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Performance Analysis of Three-Phase Six-Pulse Controlled Rectifier

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Abstract:

Three phase transformer operates on high frequency for multi-pulse ac-dc rectifier converters, deployed to generate ac-dc 6- pulse controlled rectifiers units for analysis of multi-pulse converters, since six pulse diode rectifier couldn't achieve the harmonics limits stands IEC 61000-3-4, and high frequency harmonic distortion (THD) generates in the ac side line current to replace with the thyristor gate controlled devices to detract the THD in ac currents and ripple free in dc voltage, to overcome by multi-pulse converters.

Keywords: AC-DC converters, high frequency, line current, multi-pulse converters, ripple free, total harmonic distortion

1. Introduction

In the power system planning is an important role switching towards an HVAC system into HVDC systems, applications of HVDC transmission with the bipolar link more reliable. Multi terminal dc transmission technically greater stabilization and power dispatch and economical flexible for utilization of dc power [1]. To detract dc harmonics special design of dc side filters to stability and power flow programs to determine the scheduled load and strategic control system [2]. Presently, a gigantic development had been in a semiconductor device manufacturing and applications, design of thyristor, dc side smoothing reactor, characteristics of recovery time. In power systems single network numerical, trapezoidal method, and step wise to discrete differential integration equations had been solved using Dommel model , energy stored inductor effect in-terms of backward Euler's method solving the model equations, admittance matrix for transformers, and transmission lines and the element induces voltage across at a node current injection occurs, comes to modelling tools for transients, electromagnetic and electromechanical oscillating ranges from milli to micro seconds [3], mainly, determine the HVDC operational and control, Ferro-resonance, sub-synchronous resonance due to torsional shaft twisting oscillations, line surges and switching analysis, insulation, short circuit coordination between the elements used tools ATNA(analogue transient network analysers) test the physical models. While controlling the delay angle keeping current and speed to be constant by varying voltage continuously [4].

There multi pulse converters had been stated it's keep on increases it's applications up to now HVDC transmission system, aircrafts converters, electrical vehicles, defence, space etc. so six converter generates the harmonics, and added another converter series /parallel which generated harmonics cancelled out by each other, the range of power capabilities needs more, it's mandatory to designed to upgraded to multi-pulse converters high and ultra-high power converters, dc filters makes at dc side voltage ripple free [5]. There multi pulse converters had been stated it's keep on increases it's applications up to now HVDC transmission system,

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aircrafts converters, electrical vehicles, defence, space etc. the converter generates the harmonics, and added another converter series /parallel which generated harmonics cancelled out by each other, the range of power capabilities needs more, it's mandatory to designed to upgraded to multi-pulse converters high and ultra-high power converters, dc filters makes at dc side voltage ripple free [6]. So with six pulse converters would not possible, but dc transformers design plays key role, phase shifting transformers, auto transformers, zigzag connection transformer, star- delta, delta-star, etc. 20 pulse auto transformers used in telecommunication power converter systems, uninterrupted power supplies in aircrafts, cabins, panel modules in multi pulse converters input side harmonics cancellation to detract THD and ripple free output voltage in controlled and uncontrolled rectifiers, and analysis of continuous and discontinuous with the simulations [7].

2. Simulation study of six-and twelve-pulse controlled rectifiers

2.1. Six-pulse controlled rectifier

The three-phase six-pulse controlled rectifier operating with RL load as shown in Fig.1. The reactor on the load side very large enough so that load current has small ripple current. The ac side transformer provides the isolation between three-phase supply and converter. The three-phase $\Delta - Y$ transformer has small leakage reactance of the transformer, due to which the converter thyristor valves will conduct at same time. The outgoing and incoming thyristor valves will conduct small angle due to leakage inductance of secondary side of a transformer called as overlap angle. The three-phase six pulse converter is simulated in MATLAB.

