

Control Strategy for Critical Loads in Micro grid Using Renewable Energy Sources

Lavanya S^{#1}, Sathishkumar R^{*2}

^{#1}PG Scholar, Department of Electrical & Electronics Engineering, Anna University Regional Office, Madurai, India

^{*2}Faculty, Department of Electrical & Electronics Engineering, Anna University Regional Office, Madurai, India

ABSTRACT— When hybrid power generation system integrated to power system it produces major stability and control problems. The influence of the hybrid system in the grid system concerning the power quality measurements are the active power, reactive power, voltage deviation, flicker, harmonics, and electrical behavior of switching operation and these are measured according to International Electro-Technical Commission (IEC). The STATCOM provides reactive power support to hybrid system and load. The Battery Energy Storage System (BESS) is generally required to compensate the fluctuation generated by hybrid system. The proposed Inverter control scheme to mitigate the power quality issues for power quality improvement in the grid connected hybrid power generation system is simulated using MATLAB/ SIMULINK in power system block set. The control scheme has a capability to cancel out the harmonic parts of the load current and maintains the source voltage and current in-phase. The performance of the system using PI and FUZZY controller has been studied comparatively.

KEYWORDS— Power Quality, Battery Energy Storage System, Fuzzy Logic Controller, Hybrid Power Generation System.

I. INTRODUCTION

The increasing number of Renewable Energy Sources and Distributed Generation (DG) requires new technique for the operation and management of the electricity grid to enhance power supply reliability and power quality. The distributed generation and in integration of Renewable Energy Sources into the grid provides power quality problems. By using renewable energy sources we can get pollution less environment and it is available enormously in nature. Power shortage is reduced by implementing distributed generation. The power electronic loads place a major role in industries. These nonlinear loads inject harmonic currents in the AC system and increase overall reactive power demand by the equivalent load. The major power

quality problems are from system to load voltage sag/swell, voltage unbalance, voltage distortion and interruptions and from load to system are current harmonics, reactive current, current unbalance, voltage notching and voltage flickering [1]. These problems can be mitigated by using various techniques. Proportional Integral (PI) control [3] instead of power converter is implemented to manage reactive power interchange between wind farm and grid. To control power converter, a new current sharing approach is proposed in [4]. Pulse Width Modulation (PWM) based controller operates the inverter circuit to give a desired output. When turbine starts high frequency current flows through rectifier circuit and then stores into the dc-link capacitor. Instead of using dc-link capacitor storage device [3],[4] separate Battery Energy Storage System (BESS) is proposed in [5]. By using State Of Charge (SOC) technique BESS control is done. State Of Charge (SOC) technique proposed in [5] investigates with cascade pulse width modulation are presented in [6]. The experimental system includes no voltage-balancing control because it uses nine NiMH battery units that have an almost flat charge/ discharge voltage profile. In [10] STATCOM based control scheme [5] for power quality improvement in grid connected wind generating system and with nonlinear load is presented. This method reduces harmonic parts of load current. It maintains the current and source voltage in phase and also compensates reactive power demand only but produce harmonics [4],[9]. The operation of the control system developed for the STATCOM-BESS in MATLAB/SIMULINK for maintaining the power quality is simulated. To overcome these issues I proposed this paper.

In this paper inverter control is implemented to maintain unity power factor and power quality in the point of common coupling. Active and reactive power compensation is obtained because of the absence of FACTS devices. It also cancels harmonic current in the system. Separate Battery Energy Storage System also proposed in this paper. It will give rapid response and enhance the voltage stability of the system under fluctuation of wind turbine output.

II. HYBRID POWER EXTRACTION WITH BATTERIES

The proposed hybrid power extraction from wind generator and solar panel with battery energy storage with

distributed network is configured on its operating principle and is based on switching the inverter by using control strategy for critical load application is shown in fig. 1.

