A NEW ZVT SNUBBER CELL FOR PWM-PFC BOOST CONVERTER

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ABSTRACT

A new Zero Voltage Transition (ZVT) snubber cell is developed for Pulse Width Modulated (PWM) and Power Factor Corrected (PFC) boost converters operating in Continuous Conduction Mode (CCM). A new family of PFC boost converter implemented with this new ZVT snubber cell is proposed. In this new PFC boost converter, the main switch is turned-on perfectly with ZVT and turned-off under Zero Voltage Switching (ZVS). Besides, the auxiliary switch is turned-on under Zero Current Switching (ZCS) and turned-off under ZVS. The main and all auxiliary diodes are operating under Soft Switching (SS). During ZVT operation, the switching energies on the snubber inductance are transferred to the output by a transformer, and so the current stresses of the inductance and the auxiliary switch are significantly decreased. Also, this transformer ensures the usage of sufficient capacitors for ZVS turning off of the main and auxiliary switches. The main switch and main diode are not subjected to any additional voltage and current stresses. In this study, a detailed steady state analysis of the proposed new ZVT-PWM-PFC boost converter is presented and this theoretical analysis is verified by a hardware prototype and simulations in MATLAB/Simulink environment.

INTRODUCTION

Most electronic equipment is supplied by 50 Hz or 60 Hz utility power, and in almost all of them power is processed through some kind of a power converter. Usually, power converters use a diode rectifier followed by a bulk capacitor to convert AC voltage to DC voltage. It is predicted that more than 60% of utility power will be processed through some form of power electronics equipment by the year 2010. Unless some correction circuit is used, the input rectifier with a capacitive filter circuit will draw pulsating currents from the utility grid resulting in poor power quality.

An active PFC is a power electronic system that is designed to have control over the amount of power drawn by a load and in return it obtains a power factor as close as possible to unity. Commonly any active PFC design functions by controlling the input current of the load in order to make the current waveform follow the mains voltage waveform closely. Power factor correction for mains rectifiers is an upcoming issue. Operating principles of single and three phase power factor corrected rectifiers have Suitable integrated using power semiconductors have been presented. Power factor corrected rectifier systems using these components have been rated and corrected. It is well established that three-phase power-factor-correction (PFC) rectifiers with three or more active switches exhibit superior power factor compared with those implemented with a fewer number of switches .

In the PFC boost converter equipped with new ZVT snubber cell, Soft Switching operation of all main and auxiliary semiconductor devices is provided. The switching energies are transferred to the output by using a transformer during ZVT operation, thus the current stresses of the auxiliary semiconductor devices are significantly reduced, and so the usage of sufficient capacitors for ZVS turning off of the main and auxiliary switches is ensured. The main switch and the main diode are not subjected to any additional voltage and current stresses. The proposed converter has a quite simple structure, low cost and ease of control.

EXISTING SYSTEM

Although active PFC can be achieved by any basic topology, the boost converter is the most popular topology used in PFC applications, for the following reasons: The line voltage varies from zero to some peak value typically 375V, hence; a step up converter is needed to output a dc bus voltage of 380V or more. For that reason the buck converter is eliminated, and the buck-boost converter has high switch voltage stress (Vin+Vo). Moreover, the boost converter has the filter inductor on the input side, which provides a smooth continuous input current waveform as opposed to the discontinuous input current of a buck or buck-boost topology.

Boost converter produces output voltage that is greater or equal to the input voltage.

Alternative explanation:

1. When switch is closed, diode is reversed. Thus output is isolated. The input supplies energy to inductor.
2. When switch is opened, the output stage receives energy from the input as well as from the inductor. Hence output is large.
3. Output voltage is maintained constant by virtue of large C.
4. Power factor correction Application

PROPOSED SYSTEM

With the aim of obtaining an improvement in overall performance of the PWM converters and further a reduction in size and weight of these power converters, soft-switching techniques have been the subject of intensive research. These techniques allow the power converters to operate with higher switching frequencies without penalizing the trade-off between switching losses and converter efficiency. Among these techniques, the commutation under Zero Voltage Transition – ZVT has been frequently employed, mainly when the active switches are implemented with majority carrier semiconductor devices. Besides the enhanced switching conditions for main devices, this technique also provides the absorption of main devices intrinsic capacitances.

