

A Hysteresis Current Control Technique for Electronics Converter

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ABSTRACT: In most high-performance electronic converters, we always need to reduce the harmonics. In this paper, a hysteresis current control technique for AC to DC converter is proposed. We can set the upper band limit as well as lower band limit. Also the comparison with peak current control technique is given in this paper.

KEYWORDS: Hysteresis Current control, Harmonics reduction, AC filter, Rectifier.

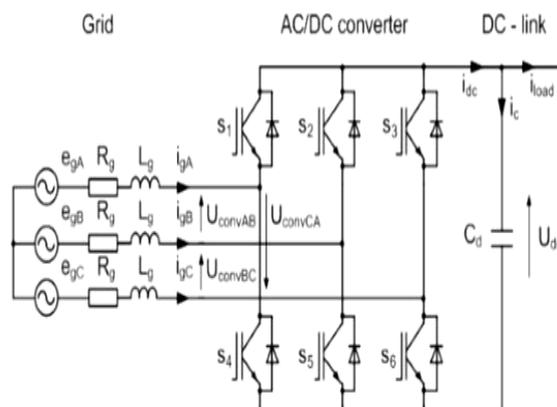
I. INTRODUCTION

During last some years, Active power converters and high frequency converters are being more and more popular. As frequency of these converters is increases, the Switching losses and source harmonics are increase with it. Passive power filters can reduce these harmonics up to some limit, but it cannot overcome non-characteristic harmonics. Passive filters have also other limitations which can overcome by the use of active filters.

Restrictions on current and voltage harmonics maintained in many countries through IEEE 519-1992 in the USA and IEC 61000-3-2/IEC 61000-3-4 in Europe standards, are associated with the popular idea of clean power. [7].

We can reduce the harmonics in source very effectively by using active power filters. We can use different technique of PWM methods for reduce these harmonics. The active power filters works on principal by detecting harmonic current to calculate the amount of the compensating current needed for feeding back to the power system in opposite direction of harmonics current. In this paper, two techniques are given 1) Hysteresis band control technique and 2) Peak current control technique.

Advantages of using hysteresis band control are excellent dynamic performance and ability to control the peak to peak value of current ripple in desired hysteresis band limit. It is also very simple for physically implementation. Simulation of Voltage source converter with hysteresis band control is shown in this paper. The PWM rectifier's bridge consists of six IGBTs which are fully controlled. It is connected with three symmetrical line inductors.



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Fig. 1. Basic Diagram of voltage source AC/DC converter

II. RELATED WORK

There are many harmonics reduction methods exist. These all techniques are based on the passive components (Diode based converters) so these converters/filters are also called as passive converters/filters. The converters which are working with passive components (controlled thyristor based convertors) are known as passive filters and converters.

They can be generally divided in following type:

- A) Harmonic reduction of already installed non-linear load;
- B) Harmonic reduction through linear power electronics load installation;

For reduction of current harmonics, in traditional method, there are passive filters used. They are parallel connected with grid. Filters are usually constructed as series-connected legs of capacitors and chokes. The number of legs depends on number of filtered harmonics (5th, 7th, 11th, 13th). In case of diode rectifier, the simpler way to harmonic reduction of current are additional series coils used in the input or output of rectifier (typical 1-5%).

The other technique, based on mixing single and three-phase non-linear loads, gives a reduced THD because the 5th and 7th harmonic current of a single-phase diode rectifier often are in counter-phase with the 5th and 7th harmonic current of a three-phase diode rectifier.

The other interesting reduction technique of current harmonic is a PWM (active) rectifier. Two types of PWM converters, with a voltage source output and a current source output can be used. First of them called a boost rectifier (increases the voltage) works with fixed DC voltage polarity, and the second, called a buck rectifier (reduces the voltage) operates with fixed DC current flow.

Among the main features of PWM rectifier are:

- bi-directional power flow.
- Almost sinusoidal input current.
- regulation of input power factor near to unity.
- Low harmonic distortion of line current (THD below 5%).
- adjustment and stabilization of DC-link voltage (or current).
- Reduced capacitor (or inductor) size due to the continues current.

