grid connection and loads. To control the converters effectively, pulse width modulation techniques are employed. During grid faults such as three-phase LLLG, power fluctuations lead to increased harmonic content, affecting both the grid and loads. Conventional methods like Static Var Compensators and super-capacitors have fallen short in mitigating harmonic distortions and improving microgrid efficiency. To tackle these issues, the project proposes integrating a UPFC controller, which combines both shunt and series control functionalities, replacing the SVC controller. This integrated approach aims to enhance current and voltage parameters, thereby improving microgrid operation in both islanded and grid-connected modes. By reducing harmonic distortions, the proposed system significantly enhances power quality, offering a more efficient and resilient microgrid solution. The presentation and evaluation of the proposed system is conducted using Matlab/Simulink.

KEYWORDS: UPFC, ANN, Micro-grid, Renewable energy sources,Grid faults,SVC, MATLAB

I. INTRODUCTION

Renewable energy sources, particularly solar and wind energy, have become prominent solutions for power generation due to their abundance. Current research is centered on hybrid renewable energy systems that combine solar and wind energies to fulfill load demands and improve reliability. However, integrating these renewable sources with the grid can disturb system balance, reliability, and quality because of harmonics introduced by power electronic switches and the unpredictable nature of solar and wind power generation, which is influenced by climate conditions. As a result, transmission and distribution networks have evolved to incorporate these renewable sources effectively.

FACTS strands for Flexible Alternating Current Transmission System have been integrated into hybrid power systems. These devices facilitate power exchange between the network and themselves, ensuring the functionality of hybrid systems in the face of disruptions and variations in weather conditions. FACTS devices are versatile and can be configured in series, switched, or combination arrangements. Devices from the Series FACTS family regulate transmission line reactance, balance voltage, and adjust active power. Examples consist of Dynamic Voltage Restorers (DVRs), Static Synchronous Series Compensators (SSSCs) and Thyristor Controller Series Capacitors (TCSCs). The Shunt
FACTS devices like Static Var Compensators (SVCs) and the Static Synchronous Compensators(STATCOMs) inject or absorb reactive power to maintain system voltage. Combining shunt and series compensators yields benefits with the Unified Power Flow Controller (UPFC) being the most commonly used combined series shunt FACTS devices.

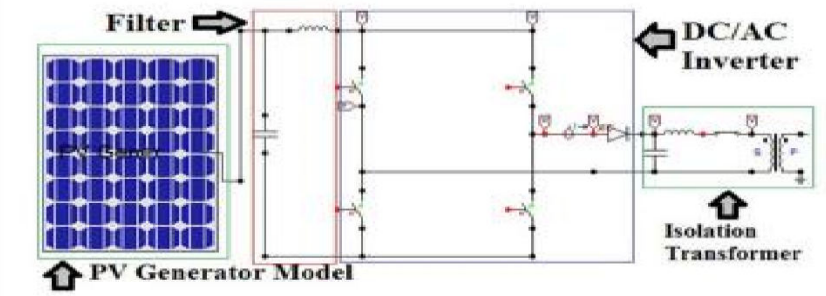

Fig.1 ATP model of PV system

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FACTS devices, known as STATCOM and SVC, are utilized in renewable energy systems like PV and WT, with their performance compared. STATCOM demonstrates superior voltage support compared to SVC, albeit at a higher cost. The hybrid system's performance is evaluated in three configurations such as independent and grid-connected with the STATCOM. Results indicate that the STATCOM connection, regulating voltage and Total Harmonic Distortions (THD) in currents and voltages that optimizes system performance. However, detailed exploration of the STATCOM controller is lacking. The controller generated by the UPFC effectively reduces overall harmonics, enhances power quality and maintains voltage during abnormal events.

The primary innovation of this study lies in implementing an Artificial Neural Network (ANN) controller for the UPFC, aimed at enhancing the efficiency of an on-grid Renewable Hybrid System. This novel controller effectively manages power flow between the UPFC and the system, thereby reducing disturbances and enhancing overall performance. The control method involves adjusting the controller's parameters and assessing the anticipated trajectory. Furthermore, this research rigorously evaluates the proposed networked system across various scenarios, including sagging, swelling, and unbalanced load conditions.