Moreover, the ZVT cell is placed in parallel with the main power path, enabling the converter to operate as close as possible to its PWM counterpart, with low conduction losses when compared to other Zero Voltage Switching - ZVS techniques. ZVT PWM PFC converters auxiliary circuit promotes inadequate commutation conditions to auxiliary switch. When auxiliary switch is implemented using power MOSFET devices, its output intrinsic capacitance enables Zero Voltage Switching - ZVS turn-off. Nevertheless, the energy stored during this process is totally dissipated when the switch is turned on reducing the efficiency gain of the soft switching approach. A new low conduction loss low-cost zero-voltage-transition (ZVT) power factor correction converter (PFC) is presented. The conventional PFC, which consists of a bridge diode rectifier and a boost converter (one active switch), always has three semiconductor conduction drops. The two-switch-type PFC, which was presented recently, reduces conduction loss by reducing one conduction drop, but the cost is increased because of one additional switch, The proposed PFC reduces conduction loss with one switch.

Conduction loss reduction is a little bit less than that of the two-switch type, but it is achieved with low cost. Operation, features, and characteristics are comparatively illustrated. Reduced conduction loss zero-voltage-transition power factor correction converter with low cost. In the main circuit, Vac is line voltage, Vi is rectified input voltage, Vo is output voltage, LB is boost inductor, Co is output capacitor, TB is main switch, DTB is body diode of TB, DB is main diode. In the active snubber cell, TS is auxiliary switch, TR is centre tapped transformer, LS is snubber inductor, CS1 and CS2 are snubber capacitors. D1, D2, D3 and D4 are auxiliary diodes.

In the steady state analysis of the circuit, semiconductors except DB, inductors and capacitors are assumed ideal. Also, it is assumed that LB inductor is high enough and current of this inductor is constant for one switching cycle. One switching cycle is started with the control signal applied to TS while DB conducts the input current Ii. Current of TS and LS increase linearly until main diode DB conducts reverse recovery current -Irr. TS is turned on with ZCS, DB is turned off with ZVS. After that a resonance starts between CS1 and equivalent inductance of LS and LM. During this stage, voltage of capacitor CS1 decreases to zero. DTB turns on with SS. After this moment, control signal of TS is removed and control signal of TB is applied. So TB is turned on with ZVT perfectly. During these intervals, most of the switching energies are transferred to the output through transformer.

When the control signal of TS is removed, stored energy in the transformer charges capacitor CS2, at the same time, energy stored in LS is transferred output through D3. After LS has finished to transferring its energy to the output, magnetizing inductor continuous to charging CS2 until capacitor voltage reaches output voltage Vo. After CS2 voltages is charged up to Vo, D4 diode turns on to transfer energy stored in magnetizing inductor to the output. After, this energy transferring completes, the current of TB reaches input current Ii and on stage of conventional boost converter starts. The control signal is removed at the end of the determined on time. Before this time, voltage of CS2 equals output voltage Vo and voltage of CS1 equals zero.

When the control signal of the main switch TB is removed, the voltage of CS1 charges up to Vo and the voltage of CS2 discharges to zero simultaneously. So, main switch TB turns off with ZVS and one switching period is completed. Sum of the capacitor values provides ZVS turn off of the main switch TB.

Block Diagram

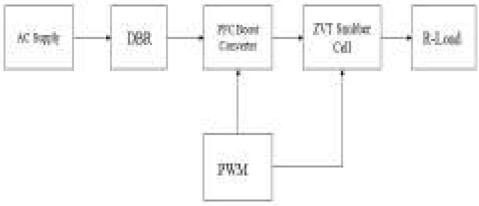


Fig. 1 Block Diagram of Proposed System

PFC Boost Converter with ZVT SnubberCell

ThecircuitschemeoftheproposedPFCboostconverter equippedwith newZVT cellisgiven in Fig. In this circuit, Vi is rectified line voltage, Vo is output voltage, TB is the main orboostswitch,DTBisthebodyoranti-paralleldiodeofthe main switch, DB is the main or boost diode, LB is the main or boostinductor,Coistheoutputcapacitor,Rois theload resistor.TheproposedZVTsnubbercellconsistsofan auxiliaryswitch(TS),foursnubberdiodes(D1,D2,D3,D4),a snubber inductor (LS), a center tapped transformer (TR) which hasmagnetizinginductor(LM),andsnubbercapacitors(CS1 and CS2). The capacitor CS1 contains the parasitic capacitors of the main switch and the main diode. Some assumptions can be made to simplify the converter steady-state analysis in a switching cycle.InputvoltageVi, outputvoltageVoandtheinputcurrentIiareconstantina switching period. The main switch TB, the auxiliary switch TS and the auxiliary diodes could be treated as ideal.