Similar to the PWM active filter, the PWM rectifier has a complex control structure, the efficiency is lower than the diode rectifier due to extra switching losses. A properly designed low-pass passive filter is needed in front of the PWM rectifier due to EMI concerns.

The last technique is most promising thanks to advances in power semiconductor devices (enhanced speed and performance, and high ratings) and digital signal processors, which allow fast operation and cost reduction. It offers possibilities for implementation of sophisticated control algorithm.

HYSTERESIS BAND TECHNIQUE: - This control technique requires defining upper hysteresis band limit and lower hysteresis band limit. In open loop control strategy, the variation in output DC voltage is common problem if load is variable, but we can get steady output if close loop strategy is used. In close loop control, output current signal is compared with reference current signal which is given. Which decrease the error in output and gives desired output. The generated gate pulses can be controlled by PI or PID controllers. These signals are for power switching devices, when upper and lower limits of hysteresis bands are exceeded. In this technique, the power switching devices will not be switched if any major error is there. We can use Ziegler-Nichols method for tuning of PID controllers.

The conventional method of hysteresis control is known as two-level hysteresis current control technique. It is nonlinear method and it is based on current error. This method consists of a comparison between the load current and band limit given to it. When it crosses the upper band limit, the switches turns off, when current crosses the lower band limit, switches turns on.

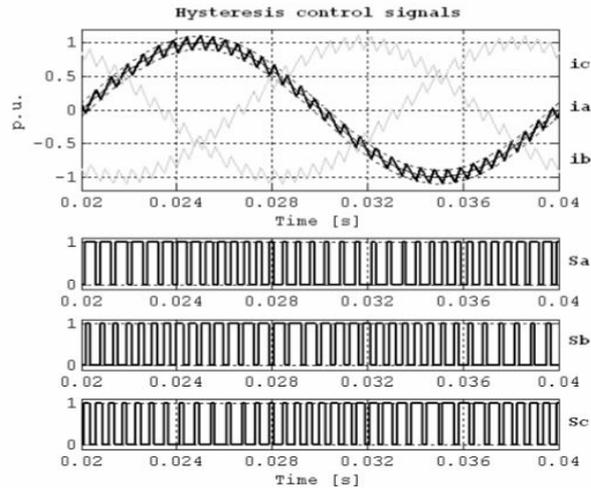


Fig. 2. The idea and control signals of Hysteresis-Band PWM

The proposed technique is with fixed hysteresis band H for open loop and variable hysteresis band H' for closed loop for obtaining the current ripple at output side, a value of hysteresis band must be as small as possible. It will cause very high switching frequency as well as high switching losses. It also required high-end controllers for better performance in practical.

III. SIMULATION MODEL

In MATLAB/SIMULINK, the model of three phase Voltage source rectifier is built for open loop strategy with variable load. Here all parameter used are same as the given in closed-loop strategy. Subsystem is also shown in figure 8.

In figure 3, simulation of open loop circuit is shown. The sources of all phases are taken separately only because of analysis purpose. V_r, V_y, V_b are phase voltage sources. L_1, L_2, L_3 are the source inductance. These three phase supply is given to the rectifier legs, which is controlled rectifier. Here load is purely resistive load. In subsystem, the sine wave is compared with the reference current limit, and it will generate the gate signals. Gate signals are given to the all thyristors (i.e. IGBTs) are coming from the Hysteresis band generator. Band is kept 0.01% here, and reference current is given to the system depends upon the requirement of output DC voltage magnitude.

