ANFIS-BASED GRID-CONNECTED INVERTERCONTROL TECHNIQUE AIMED AT IMPROVING DYNAMIC PERFORMANCE IN MICROGRID SYSTEMS

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Abstract

A micro-grid interfacing converter with multi-control is proposed here. It offers a multi-objective control technique for grid interlinked converters using an ANFIS controller. The controller under consideration uses the combined characteristics of controllers based on fuzzy logic and the structure of Neural network to substantially enhance reaction of the grid-connected converter under system disturbances. In the proposed method, the ANFIS controller's control settings are dynamically modified depending on the Sugeno control system's operational circumstances. As a consequence, it responds quickly to disruptions with slight error and settling duration. The GCI is utilized to offer many additional functions related to the proposed multi-objective control system. The suggested controller's predictive response is shown through MATLAB simulations is efficient than an AFPI controller during interruptions. The case studies and results of the suggested system are also compared to literature to verify the controller's effectiveness

Keywords Micro grid Grid Interconnected Converter ANFIS controller Power Quality Fuzzy-logic Controller

1. INTRODUCTION

Today's electricity is transitioning to a new era, with a high renewable generation incorporated into the distribution network through distributed energy resources [1], [2]. Grid-Connected Inverters (GCI) are often used to connect generating units to the utility grid. One of its main responsibilities is to deliver all active energy into the system. However, because to the scarcity and environment of renewable sources and market price concerns, It is possible that generating units will be unable to provide the rated actual power to the grid. As a result, the grade of converters is often underutilized. The GCI's unused apparent power rating may therefore be utilized for several additional functions. [3],[4]. However, the growing use of converter-based generating units and non-linear loads in the distribution network affects power quality (PQ). Renewable energy source units, critical and valuable local loads affect the power quality. Poor PQ will affect the on-grid energy price in PQ-sensitive markets [5],[6]. Various control methods for renewable generating sources connected to the electric grid have been suggested [7,8]. The electric grid's power quality is guaranteed via controlling equipment or a GCI with multipurpose capabilities. [9],[10]. Adding controlling equipment to solve the PQ issue raises system costs, perhaps unfeasible for low-voltages. A GCI with multifunctional capabilities has recently been suggested to solve this issue[11],[12].A current regulated voltage-source inverter (VSI) is used to link generating sources to the grid side place of point of coupling connection (PCC)[13],14]. The most often used current controllers for GCIs are PR, PI, and hysteresis controllers [15]. Every existing control method has benefits and drawbacks. In [16], [17], with the help of an optimization method based on grey wolf, the switches of the high-speed step-up converter are activated. The performance of the new controller is compared to that of a standard Controller based on particle swarm optimization. [18]. The use of fixed gain linear controllers Literature also describes PI/PID controllers with synchronous rotation (dq0) for regulating GCI.The literature mentions several PI controller versions to solve operating point issues (as well as the inclusion of a grid voltage feed forward link, control with many states of feedback)It increases the bandwidth of the PI controller. But it will test the system's stability. Because PI, PID, and PR controllers are neither intelligent nor adaptable, researchers have turned to intelligent methods like Neuronal networks, fuzzy logic, and evolutionary algorithms to regulate GCIs. The fuzzy logic-based supervisory control system continuously modifies the PI controller's gains depending on the operating conditions described in ref [19]. The APFI controller cannot effectively minimize disturbances during rapid load changes, and enhance settling time and overshoot.[20] controls a bidirectional converter with a battery storage depending on the microgrid's voltage to address generation and load issues. A proportional-integral controller is utilized with a selector-based control method. In [21], a control method for renewable source with hybrid storage units is used. A second harmonic phased locked- loop (PLL) is used to synchronize/resynchronize the micro-grid system in emergencies. An adaptive power management algorithm efficiently operates and manages the micro-grid system in both modes. [22] Implements consensus-based control for storage units in a DC micro-grid using a serially connected multi-input converter. The serially connected multi-input converter contains two phases, one for super-capacitors and the other for batteries. [23] Developed an adaptive droop control technique that adjusts the droop settings based on mathematical computations. The adaptive droop controller was designed to enhance the low-voltage DC microgrid's performance by balancing load sharing and voltage regulation. [24] Uses adaptive control methods for a single-stage PV based battery management system. It is linked to a micro-grid that uses maximum electricity. Two batteries and Superconducting Magnetic Energy storage (SMES) systems combined PV - Wind DC-bus micro-grid is evaluated in [25], [26].

