AN IMPROVED LUO CONVERTER FOR HIGH POWER APPLICATIONS

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Abstract

Power conversion is one of the major requirements in various industries and in daily life. Among various types of power conversion, DC-DC conversion has greater importance. DC-DC conversion can be reliably performed using luo converter. It employs voltage lift technique so that output voltage is increased stage by stage, in arithmetic progression. Luo converter can be incorporated with the Z network or impedance network so as to ensure simple start up and smooth power conversion. An impedance network consist of two identical inductors and two identical capacitors connected in 'X' shape. Besides power conversion it also offers filtering operation. The luo converter in this scheme is of switched capacitor type. It helps to provide regulated output voltage from an unregulated source of power supply. The major benefits of this proposed scheme is that it combines the advantages of the switched capacitor, voltage lift technique and the impedance network. Hence the proposed scheme has various advantages such as high power density, larger range of output DC voltage, lower or no inrush current, lower harmonic injection, simple circuit, high voltage transfer gain, can process upto several tens of watts of power. The simulation analysis and the hardware implementation shows that the output voltage obtained is higher than the expected theoretical value. i.e, it is the highly boosted voltage output.

Keywords: *Z-network, boost voltage, voltage lift technique*

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1. INTRODUCTION

Conversion technique is one of the major research areas in the field of power electronics. The equipment's used for conversion technique are found to have applications in industry, research and development, various organizations and in daily life. All the existing DC/DC converters are designed to meet the requirements of certain applications only [1]. The conventional types of DC/DC converters include Buck converter, Boost converter, Buck-Boost converter, Cuk converter etc. Among these, boost converter is found to be applicable in large number of applications like, Hybrid Electric Vehicles (HEV), lighting systems, tramways, railway electrification.

The DC/DC conversion technique was established in 1920s.The simplest form of conversion was using voltage divider[1].Now various advanced methods are available for DC/DC conversion. It ranges from voltage lift technique to superlift and ultralift technique. Here, voltage lift technique is being used due to its simplicity, ease of use and economic nature. The voltage-lift technique can be successfully applied to several series of DC-DC Luo converters. Employing voltage lift technique has opened a way in designing high voltage gain converters. It allows voltage to be increased stage by stage, in arithmetic progression[2].

Luo converters are one of the simplest form of DC/DC converters which operates on voltage lift technique[1]-[2]. Many series of luo converters are available now, ranging from elementary 2 lift to 192 lift luo converter[2]. These luo converters operates in push-pull state and can be of mainly two types, either switched capacitor type or switched inductor type. The switched capacitor type luo converter has no inductors and transformers. It allows controlled energy transfer from unregulated source to regulated output voltage.

In this paper, an improved luo converter incorporating impedance network is proposed .An impedance network or Z-network can be applied for all types of power conversion such as AC-AC,AC-DC,DC-AC and DC-DC. It helps to buck or boost the input voltage, depending on the value of boosting factor and also acts as a second order filter. The proposed scheme retains all the advantages of the conventional luo converter system such as small size, high power density, micro power consumption[2] etc and at the same time add some additional benefits such as, low or no inrush current, improve resistance to failure switching and EMI distortions, relatively simple start-up etc. This proposed scheme can be reliably used for such applications requiring high output voltage.

2. LUO CONVERTER

A luo converter mainly consist of two series, main series and additional series. The main series consist of 2 lift,4 lift,8 lift luo converter etc and additional series includes 3lift,6 lift,12 lift etc. The following is the circuit diagram of the conventional luo converter and its operation during switch on and off operation. This configuration is the basic switched

capacitor luo converter. The switched capacitor allows controlled energy transfer from unregulated source to regulated output voltage . The switched capacitor ca be easily integrated into a power IC chip, consequently the converter will be of small size and will have high power density[3].The voltage lift technique helps to reduce the effect of parasitic elements and thus opens a way to improve the circuit characteristics[4].The converter employing voltage lift technique are different from other existing DC/DC step-up converter and are featured with simple operation and simple structure [5].

