Comparative Performance analysis of Buck-Boost and Cuk converter based on various parameters using MATLAB Simulink

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Abstract- *This paper presents the design and analysis of DC-DC converters for renewable energy sources. In recent years conventional energy sources like coal, petrol, diesel and so on are decreasing and demand of electricity is increasing day by day. To achieve the demand of electrical energy alternate methods are important in solar energy generation. Now a day's solar energy plays an important due to limited availability of fossil fuels. DC-DC converters plays a vital role in many applications such as solar electric vehicles, solar water pumping, which mainly requires the increasing and decreasing of input voltage. This paper deals with two such topologies such as Buck-Boost and Cuk converter. The comparison has been made between these two topologies based on the performance of converters with resistive load .The performance of the system has been validated using MATLAB/Simulink.*

Keywords- Solar, Buck-Boost, Cuk, Fossil fuels, Energy sources.

I INTRODUCTION

Renewable energy systems offer environmental and economic benefits in clean and sustainable energy rather than conventional fossil fuels. In all sources Solar energy has received massive demands due to its pollution free characteristic as it is free from any poisonous byproducts that can harm the environment. DC-DC converters demand is increasing in renewable energy sources such as solar Photo voltaic (PV) system, fuel cell system, wind power system etc. for power conversion at different level according to requirement. DC –DC converter is a circuit which converts a source of unregulated/regulated direct current from one voltage level to another regulated voltage level. Switched DC-DC converters offers method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing also most DC to DC converters regulate the output voltage.

In recent year there has been an increasing in the development of DC-DC converter to improve the dynamic behavior. The performance of power converters is the choice of control methods. When a high step up ratio is necessary for any purpose the usual solution is use of isolated DC-DC converters. However, the isolated solution presents some problems as the efficiency reduction due to the power transformer losses and intrinsic parameters as the leakage inductance. This paper mainly focuses on comparative analysis of two DC-DC converters. It involves the performance analysis of BUCK-BOOST and CUK converter based on various parameters such as voltage, voltage gain, power loss, efficiency etc.

II BUCK-BOOST Converter

The buck-boost converter is a type of DC-DC converter, is capable of producing a dc output voltage which is either greater or smaller in magnitude than the dc input voltage. The basic BUCK is combined with BOOST converter to introduce the Buck-Boost converter topology .Different applications are based on Buck-Boost converter implementation such as stand alone, motor drives, batteries and grid connected photovoltaic system. The output voltage is depended upon the duty cycle of the switch. It is cascaded connection of two converters; step up and step down. So it is also called as step up/step down converter. The arrangement for the buck-boost converter is as shown in figure1.

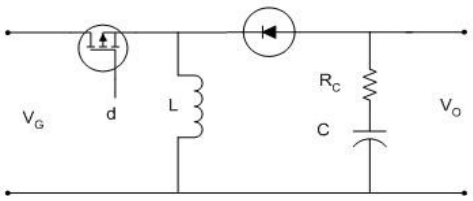


Fig 1 : Buck Boost Converter

When the transistor Q1 is on, input voltage is applied across the inductor and the current in inductor L rises linearly. At this time the capacitor C, supplies the load current, and it is partially discharged. During the second interval when the transistor is off, the voltage across the inductor reverses in polarity and the diode conducts.

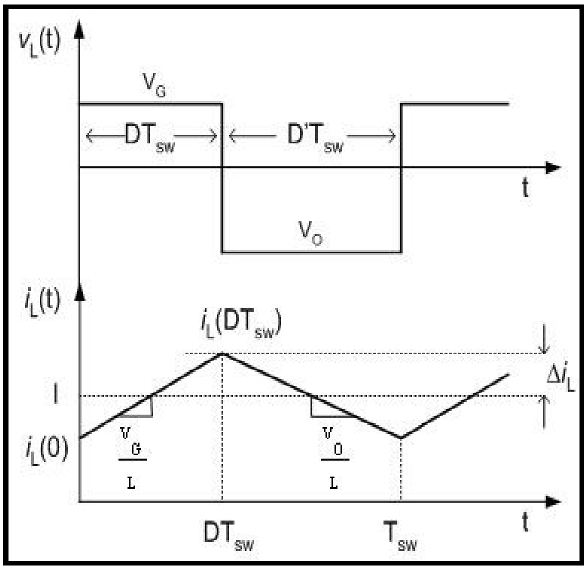


Fig 2 : Steady state inductor voltage and current waveform

During this interval the energy stored in the inductor supplies the load and, additionally, recharges the capacitor. The steady state inductor current and voltage waveform is shown in figure 2.