The advantages of the PFC boost converter equipped with the proposed ZVT snubber cell can be summarized as follows.

1. InZVToperation,theswitchingenergiesaretransferred to the output by using center tapped transformer, therefore thecurrentstressesoftheinductor,auxiliaryswitchand other auxiliary components are decreased significantly.
2. By using the center tapped transformer, also the usage of sufficient capacitors for ZVS turning off of the main and auxiliary switches is ensured.
3. With the sum of two snubber capacitors provides the ZVS turnoffforthemainswitchandwithoneofthem providestheZVSturnofffortheauxiliaryswitch,and alsothisisdecreasedthecurrentstressesoftheauxiliary components.
4. ThemainswitchturnsonwithZVTandturnsoffunder ZVS. The auxiliaryswitchturnsonwithZCSand turnsoff under ZVS.
5. All auxiliary diodes and the main diode operate under SS.
6. There is no additional voltage and current stresses on the main switch and the main diode.
7. There is no additional voltage stresses on the auxiliary switch.
8. There is no additional component on the main current path.
9. It is not necessary a body diode on the auxiliary switch.
10. Energies stored in the parasitic capacitors of the main switch and the main diode is recovered.
11. Thereisnonegativeeffectofthecenter-tapped transformerleakageinductanceonthe operationofthe converter. Leakage inductance does not affect the

operation or the performance of the converter.

12. SS conditions are maintained at very wide line and load ranges.
13. The totaltimeofthetransientperiodsisveryshort according to switching period.

Circuit Diagram

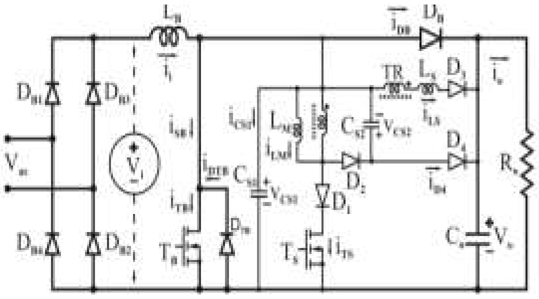


Fig. 2 Circuit Diagram of Proposed System

Ninestagesoccurinthesteadystateoperationofthe proposedconverteroveroneswitchingcycle. Theequivalent circuitschemesoftheseoperationstagesaregiveninFig. respectively.Also keywaveformsconcerningtheoperation stages are given in Fig.

Atthet<t0,TBandTSareintheoffstate.The maindiode DB is in the on state and conducts input current Ii of the main inductorLBtotheload.Atthemomentt=t0,the equations iTB=0, iTS=0, iDB=Ii, iLS=0, iLM=0, vCS1=Vo, vCS2=0 are valid.

- ➢ Key Waveforms

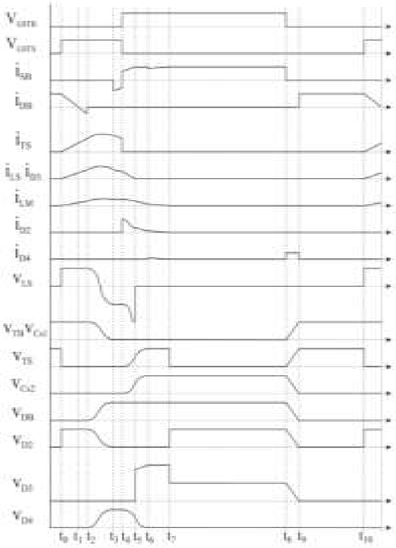


Fig 3 key waveform of PWM

SIMULATION RESULTS

PROPOSED IMPLEMENTATION

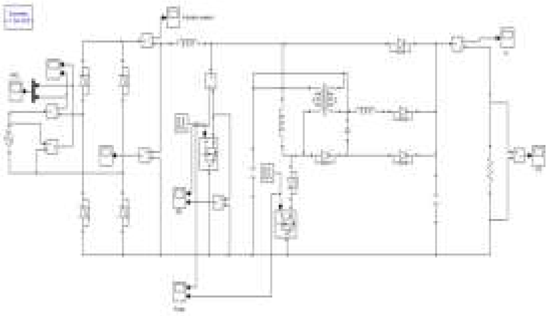


Fig4Matlab Implementation Circuit of Proposed PFC BOOST Converter with ZVT Snubber Cell