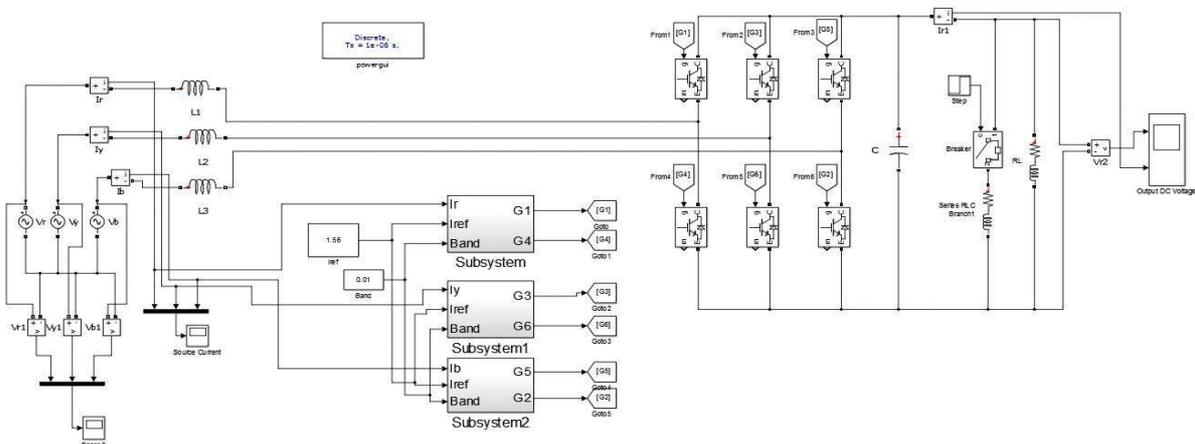


Fig. 3. Simulation of Open-loop rectifier for variable load

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In figure 3, 1st subsystem (i.e. “Subsystem” block) is operating at 0 degree phase shift, 2nd subsystem (i.e. “Subsystem1” block) is at 120 degree phase shift, and similarly, 3rd subsystem is at 240 degree of phase shift. G1 and G4, G2 and G5, G3 and G6 are the compliments of each other. That means, when G1 high, G4 will be low. Similarly for others.

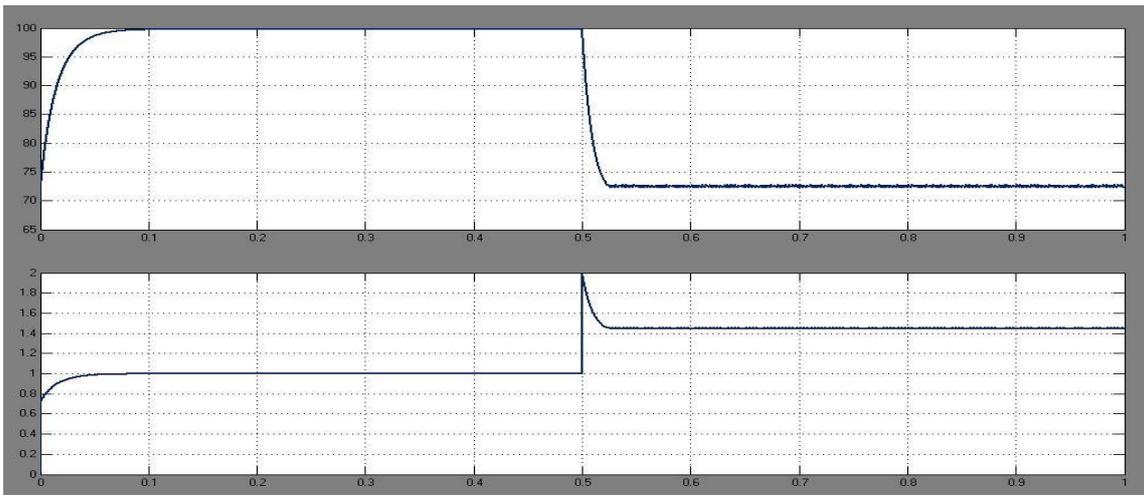


Fig. 4. Output voltage and current effect in open-loop

In figure 4, the output voltage and current for variable load open loop system is shown. After 0.5 second, the load is doubled. Because of this, current is 1.42Amp after 0.5 second. It should be 2Amp. The output voltage became unstable, and goes to 73 V. It indicates the instability for variable loads.