This work proposes an ANFIS controller to regulate the GCI. A Sugeno type fuzzy model is implemented for the ANFIS controller. The Sugeno type fuzzy model is the combination of fuzzy and neural network. As a consequence, it is easier to calculate and adjust than the Mamdani type fuzzy model.The ANFIS quickly detects changes in system circumstances and dynamically adjusts the output control signal. Because of this, the control mechanism mandates to operate in a linear zone under all operating circumstances, minimizing overshoot, oscillations, and settling time. In addition to its fundamental duty of adding active electricity into the grid at power factor equal to 1, the GCI is regulated to offer various auxiliary services. Correcting reactive load demand, disturbed load and neutral current. All are accomplished with fewer membership functions and rules than mamdani-type models, resulting in reduced computation costs. The system is modeled in Matlab. The suggested controller's efficiency is validated by comparing the results to the existing literature.

2. SYSTEM DESCRIPTION

Figure 1 shows the DG linked to a three phase four conductor generating system through a various operational GCI. A tri-phased tri-limbed, two-level inverter is implemented. The renewable generating source is powered by the dc-link (PCU). Decoupling renewable generating sources from the power grid is achieved using dc-link capacitors ($C_{dc1}$and C_{dc2}) [4]. The GCI's output connects to the utility grid via an LCL filtering circuit. To attenuate resonances, $R_d$is linked in series withC_f. Loads are linked to the PCC with both balanced and unbalanced

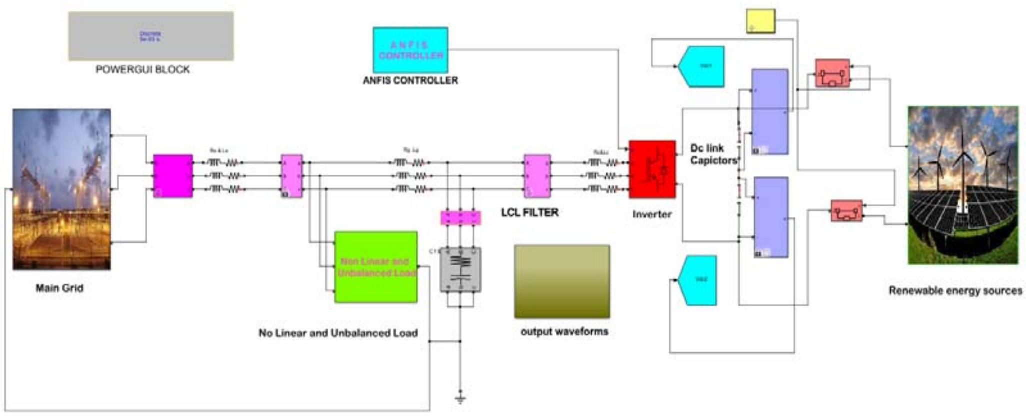


Figure 1. Schematic Diagram of Proposed System.

3. CONTROL SCHEME

The proposed multi-objective controls approach seeks to introduce DG active energy into the utility grid. Controlling load reactive energy requirement, current harmonics, neutral current, and unbalanced currents, are all regulated concurrently by the GCI to guarantee grid current is controlled in all operating circumstances with minimal THD, with IEEE standards. Operating like an active power filtering device, the GCI only provides additional services if zero DG's output. To accomplish the aforementioned objectives, appropriate reference current must be retrieved.