Using the inductor volt balance principle to find the steady state output voltage equation yields

$$V_G T_{ON} + V_O T_{OFF} = 0 \quad \ldots (1)$$

$$\frac{V_O}{V_G} = \frac{D}{1-D} \quad \ldots (2)$$

The d varies between 0 and 1 and thus output voltage can be lower or higher than the input voltage in magnitude but opposite in polarity.

A buck (step-down) converter combined with a boost (step-up) converter. The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor mode and the boost inductor mode, using switches instead of diodes.

A) Performance Analysis of Parameters of Buck Boost Converter

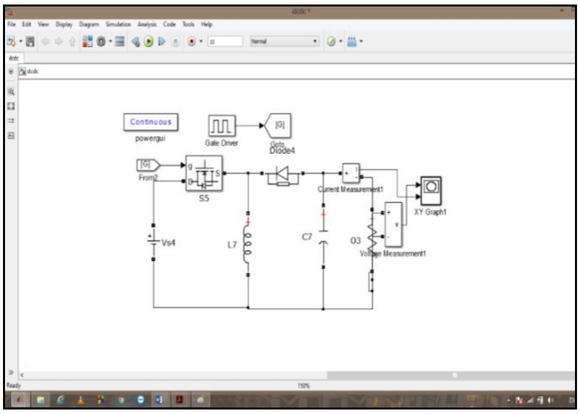


Fig-3: MATLAB Simulink model of BUCK BOOST converter.

When input voltage Vi =20Volt and load resistance is 20 ohm.

Table 1 : Buck Boost converter performance parameters

Parameters	**Parameter values**
Output(Vdc)	-12.47 Volt
Output current(Idc)	-0.6235 A
Output power(Pdc)	7.77545 Watts
Voltage Gain	0.6235
Efficiency	62.35 %
Power Loss	52.22455 Watts

Buck boost parameters are shown in table 1.Output voltage is obtained as 12.47 Volt inverted voltage keeping 20 ohm load resistance. And the comparative results are shown in later part of paper.

III CUK Converter

Cuk converters are derived from the cascading of Buck Boost and boost converters. The Buck Boost, boost and Buck Boost-boost converter all transfer energy between input and output using the inductor and analysis is based on voltage balance across the inductor.

(A) Basic configuration of CUK converter

The Cuk converter utilizes capacitive energy transfer and analysis is based on current balance of the capacitor. When the diode is on, the capacitor is connected to input through L1 and source energy is stored in capacitor. During this cycle the current in C1 is I_{IN}. When transistor Q1 is on, the energy stored in the capacitor is transferred to the load through inductor L2. During this cycle the current in C1 is I_{OUT} .The capacitive charge balance principle is used to obtain steady state solution.

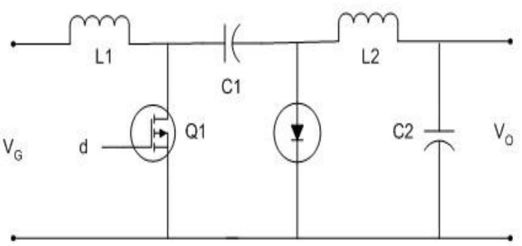


Fig 4 : CUK Converter

$$I_G * T_{OFF} + (-I_O) * T_{ON} = 0 \quad \ldots (3)$$

$$I_O = \frac{(1-D)I_G}{D} \quad \ldots (4)$$

Using Power conservation rule

$$\frac{V_O}{V_G} = \frac{D}{(1-D)} \quad \ldots (5)$$

This voltage ratio is same as the Buck Boost converter.