MATLAB simulation ofa ZVT PWM PFC converter isshowninFig 4.8was performedtoverifythetheoreticalanalysisoftheproposed newZVT-PWM-PFC boost converter. A photograph of the implementation circuit is given in Fig 4.7

PFC Response of PFC Boost Converter with ZVT Snubber Cell

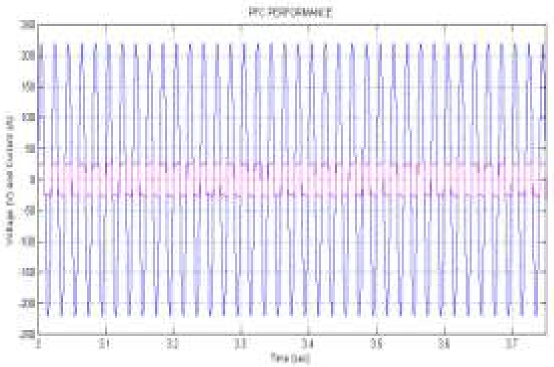


Fig. 5 PFC Response of PFC BOOST Converter with ZVT Snubber Cell

Fig 5 shows power factor correction performance of ZVT PWM PFC Converter for Resistive load. From waveform it is clear that source voltage and current are in phase with each other and the measured power factor is close to unity

DC Link Voltage of PFC Boost Converter with ZVT Snubber Cell

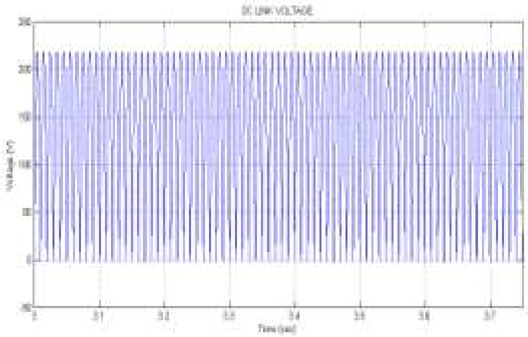


Fig. 6 DC Link Voltage of PFC BOOST Converter with ZVT Snubber Cell

Fig 6 shows dc link voltage waveform of preliminary ac to dc conversion stage using diode bridge rectifier. Since filter capacitor is not used output is pulsating DC.

Inductor Current of PFC Boost Converter with ZVT Snubber Cell

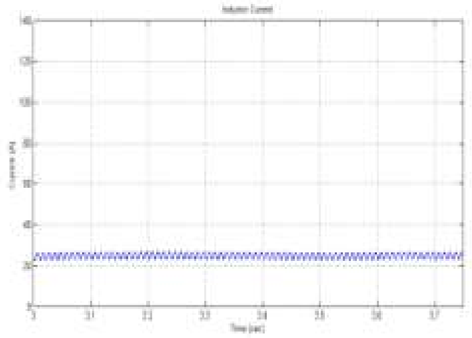


Fig. 7 Inductor Current of PFC Boost Converter with ZVT Snubber Cell

Fig 7 shows current waveform of primary inductor and it operates in CCM continuous current conduction mode where inductor current never comes to zero in each conduction cycle. In CCM converter will deliver continuous power to load.

Soft Switching of PFC Boost Converter with ZVT Snubber Cell

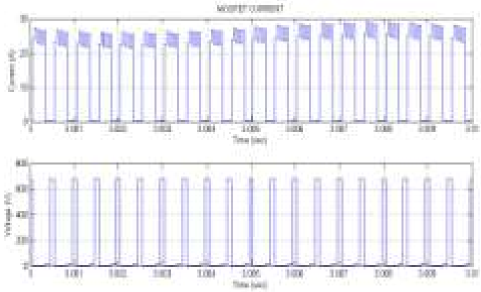


Fig. 8 Soft Switching Performance of PFC BOOST Converter with ZVT Snubber Cell

Fig 4.11 shows depicts soft switching performance of main switch. Here main switch turns on under zero voltage switching where switch voltage drops to zero and then switch current starts to increase.