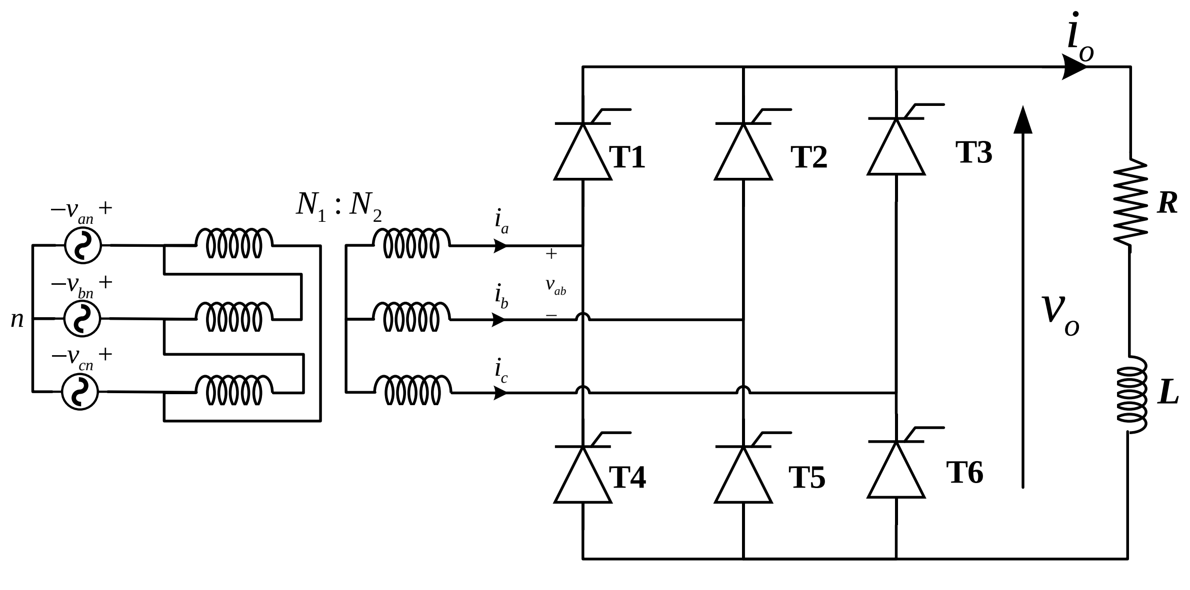

Fig. 1 The power circuit model of three-phase six-pulse controlled rectifier

The simulation of the three-phase controlled rectifier with load parameters R=10Ω, L=250mH with balanced three-phase supply 400V, 50Hz. The simulation is carried out in two modes: (a) ideal i.e. source inductance L_s is zero and (b) with source inductance L_s=0.2mH.

The synchronizing switching pulses to each thyristor switch are provided so that each 60° duration two switches will conduct. The equivalent circuit diagram for $30+\alpha \le \omega t \le 60+\alpha$ as shown in Fig.2. The equation (1) of the load current for the duration is shown below. The waveforms in Fig.3 shows balanced three-phase voltage (a), output voltage (b) for firing angle

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of α=30° and load current (c) reaching steady state $4.5\tau - 5\tau$. In this circuit τ is 25ms, it takes maximum 125ms to reach steady state.

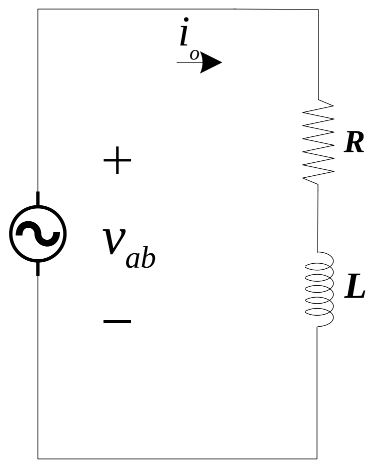

Fig. 2 Equivalent circuit for duration of $30+\alpha \le \omega t \le 60+\alpha$

$$i_o(t) = \frac{\sqrt{2}V_{ab}}{|Z|}\sin\left(\omega t' - \theta\right) + \left(I_{\min} - \frac{\sqrt{2}V_{ab}}{|Z|}\sin\left(\alpha + \frac{\pi}{3} - \theta\right)\right)e^{\frac{R}{L}\left(\left(\frac{\pi}{3}+\alpha\right)/\omega - t'\right)} \quad (1)$$

where $|Z| = \sqrt{R^2 + \left(\omega L\right)^2}$ and $\theta = \tan^{-}\left(\frac{\omega L}{R}\right)$, $\omega t' = \frac{\pi}{3} + \alpha$