A) Performance Analysis of Parameters of Cuk Converter

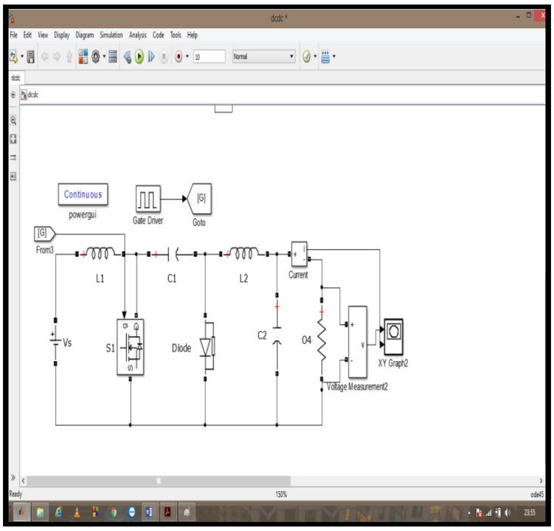


Fig-5: MATLAB Simulink model of Cuk converter.

When input voltage Vi =20Volt and load resistance is 20 ohm

Table 2 : CUK converter performance parameters

Parameters	Parameters values
Output(Vdc)	-15.3 Volt
Output current(Idc)	-0.765 A
Output power(Pdc)	11.7045 Watts
Voltage Gain	0.765
Efficiency	76.5%
Power Loss	48.296 Watts

Cuk converter parameters are shown in table 2, output voltage - 15.3 Volt is obtained by simulation when the load resistance is taken 20 ohm. Efficiency of Cuk converter is above 75%. The comparative analysis of CUK and Buck-Boost converter are described in next section of this paper.

IV Comparison of Buck-Boost and CUK Converter

Both converters are designed for a standard application need. The input voltage is set as 20 Volt and the Load resistance is 20ohm. The simulation was designed such that for the varying input voltage, the output must be constant. Simulation was proceed and the results were obtained.

Table 3 : Design parameters of DC-DC converters

Parameters	Buck-Boost Converter	Cuk Converter
Duty Cycle	40%	40%
Input Voltage (Volt)	20	20
Inductor (µH)	200	200
Capacitor (µF)	200	200
Load resistance (ohm)	20	20
Output Voltage(Volt)	-12.47	-15.34

Input and Output voltages of both converters are shown in figure.

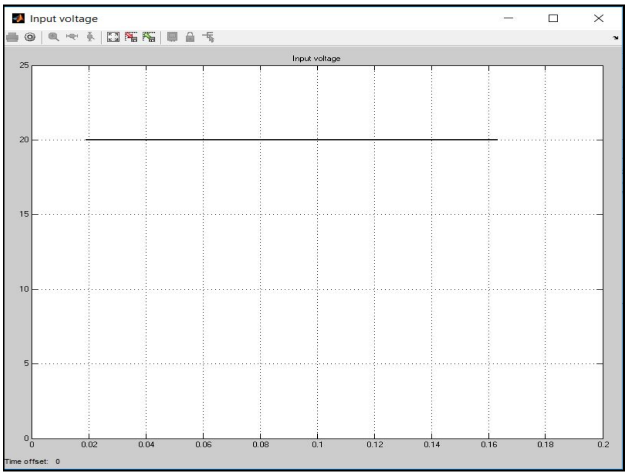


Fig 6 : Output voltage waveforms of input voltage 20 volt with load resistance 20 ohm