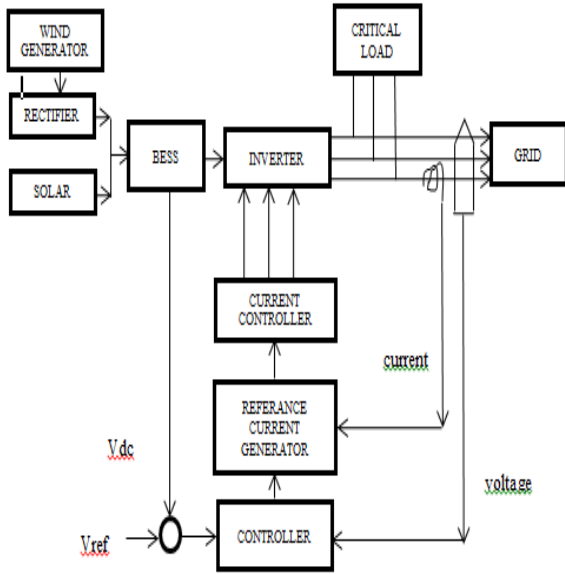


Fig. 1. Scheme for hybrid power generator with battery storage for critical load application

A. Wind Energy Generating System

It consist wind turbine, Permanent Magnet Synchronous Generator and diode rectifier to get dc bus voltage. The below mathematical relation gives wind turbine characteristic in the wind as in

$$P_{Wind} = \frac{1}{2} \rho \pi R^2 V^3 \quad (1)$$

Where ρ denotes air density (1.225 kg/m³), V_{wind} denotes the wind speed in m/s, and R denotes the rotor radius in meters. It is not possible to extract all kinetic energy of wind is called power coefficient. It is a function of tip speed ratio and pitch angle.

PMSG speed-power characteristic is given in fig. 2.

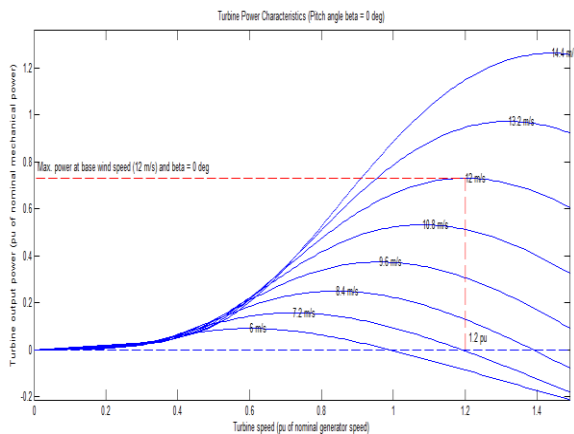


Fig. 2 Wind turbine speed-power characteristics

$$P_{Mech} = C_p P_{Wind} \quad (2)$$

$$P_{Wind} = \frac{1}{2} \rho \pi R^2 V^3 C_p \quad (3)$$

B. Solar System

Photo-Voltaic (PV) cells produce electricity from sun. Materials used in computer chips are similar to materials used in PV cells. These materials absorb energy from sunlight, which isolates the electrons from their atoms and allows them to generate electric power. PV cells are great because they don't require regular maintenance, are eco-friendly, and don't produce pollution in any form. The PV array is constructed solar cells. Each solar cell formed by a PN junction semiconductor, which produces currents by Photovoltaic effect. Fig. 3 shows solar cell parameters.

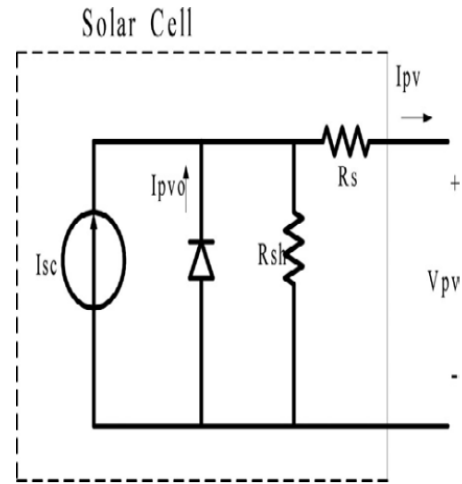


Fig. 3 Solar cell parameters

Current and voltage values injected from PV cell can be calculated by using formula given below.

$$V_{PV} = \left(\frac{nKT}{q}\right) \ln\left(\frac{I_{SC}}{I_{PV}} + 1\right) \quad (4)$$

$$I_{PV} = I_{SC} - I_{PV0} e^{\left(\frac{q(V_{PV} + I_{PV} R_s)}{nKT} - 1\right)} - \left(V_{PV} + \frac{R_s I_{SC}}{R_{sh}}\right) \quad (5)$$

Where R_s & R_{sh} - Series and Shunt resistances respectively.

- I_{SC} - The light induced current,
- N - The ideality factor of p-n junction,
- I_{PV0} -The diode saturation current,
- K - Boltzmann constant ($8.63 \times 10^{-5} \text{ J}^\circ\text{K}$),
- Q - The electronic charge.