II. PV GENERATION

A. *Modelling Of The PV Generation*

In order to create a PV module and subsequently a PV array with the appropriate power and voltage levels, it is essential to model a PV cell, which makes up the PV source. The typical equivalent circuit of a PV cell, which consists of current source and a reverse blocking diode, is seen in Fig. 1. It is made up of a photo current (Iph) that is dependent on radiation and temperature, an internal resistance (I) that allows current (I) to flow, and a shunt resistance that describes the leakage current (Ish).

$$I = I_{Ph} - I_0 - I_{sh} \tag{1}$$

$$I_{Ph} = [I_{sc} + K_i(T_k - T)] \times \frac{G}{1000} \tag{2}$$

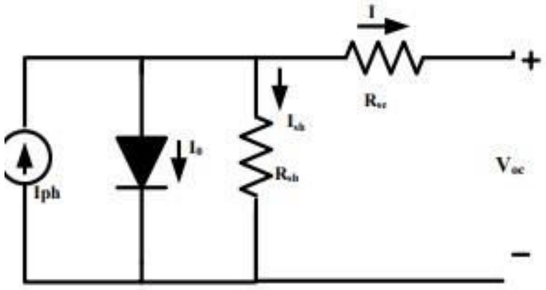

Fig.2 Solar cell equivalent model

The solar cell module current, denoted by Ipv (in Amperes), is influenced by several factors. These include the reverse saturation current of Diode denoted by Io, The leakage current denoted by Ish, the diode voltage represented by Vpv, the open circuit voltage denoted by Voc, the series resistance denoted by Rse (in ohms), the shunt resistance (also in ohms), the short circuit current denoted by Isc , and the electron charge denoted by (q), the Boltzmann constant denoted by k the diode ideality factor denoted by A, The temperature of p-n junction measured in Kelvin and the diode reverse current denoted by Irs, and the number of cells connected denoted by s and P (in Amperes).

B. *Design of Filters*

Passive power filters, comprising inductors, capacitors, and resistors, fall into two main categories: passive tuned filters and high-pass filters. These filters play a crucial role in addressing power quality issues to a certain extent.

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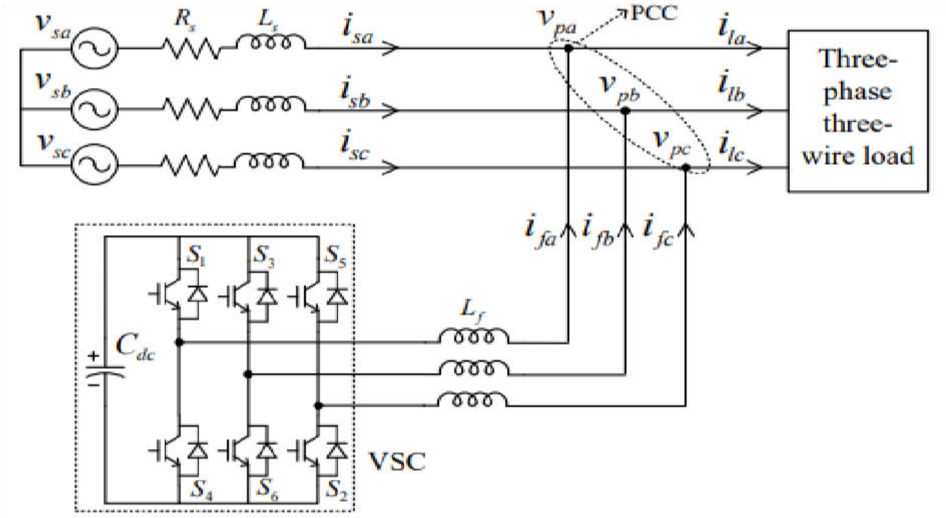

Fig.3: Design of Shunt active power filter

The Shunt-active-power filters offer the advantage of deploying and Low Rating Active Power filters in the highpower applications at a cost-effective price point. They also augment the compensating capabilities of passive filters. Additionally, integrating the active power filter with the terminals of passive filters further enhances the compensation capabilities of existing filters, thereby adding flexibility to the compensation system.