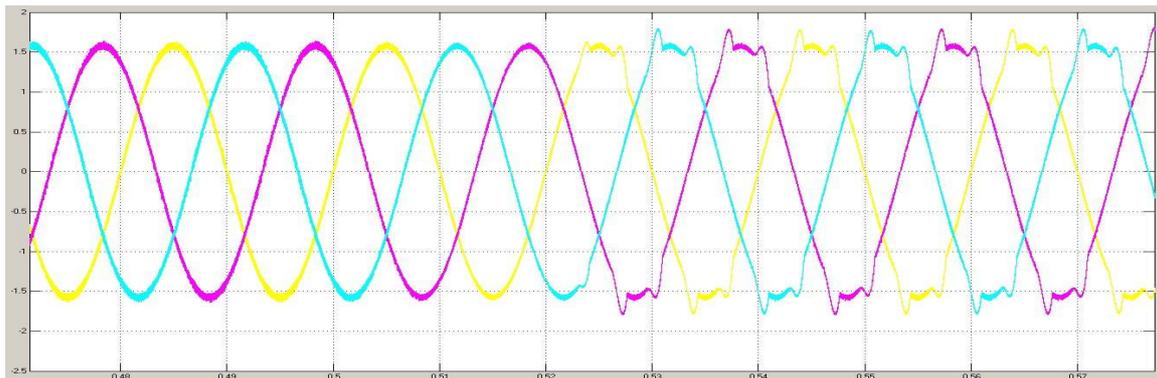


Fig. 5. Input current for open-loop configuration

Input source 3 phase current waveform is shown in figure. It can be observable that, controlled rectifier is used here but input current is almost near to sinusoidal shape, but if load changes, it is distorted. If we do THD analysis on it, it will contain very less harmonics for starting period, but after load changes it becomes more distorted.

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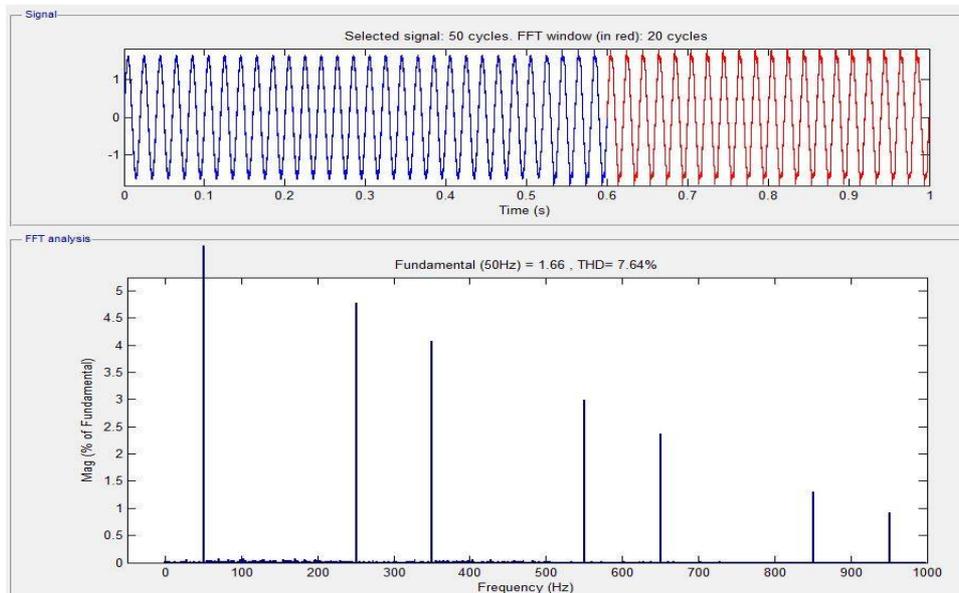


Fig. 6. Input current THD for Open-loop configuration

In figure 6, THD for open loop configuration is about 7.64% after the load RLC changed which is not in permissible limit, i.e. 5%. The open-loop configuration is only useful when constant DC load is there. It can't be used for dynamic load.

In MATLAB/SIMULINK, the model of three phase Voltage source rectifier is built which is shown in figure 7. Closed loop strategy is adopted in the Simulink model.