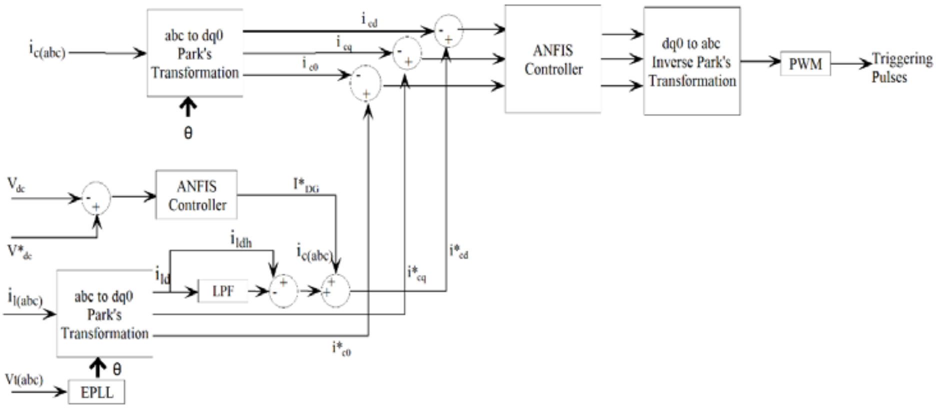


Figure 2. Control Scheme of the System

On the other hand, dc-link voltage and GCI output current are used to compute reference current. All control methods are implemented in the dq0 frame [12]. The enhanced phase locked loop (EPLL) supplies the reference angle (θ) for the dq0 transformation. to regulate the DG units produce active current i^*_{DG}, the difference between i^*_{cd} and i_{ldh} is done

$$i^*_{cd} = i^*_{DG} + i_{ldh} \tag{3.1}$$

To modify the full load side reactive power requirement, the load current's q-axis component (i_{lq}) shows the load's reactive power requirement. Thus, the GCI's q-axis reference current is represented by Eq (2). The 0-axis component additionally compensates for imbalanced load current. Equation (2) therefore sets the GCI's 0-axis reference current. Finally, the current controller produces switching signals for the GCI based on the change in the required current (i^*_{cdq0})) and the actual current (i_{cdqo}).

$$i^*_{cq} = i_{lq}; \ i^*_{c0} = i_{l0} \tag{3.2}$$

3.1 Implementation of standard AFPI controller

AFPI controller has a nonlinear adaptive control method that provides stable control performance in the face of unknown system characteristics [27–28]. Mamdani type Fuzzy controller is used to track the PI controller gain values.

4. PROPOSED ANFIS STRUCTURE.

The performance of an ANFIS controller is compared to that of a conventional AFPI controller. It explains how to create an effective transient performance for the proposed system with minimum overrun and clearing time.

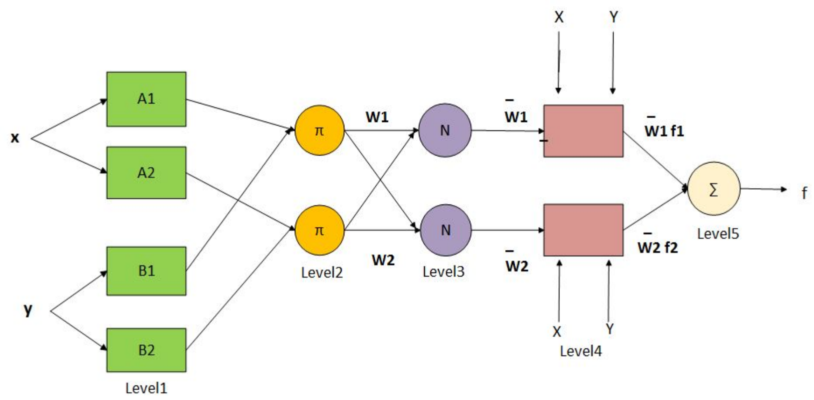


Figure 3. Type-3 ANFIS Structure

The exterior and interior current loops, which are hierarchical control loops, govern GCI. Inner control loops respond faster than outward loops for smooth system operation. As a result, the bandwidth of the inner control loop is enhanced.

Takagi and Sugeno's type-3 fuzzy inference technique is utilized here. Each rule's output is a linear combination of the input variables plus a constant term. In the final output, each rule's output is weighted. Fig. shows the comparable ANFIS structure..

The following sections explain the different levels of this ANFIS structure:

Level1: In this level, every hub I is versatile and has a hub work..

$$O_i^1 = \mu_{Ai}(x) \tag{4.1}$$

x is the hub I input, Ai is the arbitrary worth connected with this hub capacity, and Ai will be Ai's enrollment work. Commonly, Ai(x) is chosen as

$$\mu_{Ai}(x) = \frac{1}{1+\left[\left(\frac{x-c_i}{a_i}\right)^2\right]^{b_i}} \tag{4.2}$$

x is the information and ai, bi, ci signifies the reason boundary set

Level2: Each hub in this level is a decent hub that figures the terminating strength dependent on a standard.