III. SIMULATION MODEL SIMULATION RESULTS AND DISCUSSION

Two distinct electrical systems are utilized to assess the applicability of the PV system model for the switching studies. The first system operates on two modes namely single-phase and electrical setup, while the second operates on a threephase electrical setup.

In the evaluation of the solar PV system model using a single-phase electrical system. The 240V single-phase electrical power system is integrated with the PV generating system to validate it for switching studies. Upon activation, the PV generator's output voltage nearly doubles its steadystate values due to switching operations. Mainly the output voltage of the solar PV system increases from 1.07 per unit (169.66 V) to 1.835 per unit (291.06 V). To convert the generated electricity from DC to AC for integration into the utility grid, A DC to AC inverter links the solar PV generator model to the grid of AC. This DC/AC inverter is represented by two pairs of thyristors, as shown in Fig. 4.

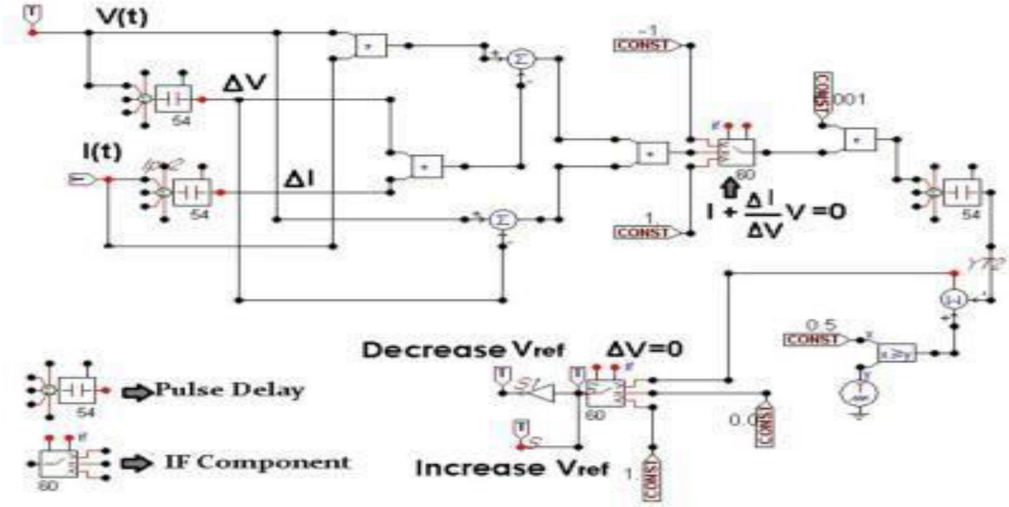

Fig.4:ATP/EMTP model of inverter model

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The performance of the microgrid system is assessed using the MATLAB/Simulink 2018a program to evaluate the simulation results of the proposed approach. The evaluation is conducted in both grid-connected and island modes to gauge how effectively the system can enhance the power quality. The performance of the improved power quality method will be verified for each of these connection options using five distinct cases: individualistic SVC; individualistic super capacitor; combined version with SVC and super capacitor; UPFC-PI and UPFC-ANN; and lack of compensating equipment.

A. Grid Connecterd Mode

The proposed system's Simulink model is depicted in the Figure 6. By integrating the UPFC in both grid mode and islanded mode during various fault occurrences, the quality and stability of the system are assessed. Simulations involve sag/swell events and imbalanced loading circumstances with varying load patterns to evaluate the UPFC controller's ability to reduce overall harmonic distortions. Using system voltage and current waveforms, the impact of introducing UPFC to the system during these failures is analyzed.

The primary objective of this study is to optimize the control of the UPFC to enhance system performance. To evaluate the effectiveness of the system using the proposed approach, an Artificial Neural Network (ANN) controller is employed to manage the DC-link voltage of UPFC during specific fault occurrences. An investigation into a 30% swell fault in condition occurring between 0.1 to 0.3 seconds will include plotting the convergence of the objective function.