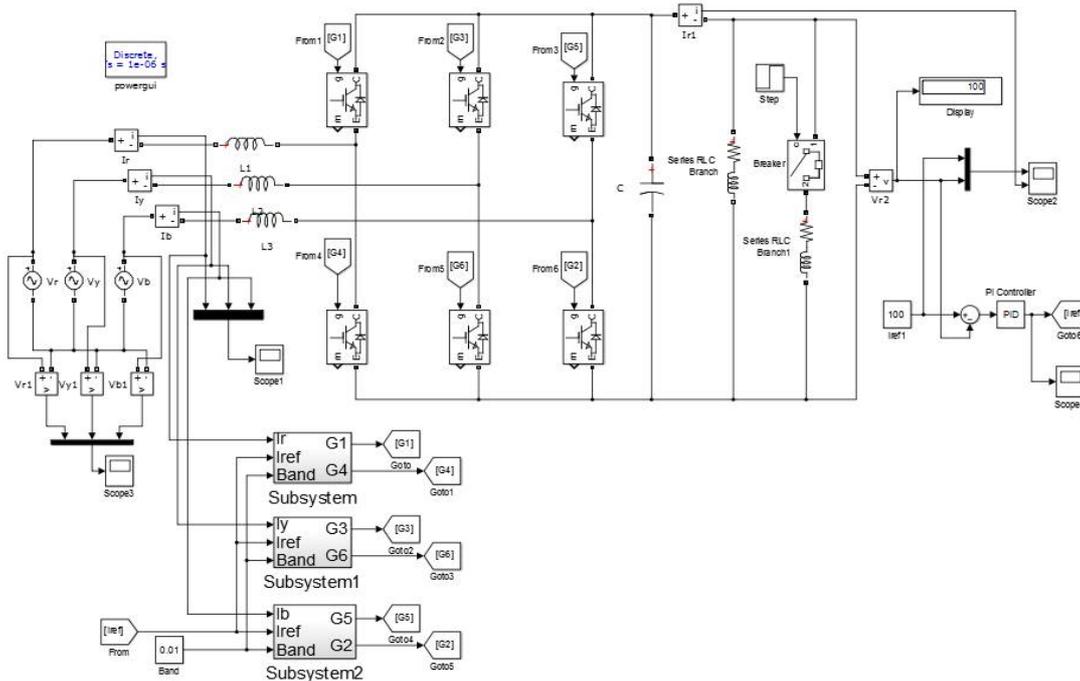


Fig. 7. Simulation of closed-loop Rectifier for variable load

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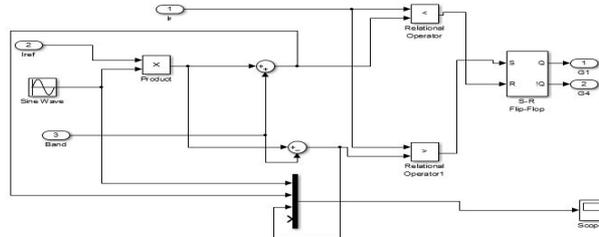


Fig. 8. Subsystem of the simulation

In figure 7, simulation of close loop circuit is shown. All other things are similar as open loop system, but here reference current (I_{ref}) is given through feedback of output voltage. So if the load is variable, then also we can keep our output voltage constant. For generate the reference current signal, PI controller is used. We have to tune the K_p and K_i parameters according to requirement of stability of output DC voltage. For tuning of PID controller, “Nicholas Ziegler” method can be used. Here also 1st subsystem (i.e. “Subsystem” block) is operating at 0 degree phase shift, 2nd subsystem (i.e. “Subsystem1” block) is at 120 degree phase shift, and similarly, 3rd subsystem is at 240 degree of phase shift. G1 and G4, G2 and G5, G3 and G6 are the compliments of each other. That means, when G1 high, G4 will be low. Similarly it would be same for other switches. In this simulation, two loads are used, one is fixed RL load, and other is RL load with circuit breaker. It is for presenting the variable load condition. After required time period, circuit breaker can be operated and we can change the load while simulation is running. It will show the effect of sudden load changes.

The Main parameters of the simulation model are shown in table 1.