I_{SC} always depend on the irradiance level 'S' and the array temperature 'T'.

$$I_{SC} = I_{ref} \left(1 + h_t(T_C - T_{ref})\right) \left(\frac{S}{S_{ref}}\right) \quad (6)$$

Where I_{ref} is the short-circuit current under the reference irradiance strength S_{ref} and temperature T_{ref} , h_t is the cell module temperature coefficient, while I_{pv0} depend on T only.

III. MODELLING OF INVERTER CONTROL

A. Using conventional PI controller

The inverter control by using PI based voltage regulator is shown in fig. 4.

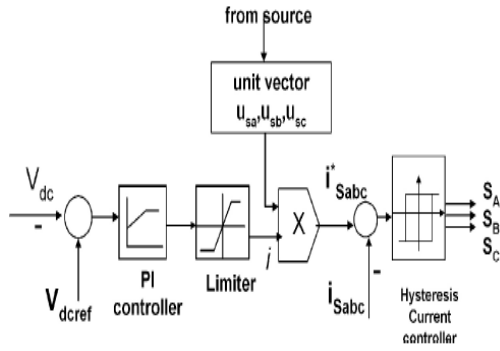


Fig. 4 PI based voltage regulator

B. Using Fuzzy controller

Fuzzy Logic Controller is fed by one input that is voltage error. This gives the source current output. Fig. 5 shows FLC based voltage regulator.

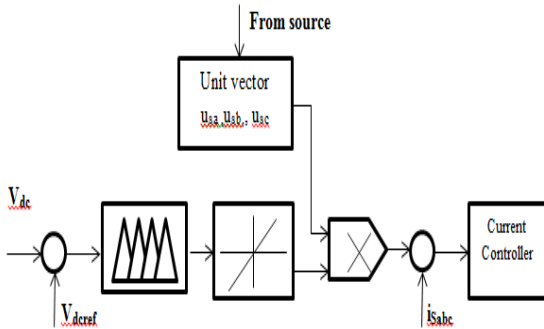


Fig. 5 Fuzzy based voltage regulator

The control scheme is simulated using SIMULINK power system block set. The system parameters for given system is listed in Table 1.

Table1. Proposed system parameters

S.NO	PARAMETERS	RATINGS
1	Grid Voltage	3-Phase, 600V,60Hz
2	Permanent Magnet Synchronous Generator	3.5KVA, 600V,60Hz,P=4, Speed=1440rpm,Rr=0.1Ω, Rs=0.15Ω,Ls=Lr=0.06H
3	Line series inductance	300mH
4	Inverter parameters	DC Link Voltage=800V,DC Link Capacitance=100μF, Switching Frequency=2kHz
5	IGBT ratings	Collector Voltage=1000V, Forward Current=50A,Gate Voltage=20V,Power Dissipation=310w
6	Load parameters	Non-linear load=50kW

IV. FUZZY LOGIC CONTROLLER

A Fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants. Fuzzy logic controller (FLC) is capable of improving its performance in the control of a nonlinear system whose dynamics are unknown or uncertain. Fuzzy controller can improve its performance without identifying the model of the plant. Fuzzy control is almost similar as that of the classic closed-loop control approaches but it differs in some factors, it is imprecise and symbolic notations for precise numeric measures. The fuzzy logic controller assigns the input values from the real world. FLC voltage regulator is fed by one input that is voltage error (Ve).The rules for the proposed FLC voltage controller are:

- i) If 'Ve' is 'ENVVH' Then 'I' is 'INVVH'
- ii) If 'Ve' is 'ENVH' Then 'I' is 'INVH'
- iii) If 'Ve' is 'ENH' Then 'I' is 'INH'
- iv) If 'Ve' is 'ENM' Then 'I' is 'INM'
- v) If 'Ve' is 'ENL' Then 'I' is 'INL'
- vi) If 'Ve' is 'EZ' Then 'I' is 'IZ'
- vii) If 'Ve' is 'EPL' Then 'I' is 'IPL'
- viii) If 'Ve' is 'EPM' Then 'I' is 'IPM'
- ix) If 'Ve' is 'EPH' Then 'I' is 'IPH'
- x) If 'Ve' is 'EPVH' Then 'I' is 'IPVH'
- xi) If 'Ve' is 'EPVVH' Then 'I' is 'IPVVH'

This scheme focuses on fuzzy logic control based on mamdani's system. Error of inputs from is chosen as input. Fig 6 and 7 shows input and output membership functions of FLC based voltage regulator. To avoid miscalculations due to fluctuations in wind speed, solar power and the effects of noise on data, the membership function chosen is triangular membership functions to have smooth and constant region in the main points.