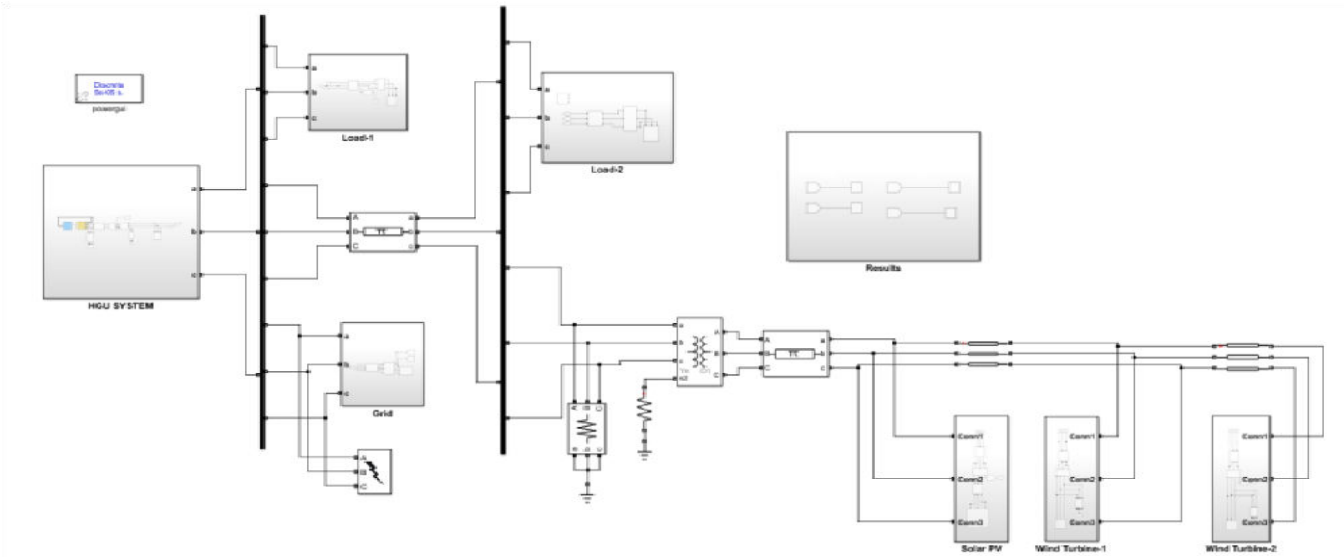

Figure. 5 Simulink Model systems in Grid Connected mode

In the grid-connected mode and the performance metrics of relevant grid-voltage (Vg) and current(Ig), as well as load voltage (VL) and current (IL), are being evaluated. These assessments are conducted in the absence of a compensatory device. The pertinent results of concern are illustrated in Figure 7.

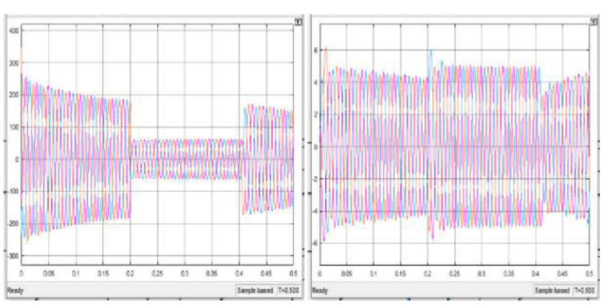

Fig.6 Voltage and Current gate response during Grid connected mode

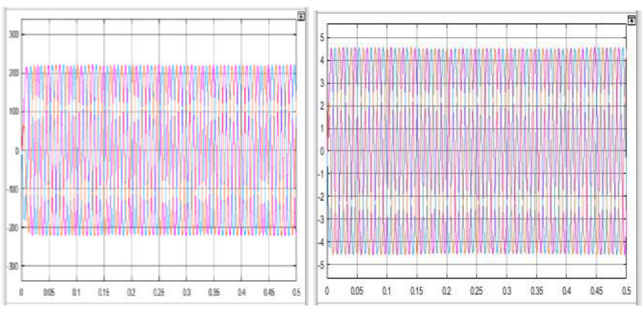

Fig.7 Perfromance of line voltage and current during Grid connected mode

To assess the regulated UPFC's capability to provide reactive power to the proposed system and uphold voltage at point of connection between UPFC and the system, voltage sag events will be simulated. This will involve

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applying the nonlinear RL load to system between 0.1 to 0.3 seconds to mimic the sag condition. Consequently, the voltage and currents will begin to decline due to the application of this non-linear load.