TABLE 1. THREE PHASE SIMULATION PARAMETERS

Parameter name	Value
Phase voltage peak: E_m	42.30
Fundamental frequency: f/Hz	50
DC-side rectifier: RL load/kW	0.2
AC-side inductance L/mH	1
DC-side capacitance: $C/\mu F$	330
DC-side reference voltage: V_{dc}/V	100

Here the PI parameter is taken as: $K_p = 0.1, K_i = 30$

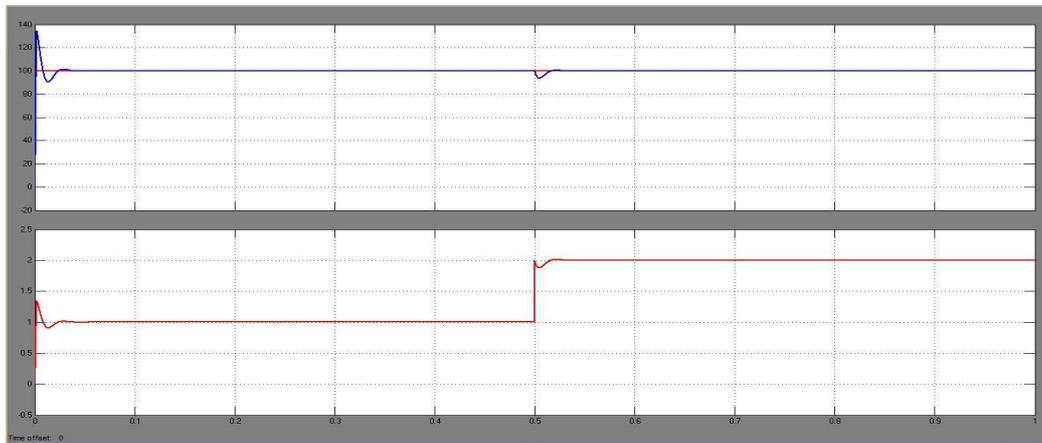


Fig. 9. Output DC voltage and current waveform for variable load

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In figure 9, the output voltage and current is shown. It is for variable load. After 0.5 second, the load it doubled. Because of this, current is 2Amp after 0.5 second. The output voltage becoming little unstable, but quickly it is gaining its reference position. So close loop system is better than open loop system.

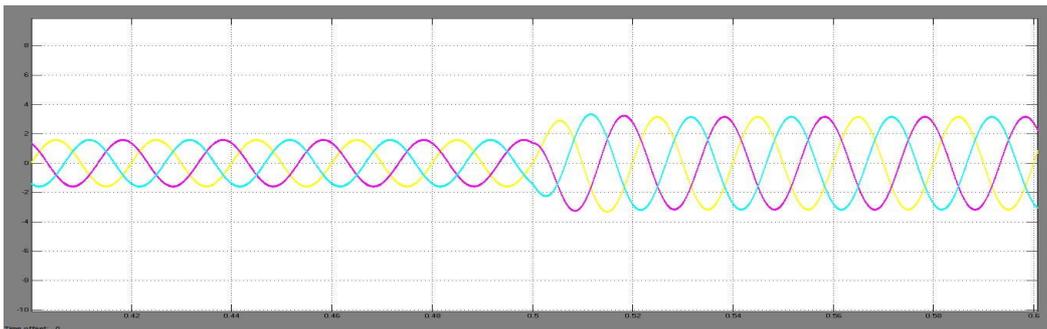


Fig. 10. Three-phase Input current waveform for variable load

In figure 10, Input source current is shown, after load changes, still it will follow the sinusoidal shape. So we can say that, this technique is very effective for reducing the source harmonics.

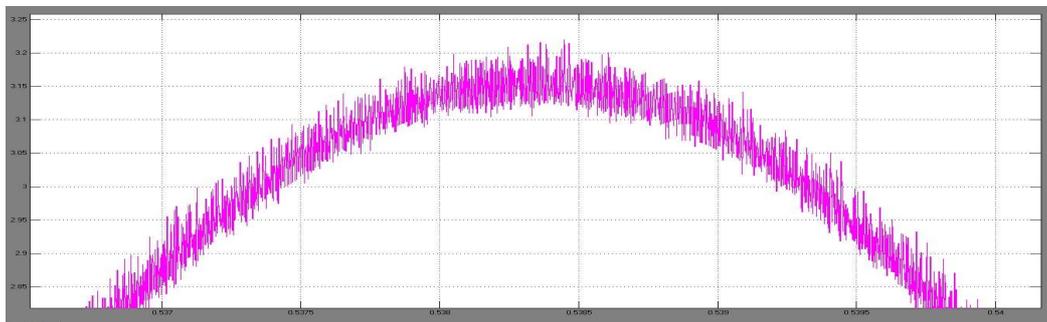


Fig. 11. Hysteresis band effect in input current.