Every hub's yield is the result of every approaching sign and is given by,,

$$O_i^2 = \omega_i = \mu_{Ai}(x) \times \mu_{Bi}(y), \quad i = 1,2 \tag{4.3}$$

Level 3: In this level, each hub is a decent hub. Each ith hub processes the proportion of the ith rule's terminating solidarity to the all out of every one of the standards' terminating qualities. The ith hub's yield is the standardized terminating strength given by

$$O_i^3 = \overline{\omega_i} = \frac{\omega_i}{\omega_1 + \omega_2}, \quad i = 1,2 \tag{4.4}$$

Level 4: In this level, every hub is a versatile hub with a hub work characterized by

$$O_i^4 = \overline{w}_i f_i = \overline{w}_i (p_i x + q_{iy} + r_i), i = 1,2 \tag{4.5}$$

wi is the Level 3 result and pi, qi, ri is the subsequent ensuing variable data

Level 5: This level has just single steady hub that produces the all out yield as the all out of all signs got, for example.

$$O_i^5 = \text{overall output} \sum_i \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \tag{4.6}$$

5. SIMULATION RESULTS AND DISCUSSION.

Here are the case studies in this simulation research. The DG unit's output power is set zero till t = 0.1 s. From t = 0.1 to 0.7 Sec, the DG can only produce 18 kW. The DG output increases from 0.7 to 1.25 sec to 27.5 kW. The load demand is 8.5 kW from t = 0 to 0.4 Sec. In this range, the load demand rises to 23.5 kW. 1 to 1.25 sec reduces the load demand to 18 kW.

5.1. Case: 1when load is constant

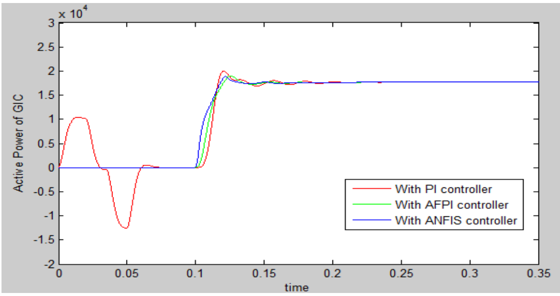
Its Simulink architecture is shown in Fig 1 and its specifications are listed in Table 1. Fig. 4compares converter and grid active powers with PI, AFPI, and ANFIS controllers. Fig. 5 shows the waveforms of Grid Current, and converter current at t=0.1. As shown in fig.8, ANFIS controller eliminates harmonics better than PI and AFPI controller. Data on GCI Active Power Dynamic Response are in Table 2.

Table 1. Simulation system parameters

S.No	Simulation Parameters	Values
1	Voltage at Grid, Frequency	400V (L-L), 50 Hertz
2	Input DC Bus Voltage, Capacitance	700 Volts, 15 milli farad
3	LCLfilter	R_C= 0.05 Ohms; R_G = 0.15 Ohms; R_D = 1 Ohm Lc = 0.214 mh; C_F= 100 micro farad; L_G= 0.145 mH
4	Non Linear Load Parameters	3 Phase: R = 50 Ohms,L = 50 mH; 1 Phase: (A-n): R = 50 Ohms, L = 50 mH; (B -n): R = 50 Ohms, L = 50 mH;
5	RES Input power Capacity	21KW

Table 2. Dynamic responses of GCI Active power with various controllers

GCI Active Power	PI Controller	AFPI Controller	ANFIS Controller
Peak Overshoot	20000	19000	18900
Settling Time	0.24	0.2	0.18
Rise Time	0.109	0.1055	0.102



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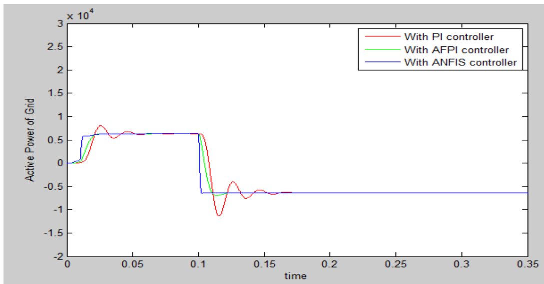