As depicted in Figure 8, the UPFC is utilized to compensate for voltage and current drop resulting from this flaw by controlling the series and shunt filters, thereby raising the voltage.

B. *Islanded mode of Operation*

The main objective to this study is to optimize the control of the UPFC to Enhance system performance, particularly when operating in Islanded Mode. This mode of operation is modeled in Figure 9.

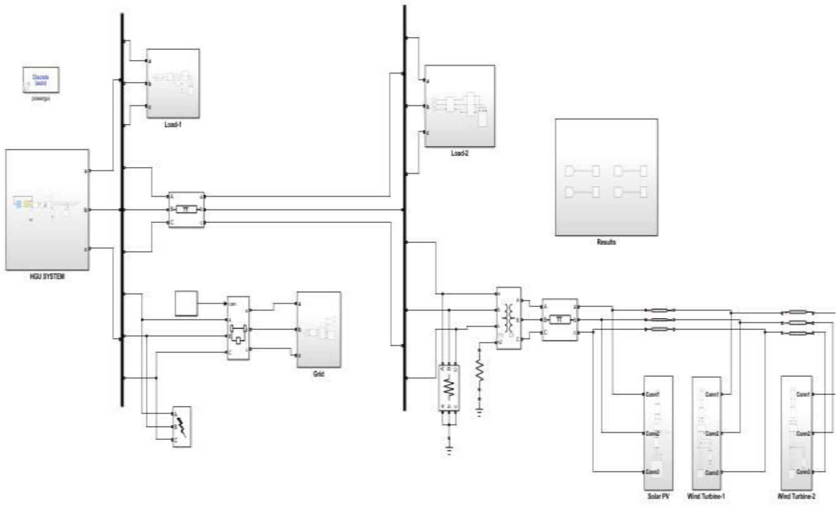

Fig. 8 Simulink model of UPQC in islanded mode

To Assess the effectiveness of the system using the Proposed approach, an Artificial Neural Network (ANN) controller is employed to regulate the DC-link voltage of the UPFC during specific fault Occurrences. An investigation into a 30% swell fault condition occurring between 0.1 to 0.3 seconds will involve plotting the convergence of the objective function.

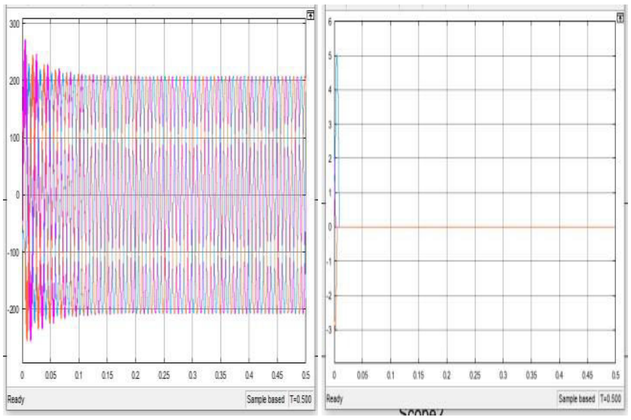

Fig.9 Performance of Gate voltage and current during Islanded mode

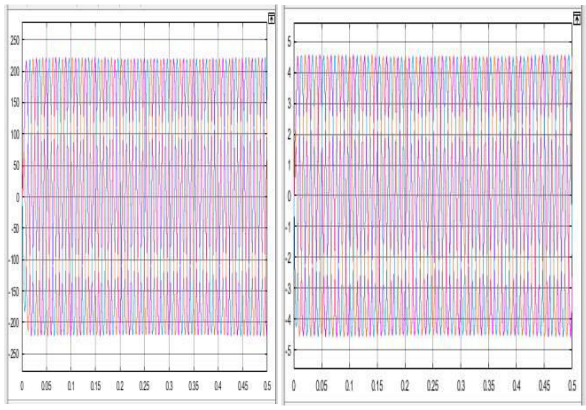

Fig.10 Performance of line voltage and current during Islanded mode

The simulation results without the use of any compensating device are depicted in Figure 10. The fault injection occurs between 0.2 and 0.4 seconds. During this time, the current increases from 4.5A to 5.2A, while the grid voltage drops from 220V to 60V. The reductions in load voltage and current are of lower magnitude. These performance parameters are evaluated in the grid-linked mode.