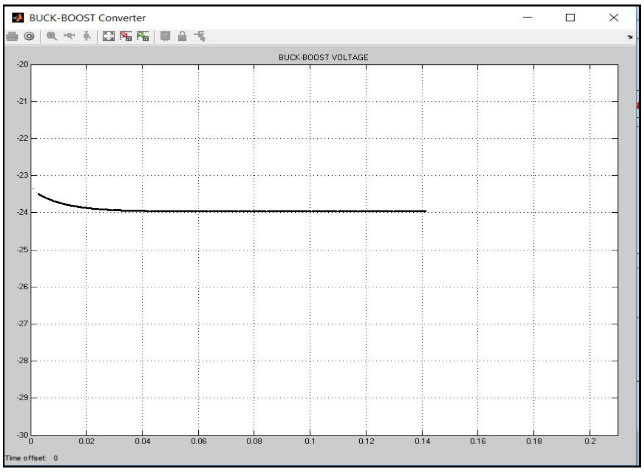


Fig 7 : Output voltage waveform of Buck-Boost converter -12.47 volt with load resistance 20 ohm

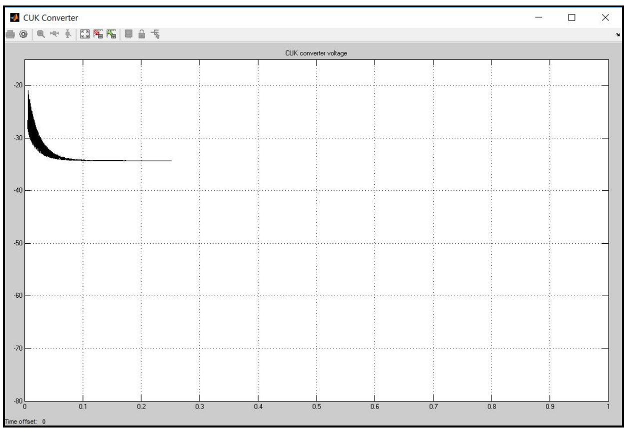


Fig 8 : Output voltage waveform of Cuk converter -15.3 Volt with load resistance 20 ohm

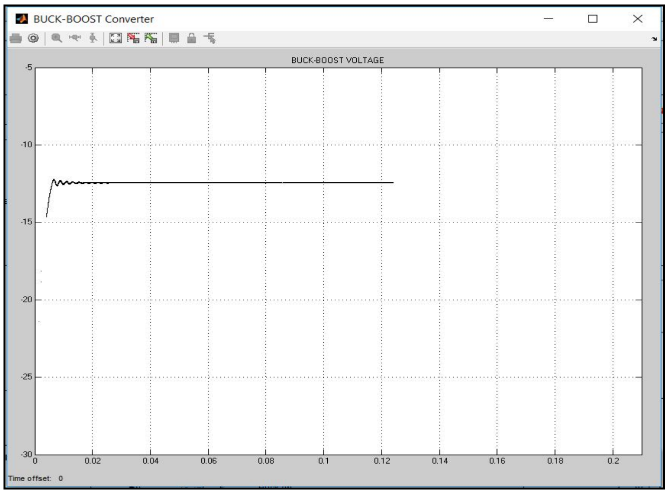


Fig 9 : Output voltage waveform of Buck-Boost converter -23.97 Volt with load resistance 100 ohm