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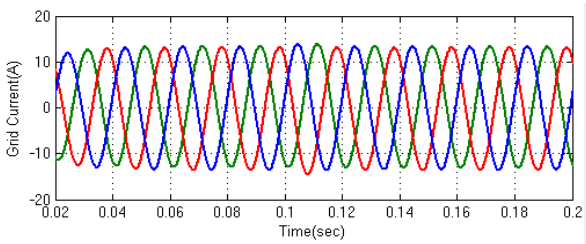
Figure 4. **(a)** Converter active Power (b) Grid Active Power



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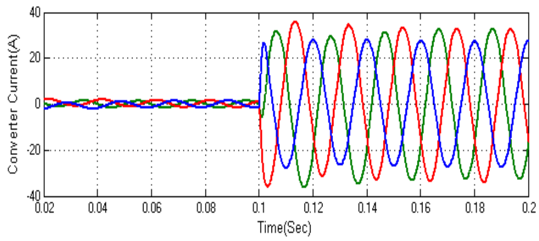

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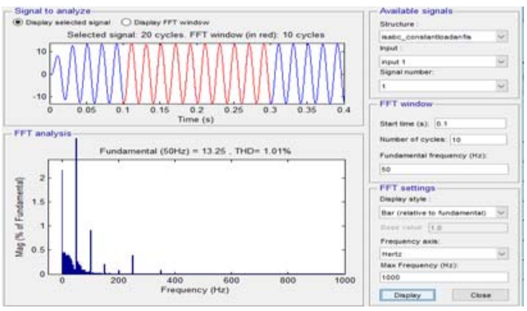
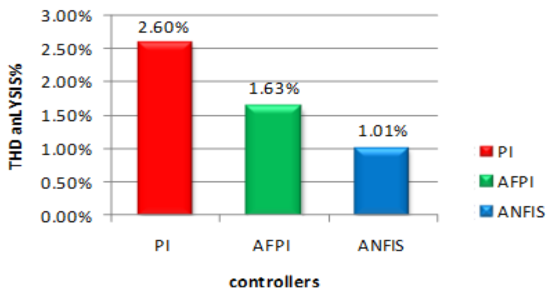




(c) (d)

Figure 5. During constant Load (a) Grid Current (b) converter current (c) ANFIS THD Analysis (d) Comparison Graph

5.2. Case2: Load changing Conditions

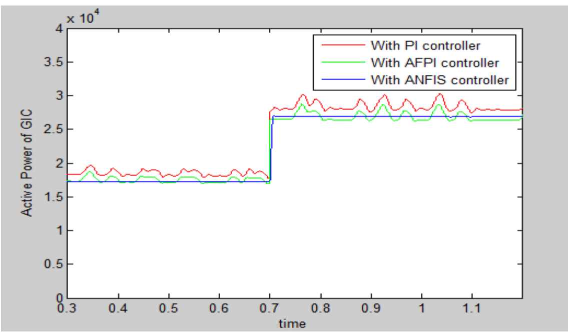
In this instance, the starting load is 8.5 kilowatts, which is raised to 23.5 kilowatts between time= 0.4 and 1 sec. Later, the load is reduced to 18 kilowatts. Fig. 6 compares converter and grid active powers as well as DC link voltage for all controllers (PI, AFPI and ANFIS). Fig. 7 shows the proposed ANFIS controller's system responses such, Grid current, and converter current. The suggested controller shows improved dynamic responsiveness to unexpected load fluctuations. Table 3 shows the THD values for grid current under constant and changing load circumstances. Table 4 shows the DC link voltage dynamic response under various load conditions.

Table 3. Grid current THD values with various controllers.

Grid Current THD	PI Controller	AFPI Controller	ANFIS Controller
During Constant Load	2.60%	1.63%	1.01%
During Load Changing Condition	3.43%	2.04%	1.20%

Table 4. Dynamic responses of DC link voltage with various controllers.