In an islanded environment, the compensating device is integrated as a super capacitor at the point of common connection. The waveforms of the grid voltages and currents are illustrated in Figure 11. The current and load voltage ratings are determined by analyzing an amplitude ranging from 0.2 to 0.4.

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Simulation results based on the fault injected between 0.2s to 0.4s are obtained by employing both a super capacitor (SC) and a Static Var Compensator (SVC) as compensating devices. The current and load voltage ratings are determined by measuring an amplitude ranging from 0.01 to 0.4.

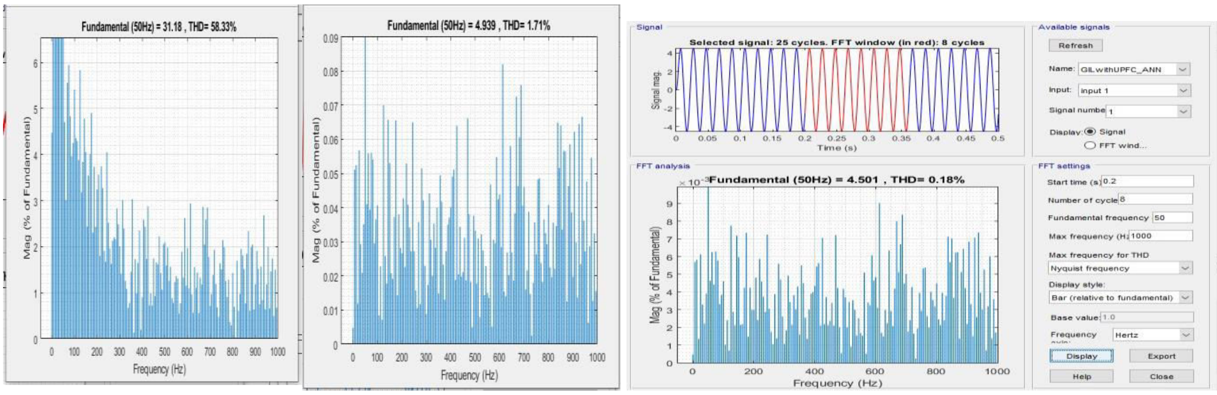

Figure.11 THD of current performance

By lowering the THD, the UPFC consist an effect on enhancing power quality of the system. In this instance, a simulation of the injection of a few harmonics will be used to assess how well the regulated UPFC reduces THD. By connecting the induction motor, R, and RL as separate loads, the harmonics are simulated. Using different loads for voltage and current profile and the tuned ANN controller was able to regulate the UPFC and lower the THD is illustrated in Fig.12 and 13. Furthermore, in order to review the anticipated methods, in the context of islanded and grid operation, an ANN-based controller in the UPFC interconnected system is investigated. Utilizing the suggested control approach, the real and reactive power yields result with extremely low error rates, saving energy on the grid side and lowering THD losses.