In figure 11, effect of hysteresis band control technique in input current waveform is shown. It can be observed that the waveform is following the sinusoidal shape in given band limit. This band width can be increased or decreased according to requirement but it also depends on the frequency generation capacity of the controller used in practice.

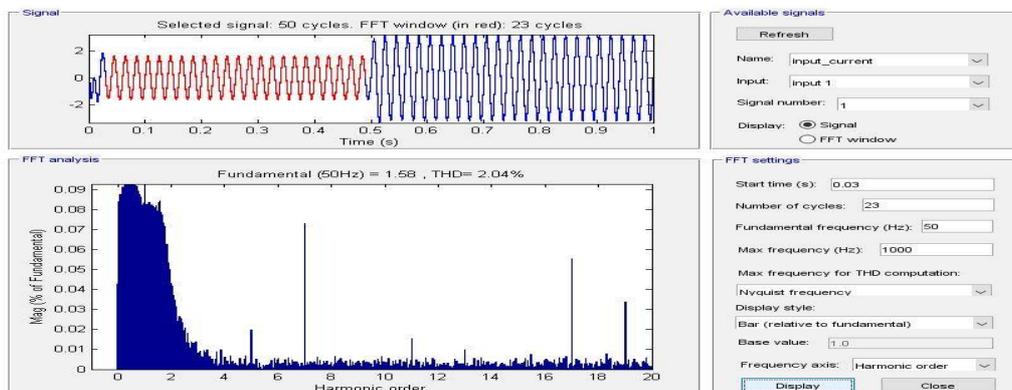


Fig. 12. THD analysis of input current

In figure 12, THD of the close loop simulation is shown. It is 2.04% which is within the permissible limit.

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IV. CONCLUSION

This paper presents the analysis and simulation of hysteresis band current control technique for model of AC/DC line side converters. Open-loop and closed-loop both configurations can be used for reducing harmonics but where variable load is there, closed-loop configuration is applicable. In open-loop, if load is changed, the output voltage becomes low because source current doesn't increase. We cannot get constant voltage at output side in it. But if we are using closed-loop system, then we can connect variable dc load also. It doesn't need load information for controlling the source current THD. It will produce the constant voltage in variable load condition also.

REFERENCES

- [1] Vladimir A. Katic, Du`san Graovac, "A Method for PWM Rectifier Line Side Filter Optimization in Transient and Steady States," IEEE transactions on power electronics, vol. 17, no. 3, may 2002.
- [2] A. Karaarslan, I. Iskender "The analysis of ac-dc boost pfc converter based on peak and hysteresis current control techniques," (IJTPE) ISSN 2077-3528.
- [3] Yajing Gao, Junqiang Li & Haifeng Liang, "The Simulation of Three-phase Voltage Source PWM Rectifier" , 978-1-4577-0547-2/12 ©2012 IEEE.
- [4] N. Silva, A. Martins, and A. Carvalho, "Design and Evaluation of a PWM Rectifier Control System for Testing Renewable DC Sources Connected to the Grid" 1-4244-0194-1/06 ©2006 IEEE.
- [5] S. Begag, N. Belhaouchet, L. Rahmani "Three-Phase PWM Rectifier with Constant Switching Frequency" USTHB, Algiers, Algeria "JES" third ICEE 2009.
- [6] K. M. Rahman, M. Rezwan Khan, M. A. Choudhury, and M. A. Rahman, "Variable-Band Hysteresis Current Controllers for PWM Voltage-Source Inverters" , IEEE transactions on power electronics, vol. 12, no. 6, november 1997.
- [7] Angit Kumar.G, Ramesh Babu.U "Control Strategy of Three Phase Shunt Active Power Filter for Power Quality Improvement" IJEST, Vol. 4 No.05 May 2012.