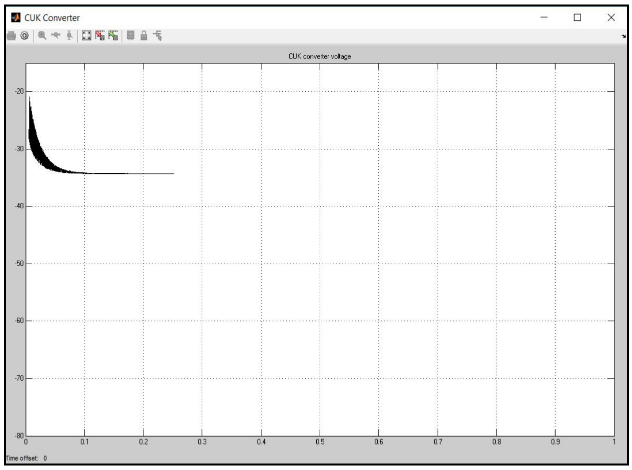
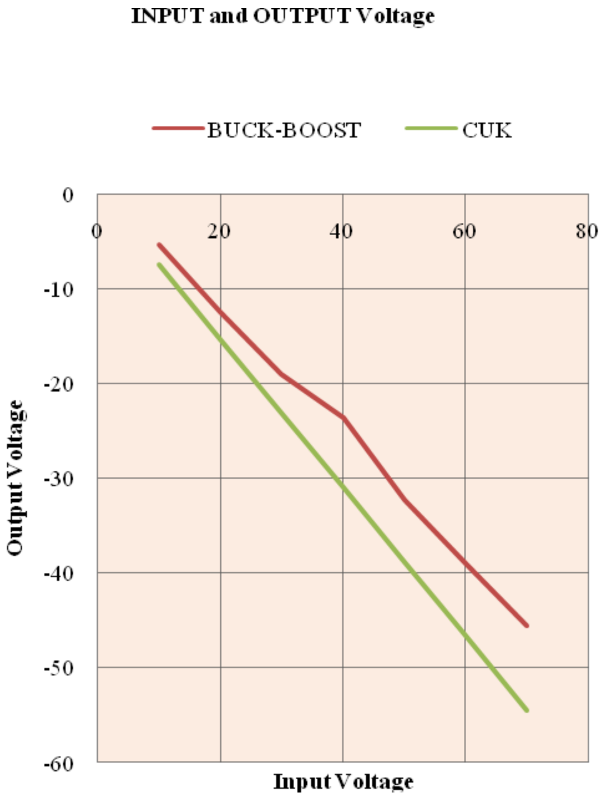


Fig 10 : Output voltage waveform of Cuk converter -34.27 Volt with load resistance 100 ohm

Table 4: Comparison of output voltages of both converters

Input Voltage (Volt)	Output Voltage BUCK-BOOST (Volt)	Output Voltage CUK (Volt)
10	-5.386	-7.457
20	-12.47	-15.3
30	-19.1	-23.15
40	-23.73	-31.05
50	-32.37	-38.86
60	-39	-46.71
70	-45.63	-54.55



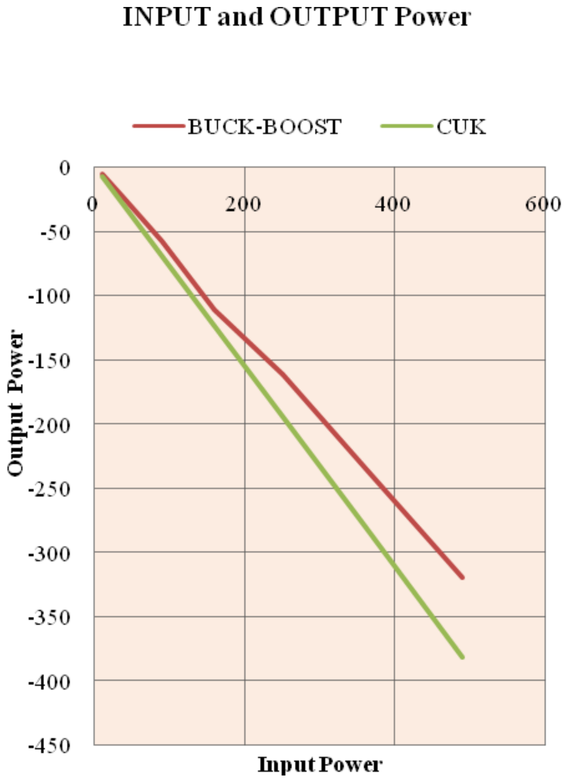
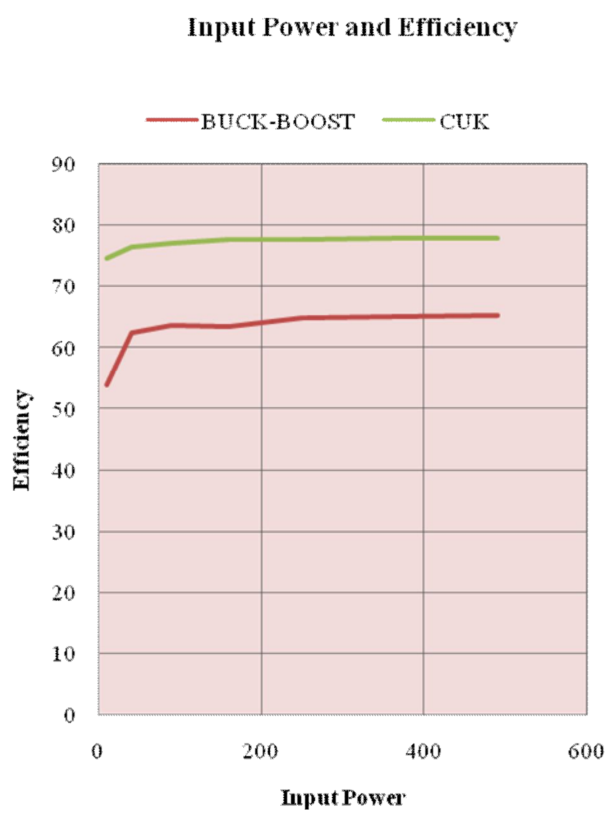