In ideal case the average load voltage for continuous conduction mode is

$$V_{do} = \frac{3V_{ml}\cos\alpha}{\pi} \quad (2)$$

The average load voltage with effect of source for continuous conduction mode is

$$V_o = V_{do} - \frac{3\omega L_s}{\pi} I_o \quad (3)$$

For the calculation of commutation interval

$$\cos\left(\alpha + u\right) = \cos\left(\alpha\right) - \frac{2\omega L_s}{\sqrt{2}V_{LL}} I_d \quad (4)$$

The drop of voltage in output side is dependents on leakage reactance of the transformer and load average current I_o. The waveforms in Fig.4, almost have same results as with ideal case except a notch in the load voltage waveform. During that time, three devices in each phase will conduct so that output voltage magnitude is reducing. The dotted lines in waveform (b) is shown the notch voltage at this point commutation of devices are occurring. The load current (c) almost same as ideal current waveform. In Fig.5 shows ripple current in the load current 0.5A. The source current for phase ‘a’ as shown in Fig.6. The THD spectrum as shown in Fig.7. The THD is 30.54% and it can be reduced by using multi-pulse converters i.e. 12, 24 and 48 etc.

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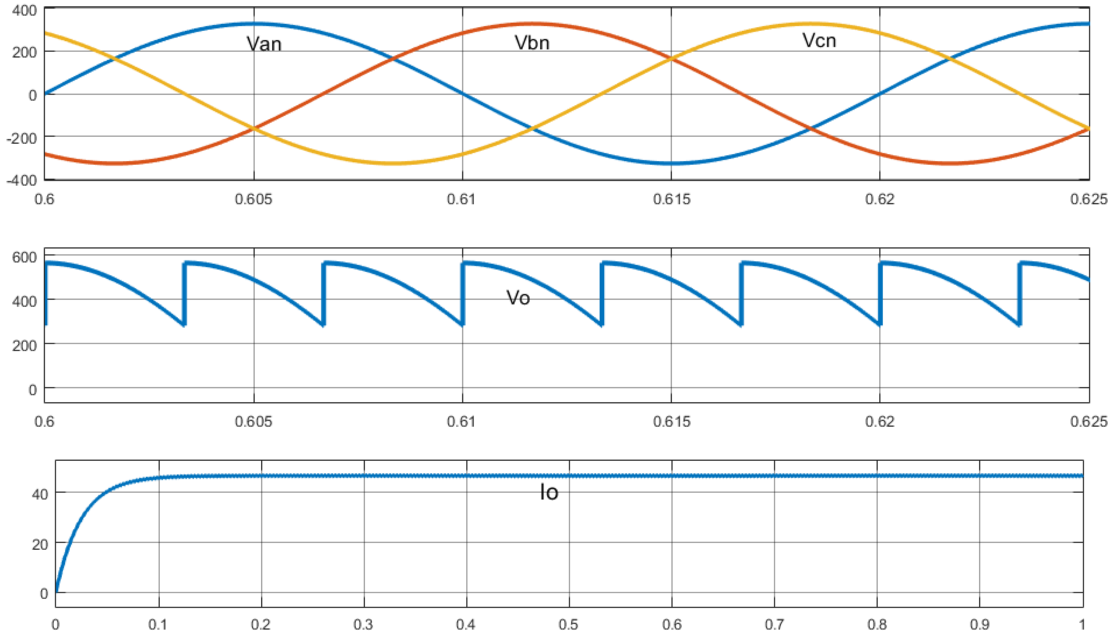

Fig. 3 Waveforms of three-phase six-pulse rectifier (a) balanced supply V_{abc}, (b) output voltage V_o and (c) output current I_o