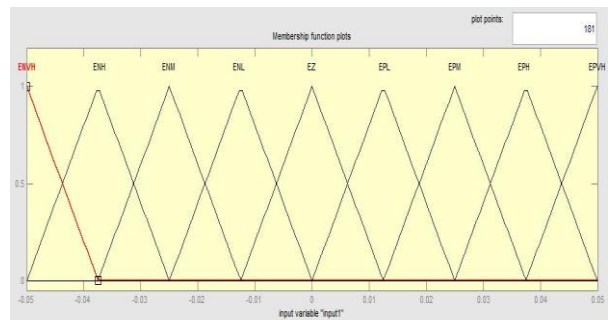


Fig. 6 Input membership function

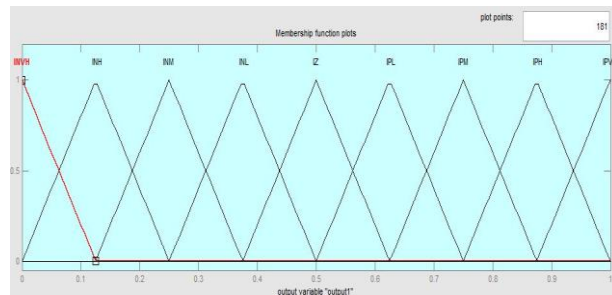


Fig. 7 Output Membership function

V. RESULTS AND DISCUSSIONS

The hybrid power generating system is integrated with the grid having critical load. Due to variation in hybrid power generation and nonlinear load source current of the grid affected. The three phase injected current into the grid from Inverter will cancel out the distortion caused by the non-linear load. Figure 8 shows the source current and voltage waveform of the test system without Inverter Control and the Figure 9 and 10 shows the corresponding FFT analysis waveform. From FFT analysis, it is shown that the Total Harmonic Distortion (THD) of the source current and voltage waveforms of the test system without Inverter Control are 24.42% and 25.03% respectively

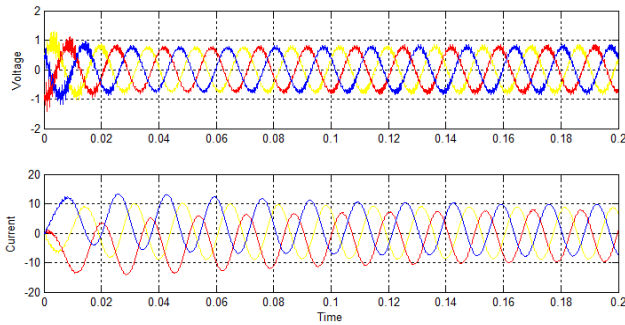


Fig. 8 Source current and voltage waveform without inverter control

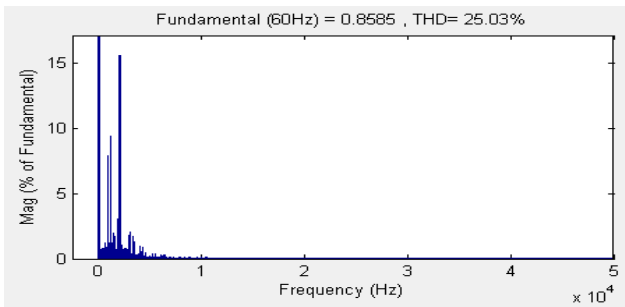


Fig. 9 THD value of voltage signal without inverter control

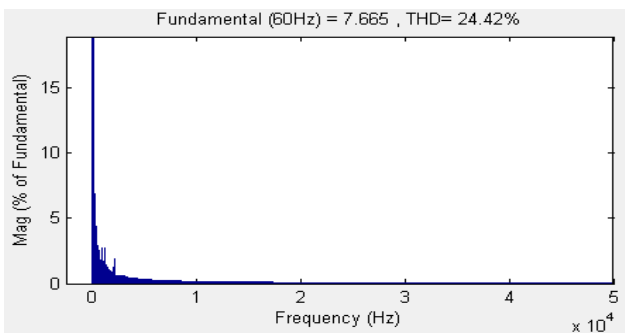


Fig. 10 THD value of current signal without inverter control

A. Using PI Control Strategy

Figure 11 shows the source voltage and current waveforms of the test system with PI controller based INVERTER and the Figure 12 and 13 shows the corresponding FFT analysis waveform. From FFT analysis, it is observed that

the THD of the source voltage and current waveforms of the test system with PI controller based INVERTER are 2.95% and 0.79% respectively.