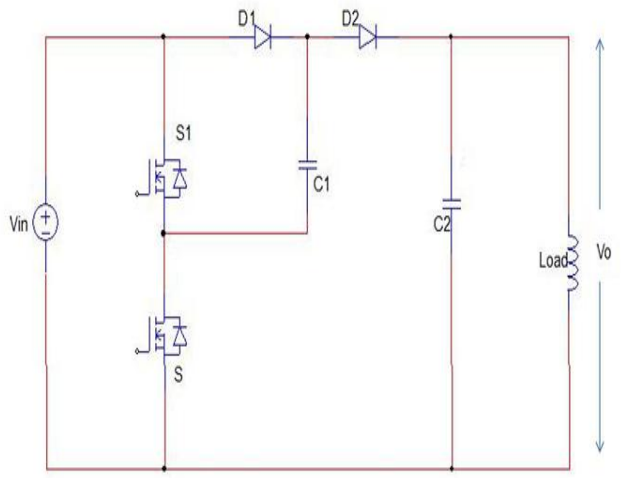

Fig 1 Circuit diagram of the conventional luo converter

The main switch is S in all circuits, and other switches act as the slaves. The two switches S and S1 operate in push-pull state. In this paper the switches are realized using MOSFET. VS is used to represent voltage drop of switches and VD, to represent voltage drop of diodes. The load here is the inductive load L1. Input voltage is Vin and Current is denoted by Iin . The output voltage is represented by Vo and current is denoted by Io.

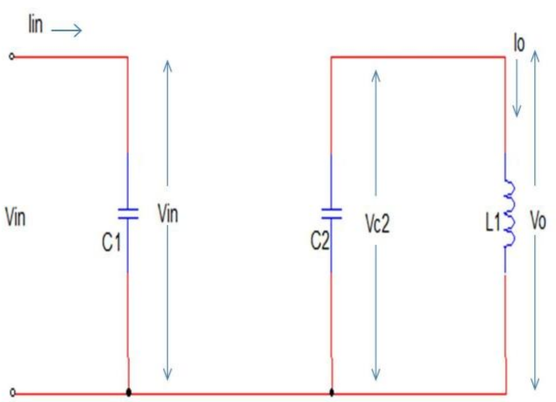

Fig 2 Equivalent circuit during switching-on (S on)

The voltage across the capacitor C1 is charged to Vin during switching-on. In this period the main switch S will be on and the slave switch S1 will be off.

The switch S will be off and slave switch S1 will be on during the switching-off period .The voltage across the capacitor C2 is charged to V_O = 2Vin

Hence the output voltage is given by,

Vo = 2Vin …………………………………..(1)

In practical case,

Vo = 2Vin-ΔV1……………………………...(2)

Vo =2Vin – (VD1+VD2+VS1+VS2)...………(3)

VO = 2Vin-(2VS+2VD)……………………..(4)

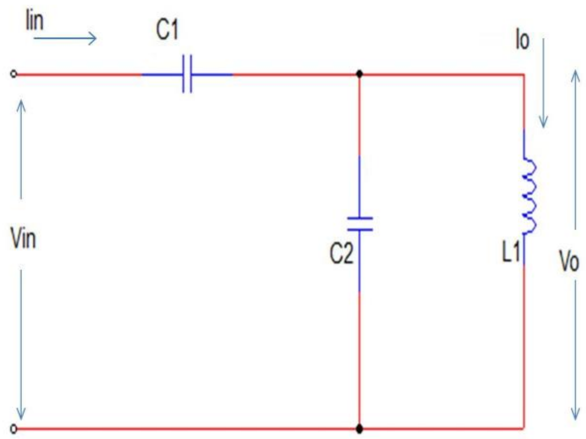

Fig 3 Equivalent circuit during switching-off (S1 on)

Eventhough, the expected output as per eq.(1) is twice the input voltage, due various component drops, the obtained output will be lesser as per eq.(2).This drop in general is represented by ΔV1.The drop consist of voltage drop associated with two switches and two diode as described in the eq.(3).The eq.(4) shows the combined voltage drop of diodes and switches.