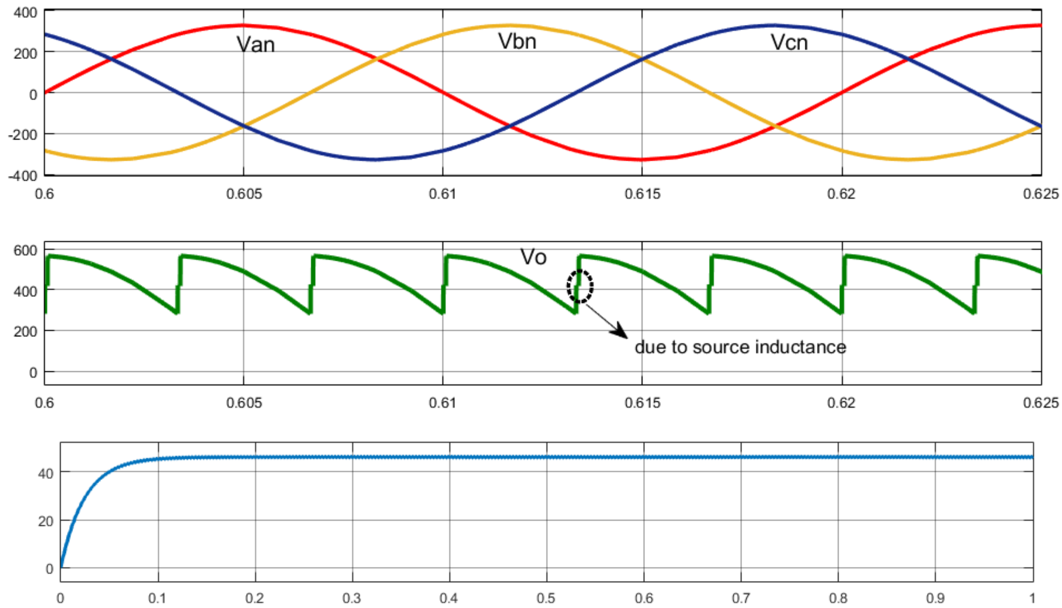

Fig. 4Waveforms of three-phase six-pulse rectifier due to source inductance effect (a) balanced supply Vabc, (b) output voltage Vo and (c) output current Io

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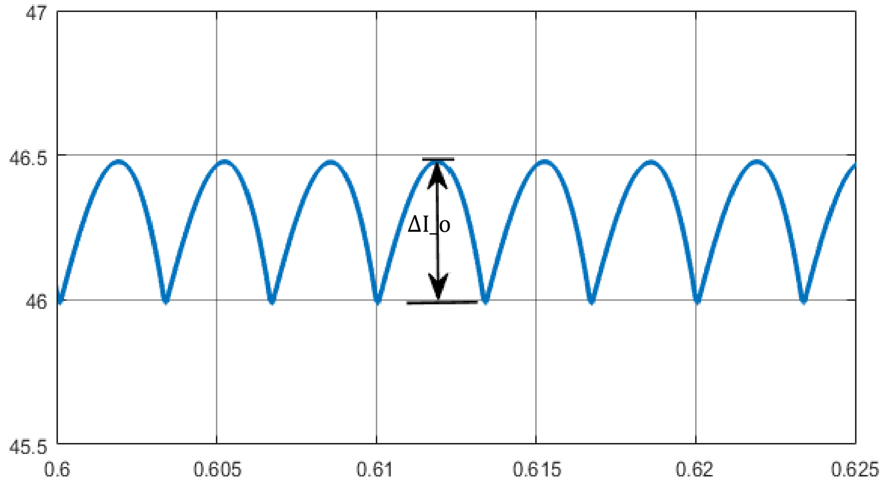