DC link Voltage	PI Controller	AFPI Controller	ANFIS Controller
Peak Overshoot	710	703	700.012
Ripple %	2.57%	0.71%	0.0031%



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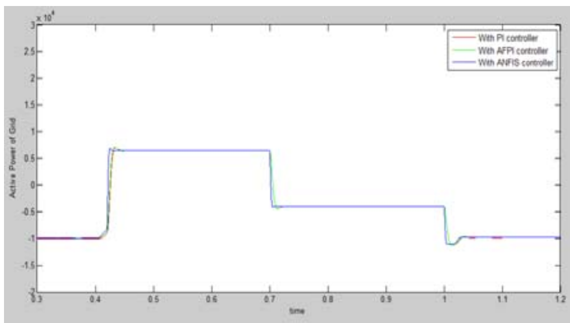

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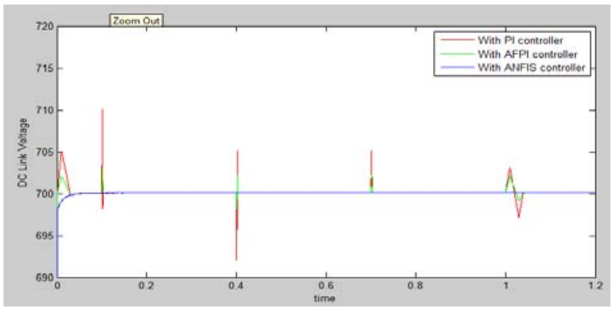

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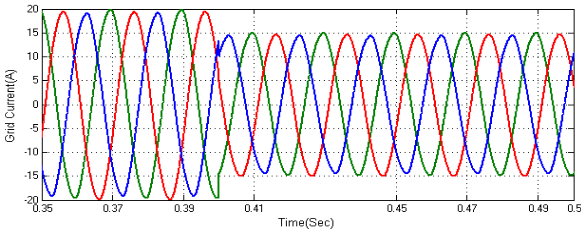
Figure 6. (a) Converter active Power of Grid (b) Active Power of Grid (c) DCLink voltage



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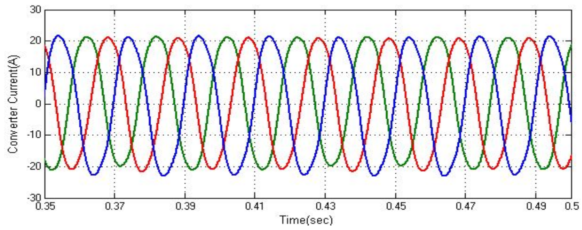

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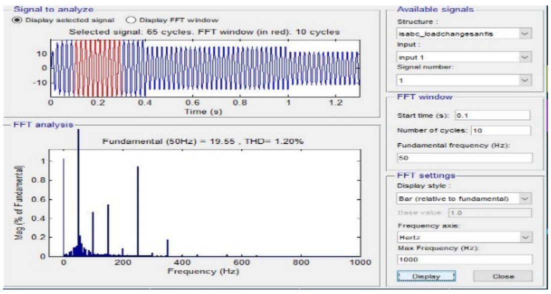

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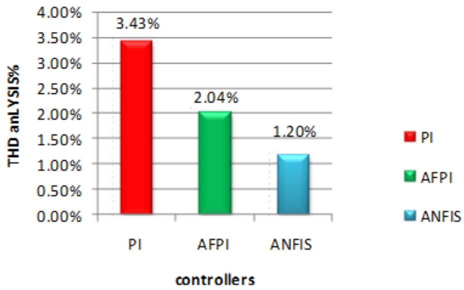

(d)

Figure 7. During Variable Load (a) Grid Current (d) Converter Current(c) ANFIS THD Analysis (d) Comparison Graph

6. CONCLUSION

The above research proposed a multi-target GCI control using an ANFIS controller. The proposed control method successfully enhanced the AFPI controller's basic structure and the FLC's resilience to a range of uncertainties. The suggested multi-target control method utilized GCI to inject active electricity from generating units into the utility grid. At the same time, reduction of harmonics in load current, reactive power control, unequal and neutral control of currents were measured. The grid current was, therefore, nearly balanced in all operating situations. The ANFIS models are also faster than AFPI designs. Matlab/Simulink simulation tests were used to assess the effectiveness of the suggested controller. The controller's performance is evaluated in a number of scenarios, and its accomplishments are as follows: 1) The Grid current THD is reduced to 1.2% during the dynamic condition. 2) GCI active power settling time is minimized to 0.18 sec compared to AFPI's 0.24 sec. 3) The DC link voltage ripple is reduced with less overshoot. The recommended controller outperformed the AFPI Controller in all circumstances, with lower overhead and faster adjustment times. The IEEE standards were met while reducing THD of current at grid side.

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