3. SIMULATION RESULT

The following fig.4.is the simulation result of the luo converter. The simulation is done on MATLAB2013 with Vin=100V, capacitors C1 and C2=2µF, switching frequency=100KHZ, load L1=60H and duty cycle k=0.5

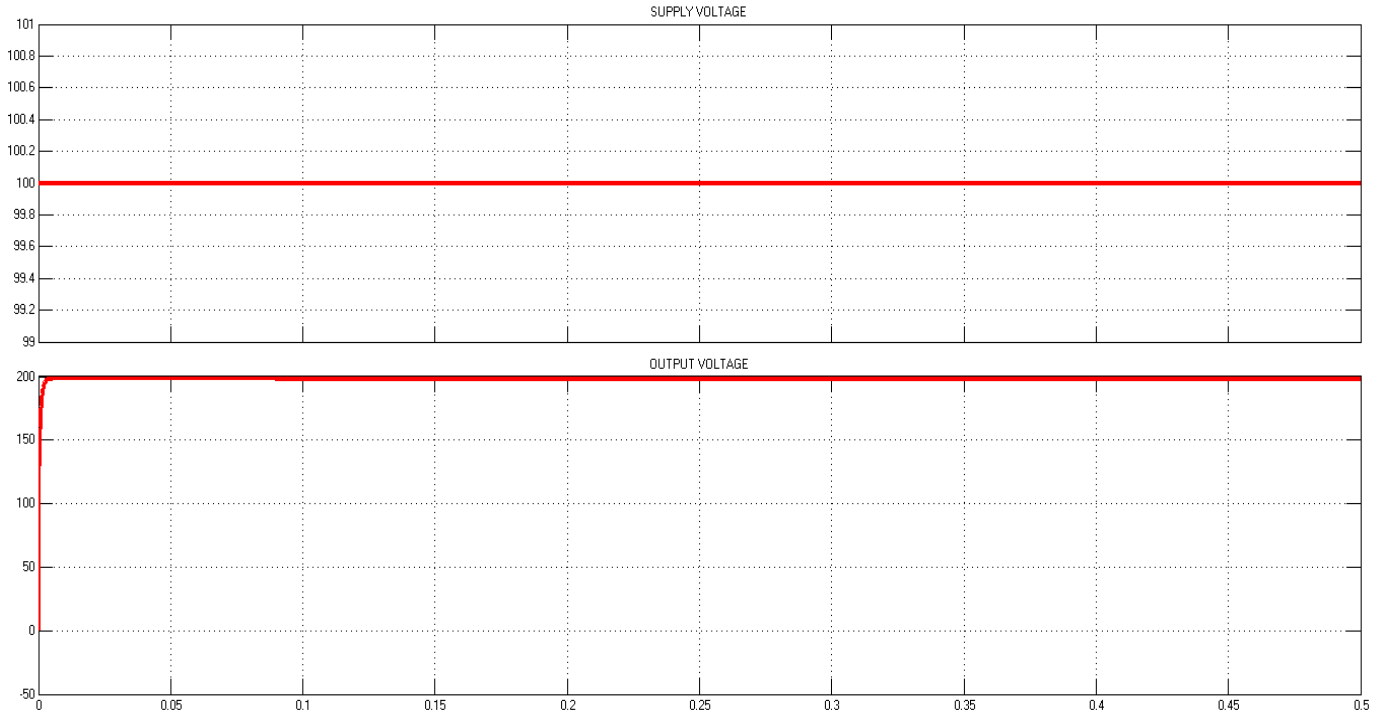

Fig 4 Simulation result

From the simulation result it can be found that for an input voltage of 100V DC, the output obtained is 197.7V, whereas the expected output is,Vo =2Vin

Hence,

$$Vo=2*100=200V$$

But the obtained output is 197.7V which is lesser than the desired value. Moreover in practical applications, the output will be still lesser which may affect the performance of the system. The proposed scheme is a solution to overcome this problem.

4. PROPOSED SCHEME

The proposed scheme is an improved luo converter which can provide better performance. It incorporates an impedance network. The impedance network consist of anti parallel connection of the inductors and capacitors .It is mainly meant to ensure the voltage and current balance. Moreover ,it also add some filters inorder to obtain smoothened output. The following fig.5 is the circuit diagram of the proposed scheme.