PWM of PFC Boost Converter with ZVT Snubber Cell

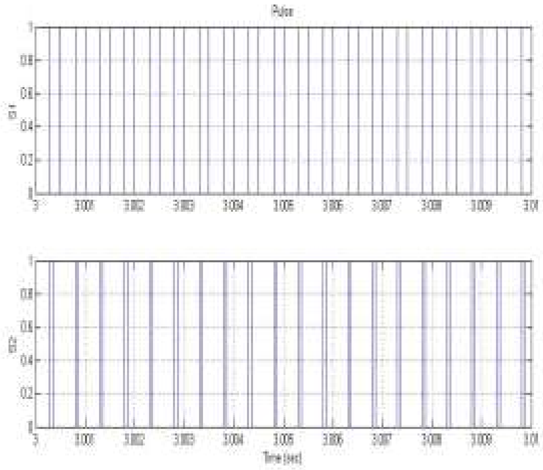


Fig. 9 PWM Pulse of PFC BOOST Converter with ZVT Snubber Cell

Fig 9 shows switching pulse of main boost switch and auxiliary switch used in ZVT snubber cell. Both the switches are operated in same frequency of 1000 Hz and duty cycle of boost switch switch 0.6 and auxiliary switch is 0.2 with a phase delay of (0.7/1000) seconds.

Load Voltage of PFC Boost Converter with ZVT Snubber Cell

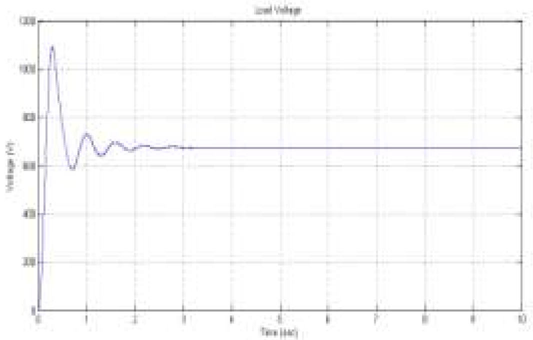


FiG. 10 Load Voltage of PFC BOOST Converter with ZVT Snubber Cell

Fig. 10 shows load output voltage (Vload=675) of ZVT PWM PFC converter which has a boost conversion ratio of 1:3 with respect to peak ac voltage magnitude.

Load Current of PFC Boost Converter with ZVT Snubber Cell

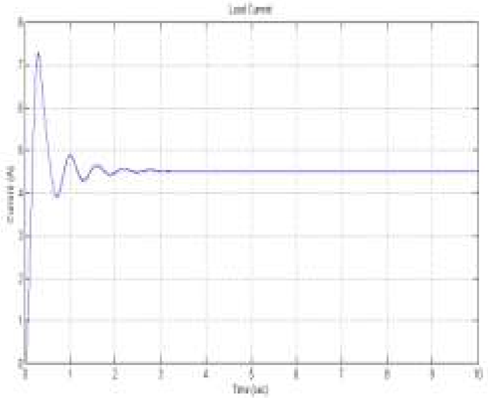


Fig. 11 Load Current of PFC BOOST Converter with ZVT Snubber Cell

Fig 4.14 shows load output current(Iload=4.5A) of ZVT PWM PFC converter and the load current depends on the rating of resistive load used and the corresponding output power is 3KW.