Fig. 5 Output ripple current of 0.5A with reactor inductance of 0.2mH

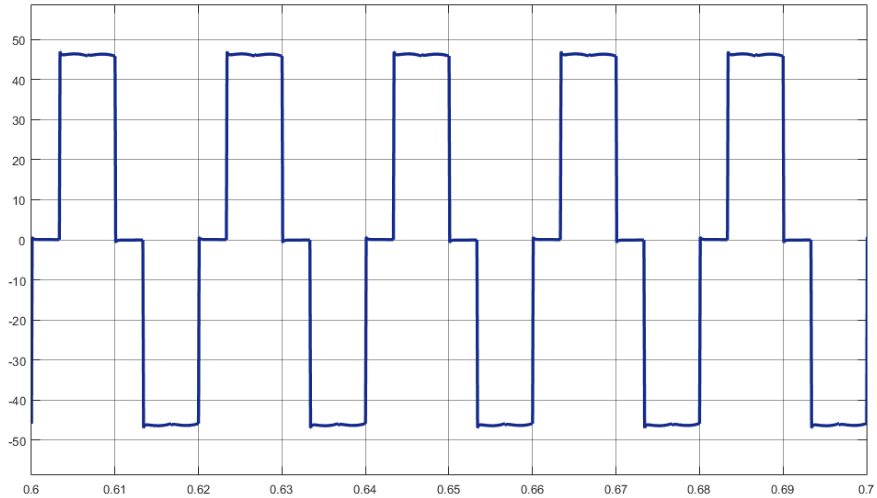

Fig. 6 Phase 'a' current waveform with source inductance of 0.2mH

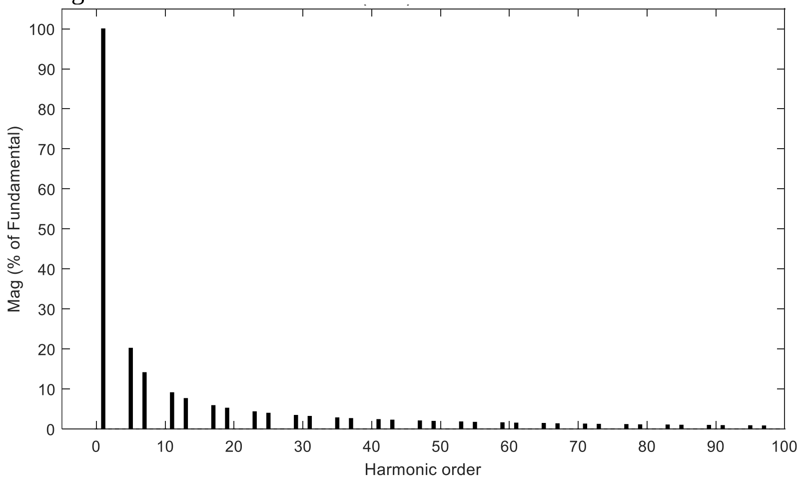

Fig. 7 THD spectrum of source current

3. Experimental analysis

The prototype model of hardware circuit in Fig.8, is tested in the laboratory with load resistance of 300Ω and L=10mH. The balanced supply voltage 36V line, 50Hz as shown in Fig.9. The upper leg of the switches is shown in Fig.10. The Fig.11-13 shows the load voltage operating with resistive load at different firing angles and Fig.14, shows load voltage operating with RL load at $\alpha > 60^\circ$. The output voltage is discontinued because of small value of reactor.

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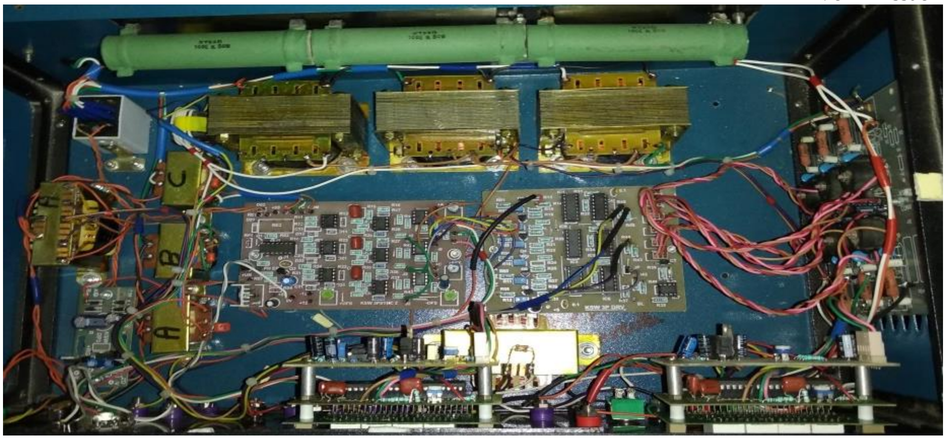