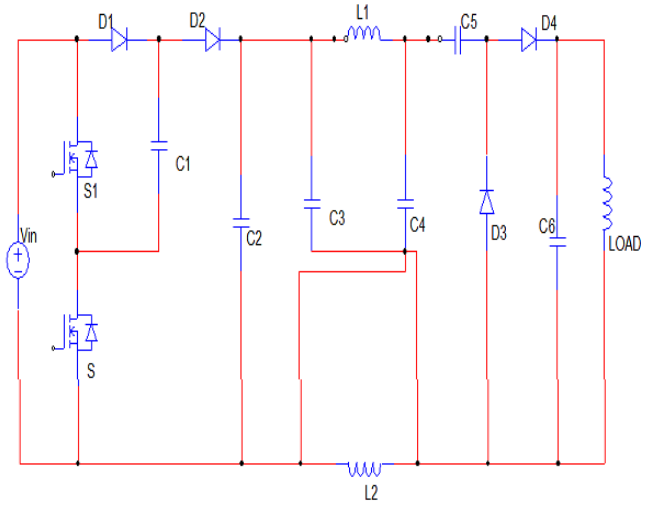

Fig.5.Circuit diagram of the proposed scheme

4.1 Circuit Description

The components S, S1,D1, D2,C1 and C2 are the components of the conventional luo converter. The switched capacitor configuration and voltage lift technique are retained in improved version. It helps to achieve an output of low ripple ,high power density, high voltage transfer gain[6]-[8].The inductances L1, L2 and capacitances C1,C2 form the components of the Z network or impedance network. The two inductances L1 and L2 are connected in series arms and will have equal value. Similarly the two capacitances C3 and C4 are connected in diagonal arms and will have the same value. The rest of the portion in the circuit serve as the filter for smoothening the output.

4.2 Impedence Network

The impedance network, also called as Z-source converter or Z network is a unique 'X' shaped network that couples the converter with the source[9]. Impedance network is a combination of two inductors and capacitors. This combination is found to be more effective in suppressing the voltage and current ripple than when capacitors or inductors are used alone. Inorder to ensure filtering and energy storage, the impedance network should require lower capacitance value. The parallel operation of trans Z-source network can also be implemented, so that the converter can be open and short circuited without damaging the switching devices. This will helps to improve converter reliability and also buck and boost operation can be achieved.

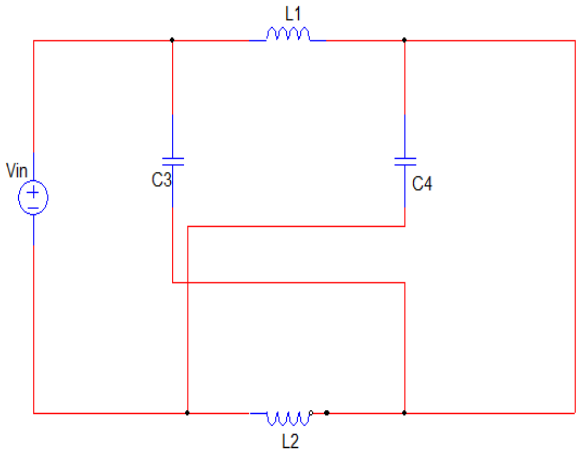

Fig.6.Equivalent circuit of impedance network

4.3 Simulation Result

The following is the simulation result of the proposed scheme. From the simulation analysis it can be found that, for this proposed scheme with same parameter values