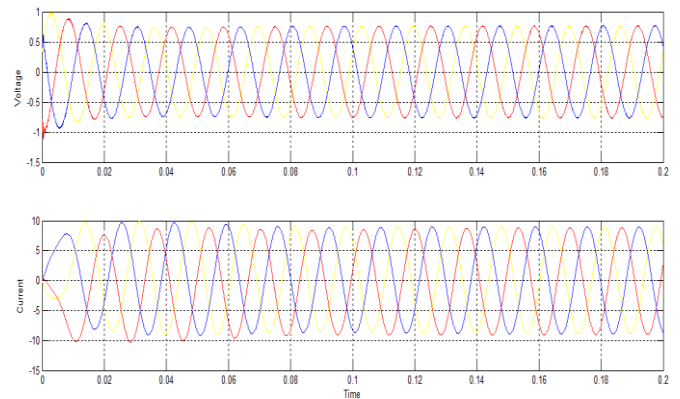


Fig. 11 Source voltage and current waveform with PI control

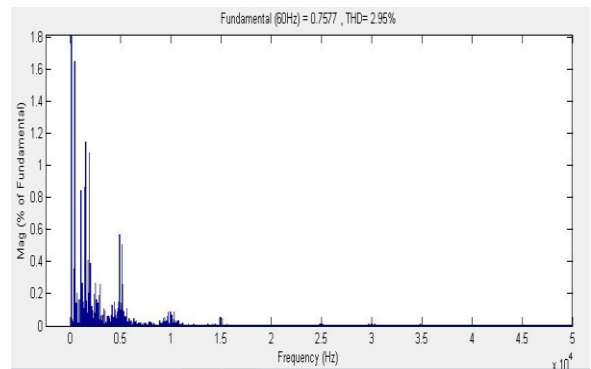


Fig. 12 THD value of voltage signal with PI control

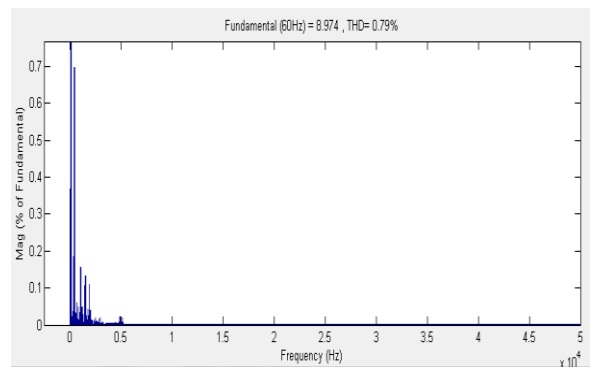


Fig. 13 THD value of current signal with PI control

B. Using Fuzzy Controller

Figure 14 shows the source voltage and current waveforms of the test system with FLC based INVERTER control and the Figure 15 and 16 shows the corresponding FFT analysis waveform. It is shown from the FFT analysis, THD of the source

voltage and current waveforms of the test system with FLC based INVERTER control are 0.49% and 0.29% THD. Thus, it is observed that there is a further reduction in the THD value of the source voltage and current waveforms.

VI. CONCLUSION

The wind-solar hybrid system with battery energy storage and an inverter in current control mode for exchange of real and reactive power support to the non-linear load was proposed. The Fuzzy Logic controller based inverter control strategy has been developed for grid connected wind-solar hybrid system. Distributed Generation produce harmonics when integrate with grid sources. By using suitable control circuit this harmonics are reduced. The fuzzy logic controller based INVERTER is presented for grid connected Wind Energy Generating System. The proposed FLC based INVERTER have improved the power quality of source current significantly by reducing the THD from 22.45% to 0.29%. It is clearly presented that INVERTER with FLC gives better performance than INVERTER with conventional PI controller.