Fig. 8 The hardware testing circuit of six-pulse converter

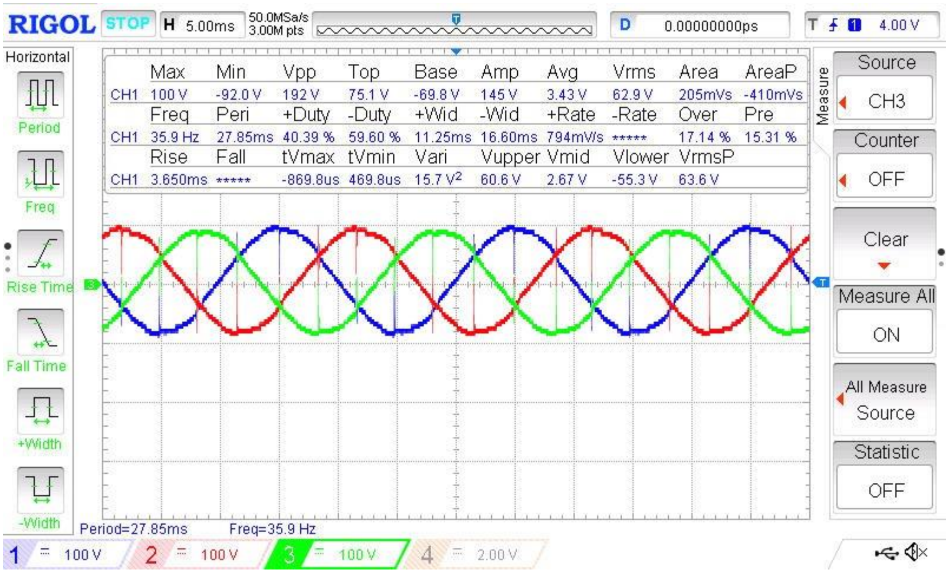

Fig. 9 The balanced three-phase supply

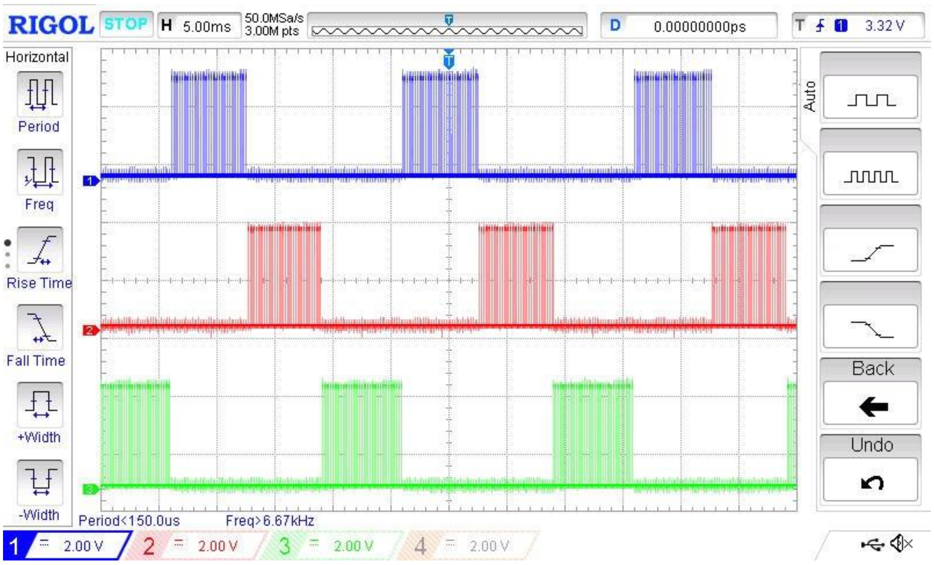

Fig. 10 The switching pulses of upper switches of leg in six-pulse converter

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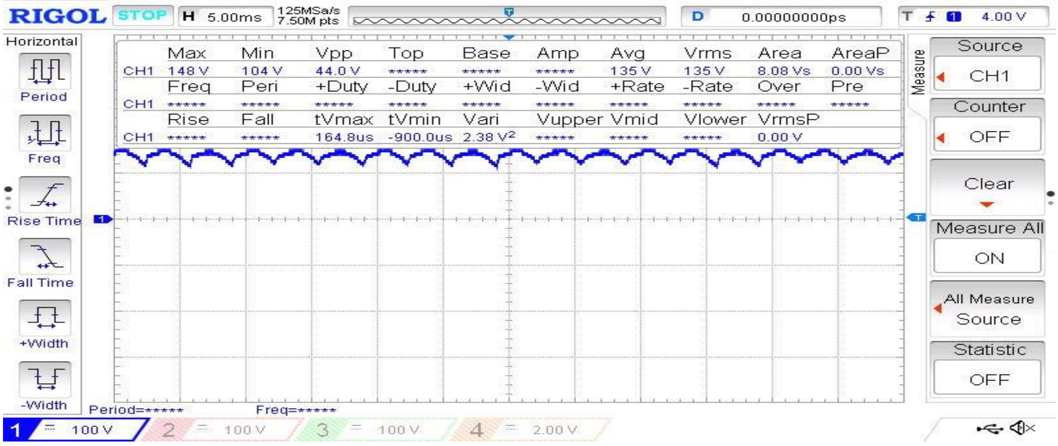