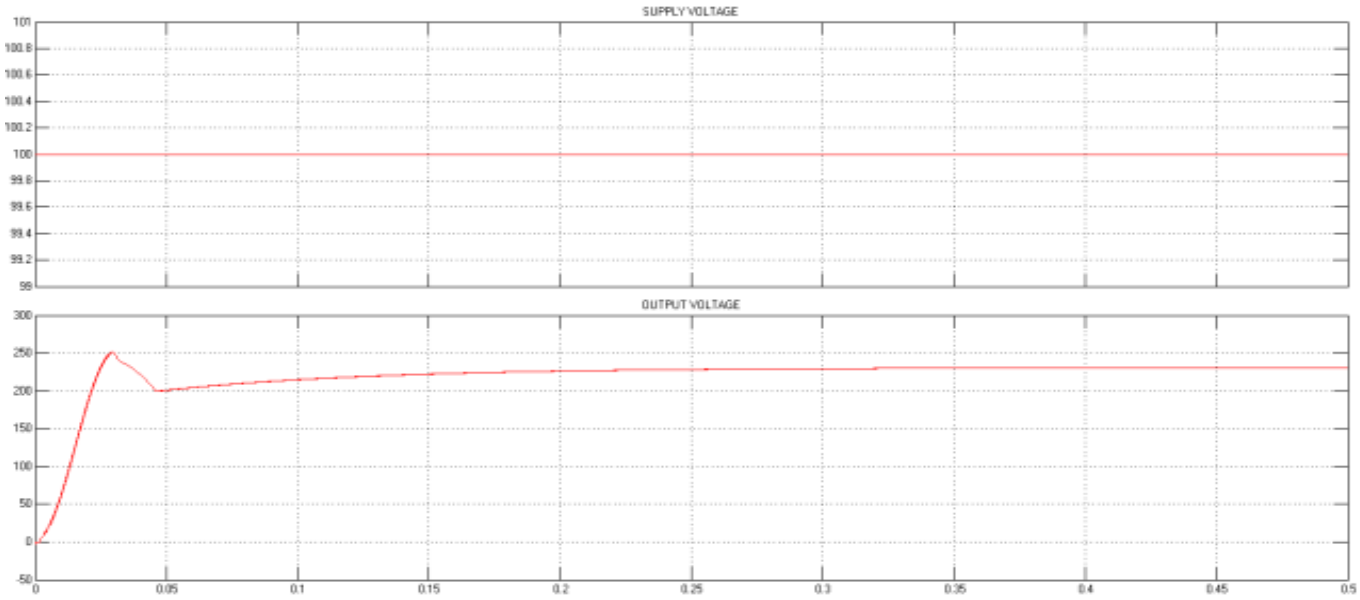

Fig.7 simulation result of the proposed scheme

From the simulation analysis ,it can be realized that the proposed scheme is an advantageous one as it offers higher output. For the simulation with same parameter values such as supply voltage Vin=100V, capacitors being 2μF,switching frequency=100KHZ, and duty cycle=0.5, the result is obtained as follows.

INPUT – 100V DC
OUTPUT – 230.5V DC

So, here the value of the output voltage obtained is higher than the expected value. Here the simulation is done for the elementary two lift luo converter and the same can be implemented for the higher order voltage lift circuits such as 3-lift,4-lift,6-lift,8-lift,12-lift etc.

The following is a table showing the performance analysis of the conventional luo converter and the proposed scheme. It is tabulated based on the simulation result done in MATLAB2013. All the simulations are carried out with the parameter values as mentioned above.

From the performance analysis it can be concluded that the proposed scheme can be used for various applications such as, DC welding applications, HEV-Hybrid Electric Vehicle, in cement manufacturing industry, HVDC lines, electrophoretic deposition, tramway and railway electrification.

4.4 Benefits of the Proposed Scheme

The proposed scheme offers various benefits. It retains the benefits of the traditional converter and in addition has the benefits of the impedance network too .Some of the advantages are as follows [1]-[5].

- ✓ Larger range of output DC voltage-(higher than the expected theoretical value)
- ✓ Lower or no inrush current
- ✓ Lower harmonic injection
- ✓ High power density
- ✓ Improved reliability
- ✓ Based on the duty ratio, it is possible to have buck or boost operation
- ✓ Simple start-up(low current and voltage surge)
- ✓ Simple circuit
- ✓ High voltage transfer gain
- ✓ The Z-network is symmetrical, i.e the two inductors are identical and is the same for capacitor
- ✓ High efficiency
- ✓ Simple structure
- ✓ Can process upto several tens of watts of output power

From the above given benefits or advantages,it can be realized that, the proposed system combines the various advantages of the switched capacitor, voltage lift technique, and the Znetwork or the impedence network.

4.5 Performance Analysis

Table 1:

Input Voltage	Expected Output Voltage	Convent-Ional System	Proposed Scheme
10V	20V	18.33V	20.2V
50V	100V	98.05V	113.7V
100V	200V	197.7V	230.5V
400V	800V	795.5V	931.5V
600V	1200V	1194V	1399V
Vo	VO=2Vin	Vo< 2Vin	Vo> 2Vin

4.6 Hardware Implementation

The hardware consist of driver circuit, PIC controller, LUO converter and the impedence network. Here the switches in luo converter is realized by using the MOSFET

Fig.8. Hardware snapshot

The 230V AC is step –down to 12V using a step down transformer. As the step down AC is to be given to both the driver circuit and the PIC controller, a multitaping transformer is used. The transformer output is first fed to the controller, which provides a regulated DC by means of 7805 regulator and diode embedded in it. The driver circuit provides the desired PWM switching pulse for the MOSFET to operate. The final output at the load side can be measured using multimeter.