REFERENCES

1. D. Graovac, V. A. Katic, and A. Rufer, "Power quality problems compensation with universal power quality conditioning system," *IEEE Trans. Power Delivery*, vol. 22, no. 2, pp. 968–997, Apr. 2007.
2. J. M. Carrasco, "Power-electronic system for grid integration of renewable energy source: A survey," *IEEE Trans. Ind. Electron.*, vol. 53, no.4, pp. 1002–1014, Jun. 2006.
3. G. Tapia, "Proportional-integral regulator based application to wind farm reactive power management for secondary voltage control," *IEEE Trans. Energy Conversion*, vol. 22, no. 2, pp. 488–498, Jun. 2007.
4. F. S. Pai and S.-I. Hung, "Design and operation of power converter for microturbine powered distributed generator with capacity expansion capability," *IEEE Trans. Energy Conversion*, vol. 3, no. 1, pp. 110–116, Mar. 2008.
5. S. Teleke, M. E. Baran, A. Q. Huang, S. Bhattacharya, and L. Anderson, "Control strategy for battery energy storage for wind farms dispatching," *IEEE Trans Energy Conversion*, vol. 24, no. 3, pp. 725–731, Sep. 2009.
6. L. Maharjan, S. Inoue, H. Akagi, and J. Asakur, "State-of-charge (SoC)-balancing control of a battery energy storage system based on a cascade PWM converter," *IEEE Trans. Power Electron*, vol. 24, no. 6, pp. 1628–1636, Jun. 2009.
7. HengNian, Yipeng Song, Peng Zhou, and Yikang He, "Improved Direct Power Control of a Wind Turbine Driven Doubly Fed Induction Generator During Transient Grid Voltage Unbalance," *IEEE Trans. on Energy Conversion*, vol. 26, no. 3, September 2011.
8. S.D.GaminiJayasinghe, D.MahindaVilathgamuva and UdayaK.Madawala, "Direct Integration of Battery Energy Storage Systems in Distributed Power Generation," *IEEE Trans. Energy Conversion*, vol. 26, no. 2, June 2011.
9. HanyM.Hasanien, EssamA.Al-Ammar, "Dynamic Response Improvement Of Doubly Fed Induction Generator-Based Wind Farm Using Fuzzy Logic Controller," *IEEE Trans. Electrical Engineering*, vol. 63, no. 5, pp. 281–288, 2012.
10. S. W. Mohod and M. V. Aware, "A STATCOM-control scheme for grid connected wind energy system for power quality improvement," *IEEE Syst. J.*, vol. 2, no. 3, pp. 346–352, Sep. 2010.

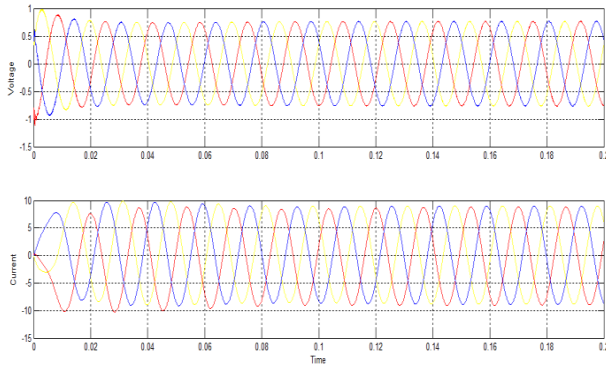


Fig. 14 Source voltage and current signal with FLC control

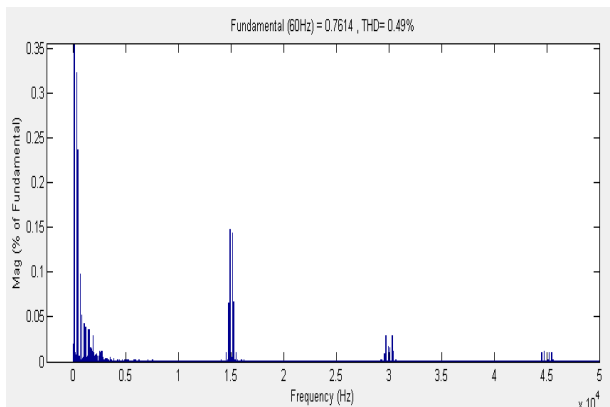


Fig. 15 THD value of voltage signal with FLC control

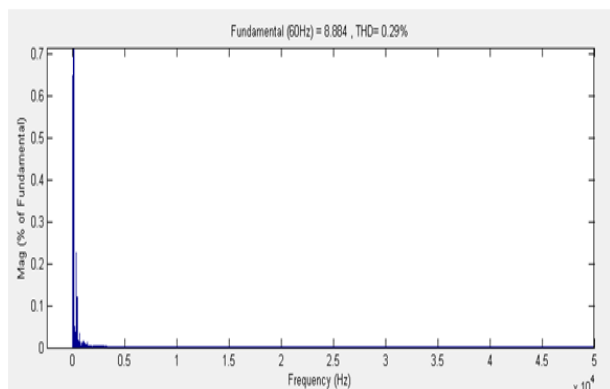


Fig. 16 THD value of current signal with FLC control