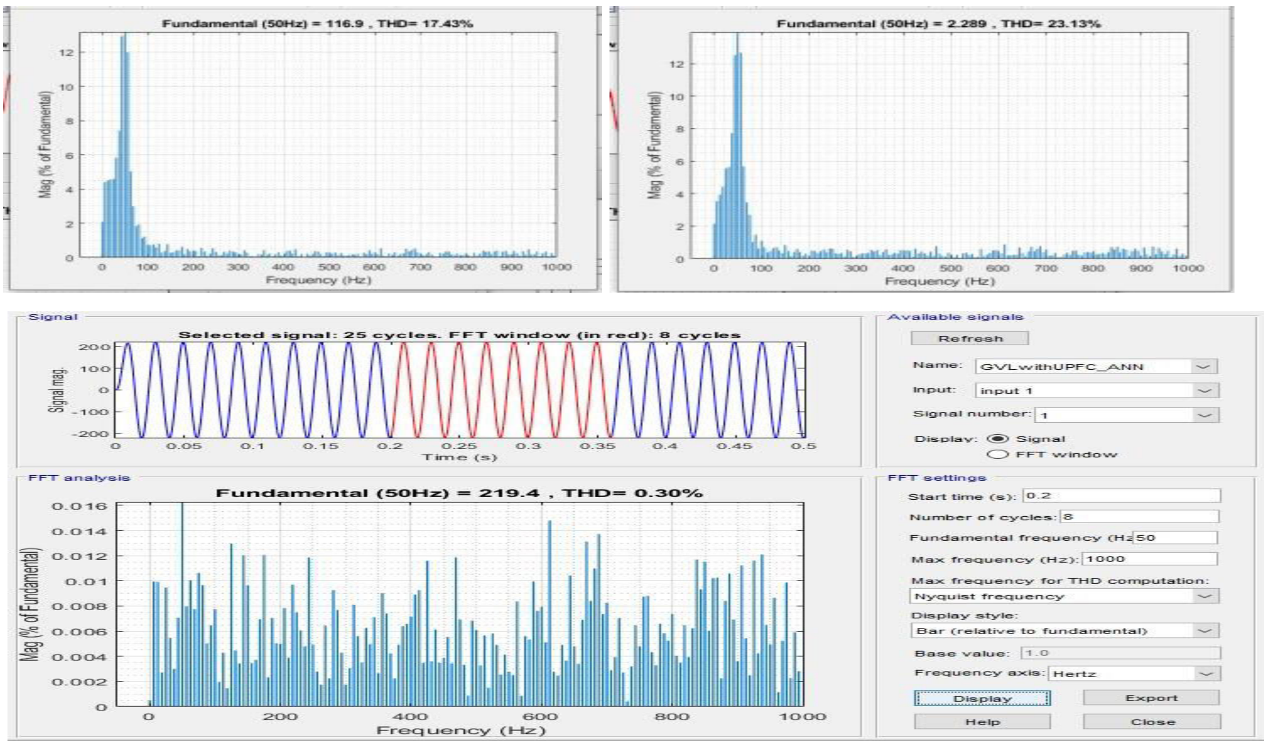

Fig. 12 THD performance of VL

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Table.1THD comparison table

COMPENSATION	Grid connected mode		Islanded mode	
	VL	IL	VL	IL
Without compensation	58.33%	68.18 %	17.43%	23.13 %
Super capacitor	7.31 %	8.28 %	16.90%	9.32 %
Static var compensator	4.16 %	7.18 %	7.52 %	3.68 %
SVC + SC	1.93 %	1.71 %	1.49 %	1.32 %
UPFC-PI	0.45 %	0.47 %	0.45 %	0.46 %
UPFC-ANN	0.30 %	0.18 %	0.29 %	0.22 %

The simulation results are illustrated based on Table.1 showcase the performance of the ANN-tuned UPQC system in both Grid Connected as well as Islanded Modes of the operation. Despite the occurrence of faults, load voltage and currents remain nearly unchanged, closely resembling their original values. This demonstrates the effectiveness of the UPQC system in maintaining grid stability and ensuring reliable operation of the microgrid under varying operating conditions. The ability to sustain load parameters close to the nominal values and even in the presence of faults, highlights the robustness and efficiency of the proposed ANN-based control strategy for microgrid stability enhancement.

IV. CONCLUSION

To improve the quality of electricity in a microgrid, a Unified electricity Flow Controller (UPFC) has been installed. A solar PV array, wind turbines, a synchronous generator, a grid link, and loads make up the microgrid. Pulse width modulation methods are used to control the converters. Power fluctuations and a rise in harmonic content are the results of faults like three-phase LLLG that influence the grid and the loads. Traditional approaches to addressing these issues, such the implementation of super-capacitors and static vara compensators, were ineffective in reducing harmonic distortions. Total harmonic distortions were used as the basis for a comparative analysis of the suggested UPFC system, the super-capacitor system, and the conventional SVC system. Matlab/Simulink 2018a was used to conduct the performance analysis, which showed that the ANN-based UPFC system outperformed its PI-based equivalent in terms of performance.