4.7 Applications

The DC/DC conversion technique has been developed rapidly, and it is widely used in industrial applications and computer peripheral equipment[4].

i. Welding applications: In case of welding, the ease of starting and harshness of the arc is determined by electrical potential (volts).that is, the voltage is directly related to arc length. Hence this improved luo converter can be applied for welding applications requiring long arc.

ii. Cement manufacturing industry: In cement manufacturing industry, the process of crushing the raw materials like gypsum etc require high voltage. This requirement can be satisfied by using this proposed scheme as it provides voltage higher than twice the input.

iii. Hybrid electric vehicle: Hybrid electric vehicle is one of the application which use boost converter. The conventional boost converter can be replaced by the proposed scheme so that reliable operation can be achieved.

iv. Electrophoretic deposition: Electrophoretic deposition (EPD), is the term used for a wide range of industrial processes which includes electrocoating, cathodic electrodeposition , anodic electrodeposition, and electrophoretic coating, or electrophoretic painting. Normally voltage of 25 - 400 volts DC is used in electrocoating or electrophoretic painting applications. The proposed system can conveniently satisfy this requirement also

v. Tramway and railway electrification system: Typically power supply ranging from 600V DC to 4.3KV DC is required for the tramway and railway electrification system

vi. Other applications: Electrically powered rail vehicles such as electric multiple units and electric locomotives, elevators, conveyors, battery operated electric vehicles.

5. CONCLUSION

An improved luo converter that can provide high output has been successfully created. The proposed scheme is an elementary two lift luo converter incorporating impedance network and filters. This modification doesn't makes the system bulky, and at the same time provides a lot of additional benefits. The Z network supports in smooth DC-DC power conversion. It also ensures the filtering operation. The voltage lift technique helps us to easily design a higher order lift circuit (such as 3-lift,4 lift,6-lift,8-lift etc.), so as to obtain still higher voltage[3]. From the simulation analysis it can be found that the proposed two lift luo converter can provide higher output than expected. As both the simulation analysis and hardware implementation is done for the inductive load and found to provide the desired output, it can be reliably applied for various industrial applications.

REFERENCES

[1]. Fang Lin Luo and Hong Ye,'Essential DC/DC converters',CRC Press,Taylor and Francis Group,2006

[2]. Fang Lin Luo ad Hong YE 'Positive Output Multiple Lift Push-Pull Switched Capacitor Luo converter'.IEEE transactions on industrial Electronics,Vol.51,No.3,June 2004

[3]. Fang Lin Luo,' Switched capacitorized DC/DC Converters', industrial electronics and applications,4th IEEE conference on digital object,2009

[4]. Luo.F.L, 'Positive Output Luo Converter;Voltage Lift Technique', Electric poer applications-IEE-proceedings,Vol.146,issue.4,1999

[5]. Mia Zhu, Tao Wang, Fang Lin Luo'Analysis of Voltage Lift Type Boost Converter', Industrial Electronics and Applications,2012

[6]. Amjad. .Z,Williamson.S.S,"Design and Implementation of a Bidirectional HEV Energy Management Strategy Using a Switched Capacitor Luo Converter

[7]. Harris.W.S, Ngo.K.D.T,'Power Switched Capacitor DC/DC Converter;Analysis and Design,Aerospace and Electronic System,IEE Transaction on Vol.33,Issue 2,1997

[8]. Luo.F.L,,Hong Ye,Rashid.M.H,'Switched Capacitor Four Quadrant DC/DC Luo Converter',Industry Applications Conference,Vol.3,1999

[9]. Florescu.a, Stocklosa.O, Tedorescu.M, Radoi.C, Stoichescu.D.a, Rosu.S, 'The advantages ,limitations and disadvantages of Z-source inverter',Semiconductor conference,Vol.2,.2010

[10]. Hyeongmin Lee, Heung Geun Kim, Honnyong Cha, 'Parallel operation of Trans Z-Source Network Full Bridge DC-DC Converter for Wide Input Voltage Range', Power Electronics and Motion Control Conference,Vol.3,2012

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