Fig. 11 Six pulse converter with R-load at α = 3°

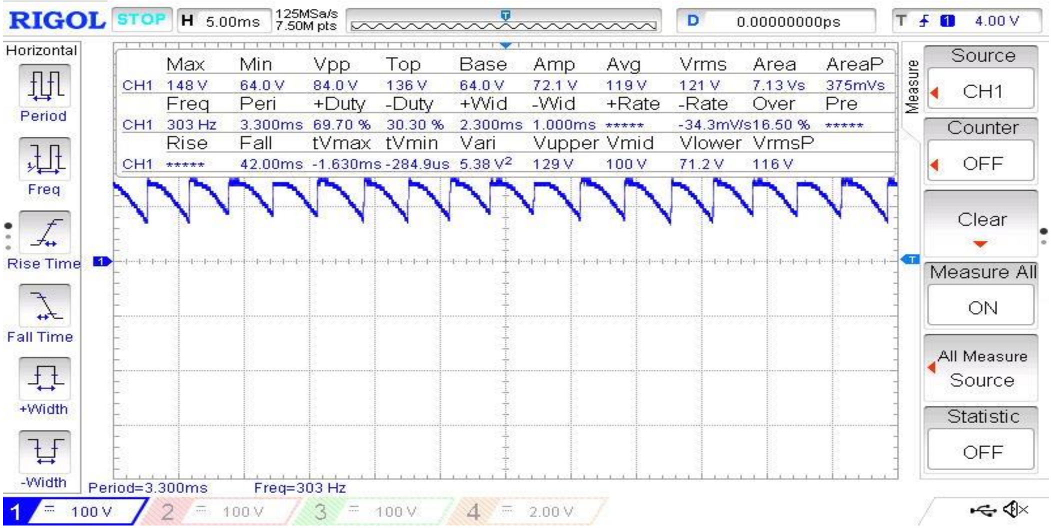

Fig. 12 Six pulse converter with R-load at α = 30°

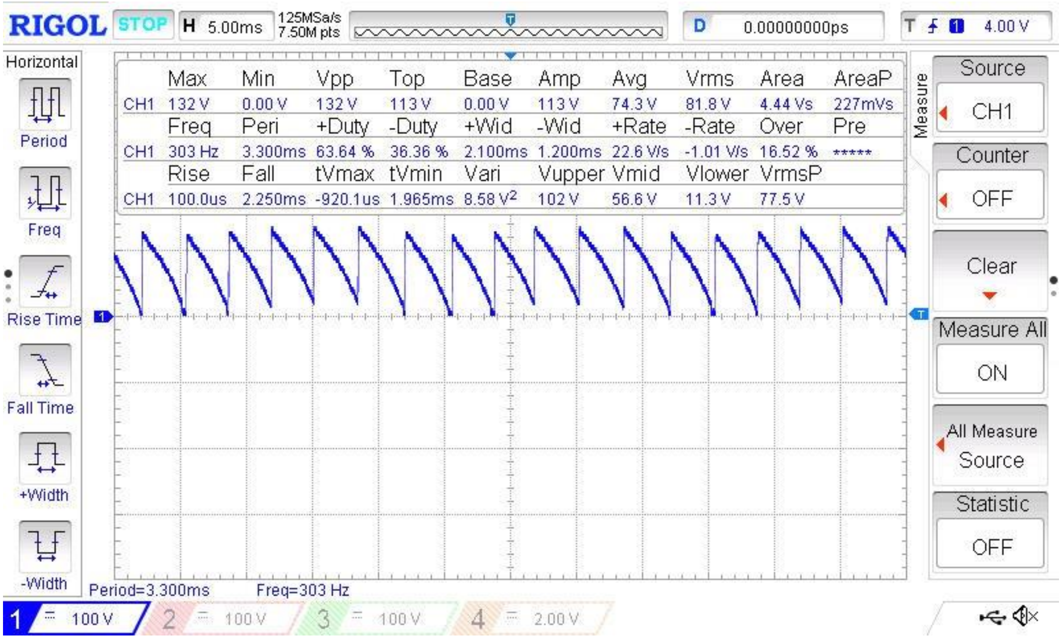

Fig. 13 Six- Pulse convertor with R- load at α = 60°

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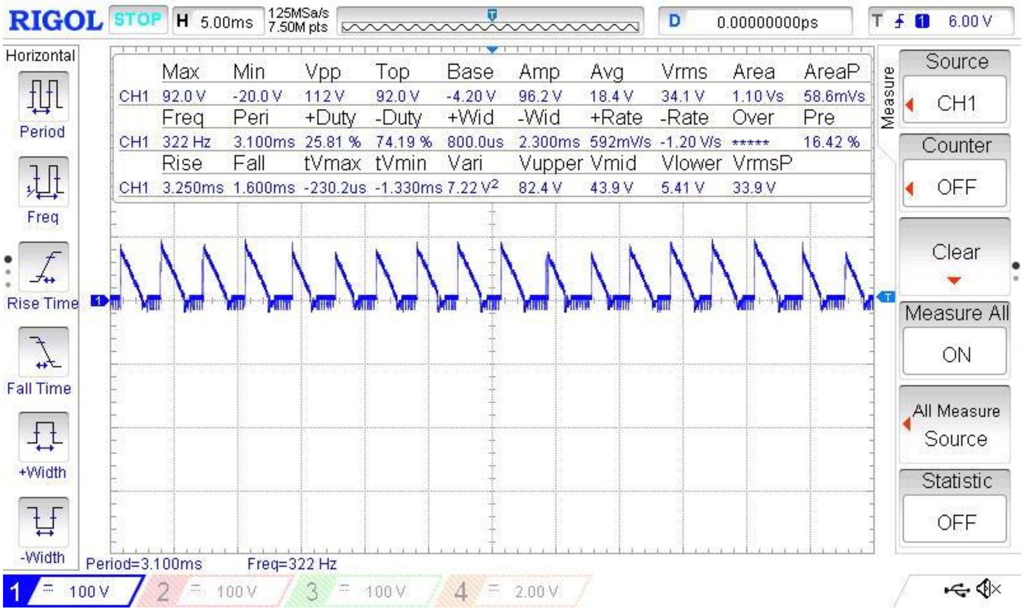

Fig. 14 Six- Pulse convertor with R- load with α > 60°

4. Conclusion

The simulation and hardware circuit of the three-phase six-pulse converter is designed. The experimental analysis of converter with RL load is providing large spikes in load voltage waveform and poor performance of snubber circuit at high load and high voltage. The maximum load tested with hardware is 60W. In future, the same topology will be implemented for speed control of dc motors.

5. References

[1] Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, and Seok-Jin Lee, "HVDC transmission power conversion applications in power systems," in Wiley-IEEE Press, 1st edition, pp. 349-362, Jun. 2009.