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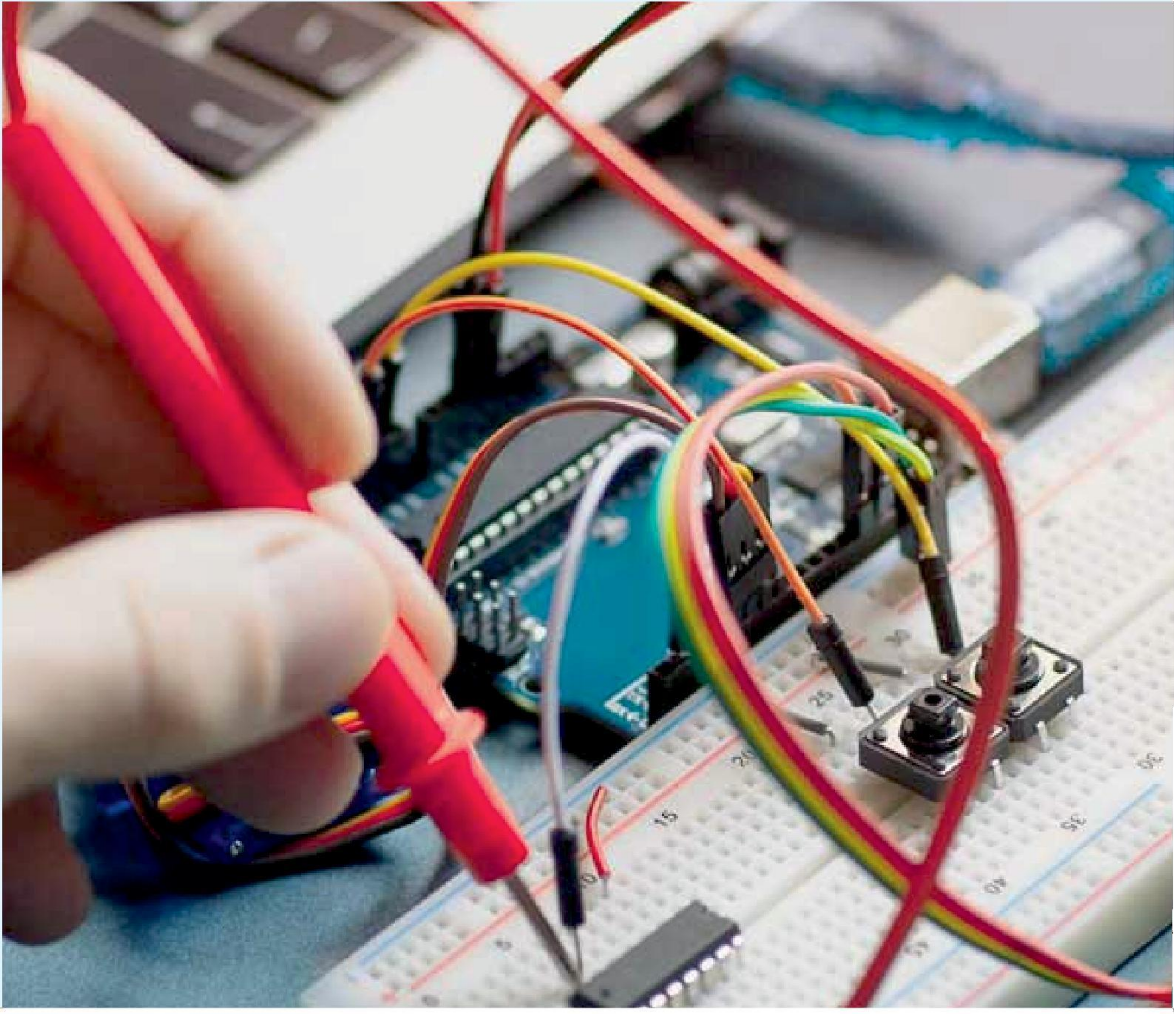

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