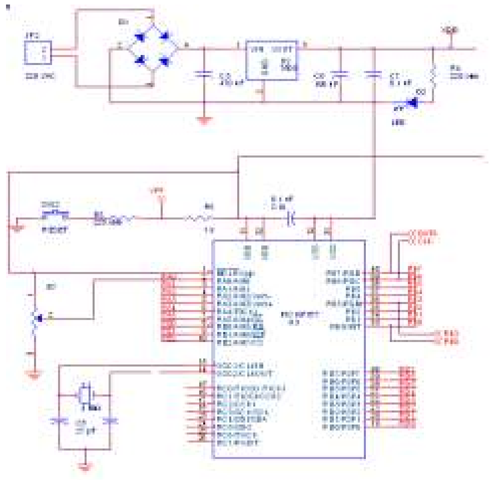
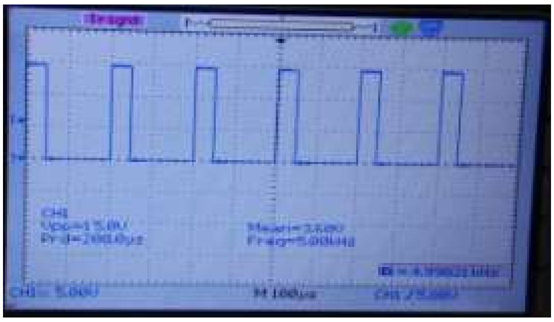
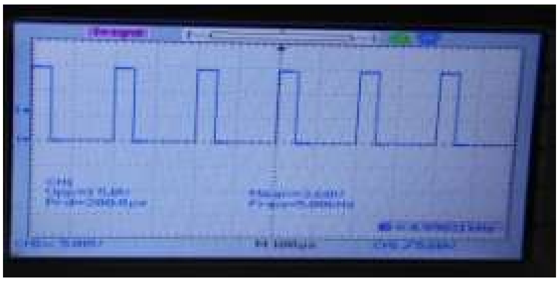


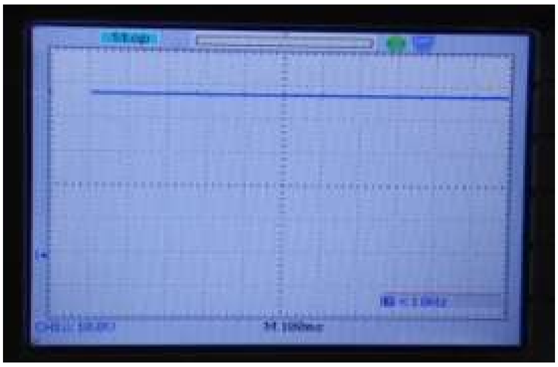
Fig. 12 Control Circuit



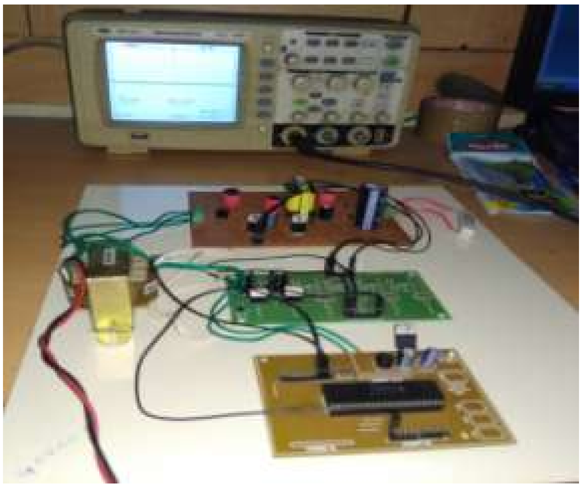
Gate Pulse from Driver Circuit



Gate Pulse from Microcontroller



Output Voltage(48V)



CONCLUSION

A new Zero Voltage Transition (ZVT) snubber cell for high power factor AC-DC converter. In the proposed AC-DC converter, all of the semiconductor components operate with Soft Switching. There are no additional voltage and current stresses on the main switch, main diode and auxiliary switch. Besides, there is reduced current stress on the auxiliary switch by using snubber transformer. Soft switching conditions are maintained at very wide line and load ranges, the total time of the transient periods is very short and there is not any additional component on the main current line. The proposed converter has increased boost ratio and the produced output power is also quite high when compared with existing PFC converter. Simulation of the proposed AC-DC converter is presented to verify the merits of proposed converter.

Applicationof proposed ZVT PFC converter for renewable power generation system employing Wind- PMSG with improved voltage conversion ratio at high power factor and high efficiency has been discussed..ZVT PFC Converter can be considered as an intermediate dc-dc conversion stage of renewable energy driven motor drives like Induction motor drives, BLDC, PMSM drives.Operation of ZVT PFC in CCM mode is studied it is possible to future enhance the efficiency of converter in DCM mode where stress on switches and passive devices will be less when used for high voltage conversion.

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