[2] Muhammad H. Rashid, "Power electronics handbook, devices, circuits, and applications," Elsevier Academic press, 2nd edition, pp. 769-794, Nov.2007.

[3] Jean Mahseredjian, Venkata Dinavahi and Juan A. Martinez, "Simulation Tools for Electromagnetic Transients in Power Systems: Overview and Challenges", IEEE Trans. Power Del., vol. 24, no. 3, pp. 1657-1699, Jul. 2009

[4] J. Arrillaga, Y. H. Liu, and N. R. Watson, "Flexible Power Transmission: The HVDC Options," John Wiley & Sons, 1st edition, pp. 21-56, Aug. 2007.

[5] Bhim Singh, Sanjay Gairola, Brij N. Singh, Ambrish Chandra, and Kamal Al-Haddad, "Multi-pulse AC–DC Converters for Improving Power Quality: A Review", IEEE Trans. Power Electron., vol. 23, no. 1, pp. 260-272, Jan. 2008.

[6] Bin Wu and Mehdi Narimani, "High-Power Converters and AC Drives," Wiley-IEEE Press, 2nd edition, pp. 37-64, Jan. 2017.

[7] Bhim Singh, G. Bhuvaneswari, and Vipin Garg, "An Improved Power-Quality 30-Pulse AC–DC for Varying Loads". In IEEE Trans. Power Del., vol.no pp. 1-9, April 2007.