Table 5: Comparison of output power of both converters

Input Voltage (Volt)	Input Current (A)	Input Power (Watts)	Output Power BUCK-BOOST (Watts)	Output Power CUK (Watts)
10	1	10	-5.386	-7.457
20	2	40	-24.94	-30.6
30	3	90	-57.3	-69.45
40	4	160	-110.92	-124.2
50	5	250	-161.85	-194.3
60	6	360	-234	-280.26
70	7	490	-319.41	-381.85

Table 6: Comparison of Efficiency of both converters

Input Voltage (Volt)	Input Current (A)	Input Power (Watts)	Efficiency BUCK-BOOST (%)	Efficiency CUK (%)
10	1	10	53.86	74.57
20	2	40	62.35	76.5
30	3	90	63.6666	77.16666
40	4	160	63.325	77.625
50	5	250	64.74	77.72
60	6	360	65	77.85
70	7	490	65.185	77.9285



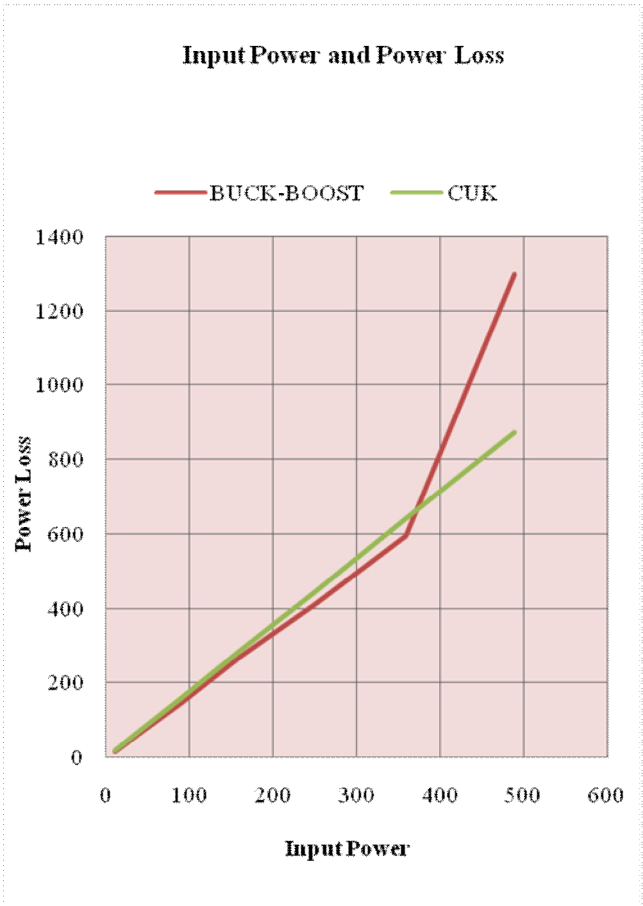


Table 7: Comparison of Power Loss of both converters

Input Voltage (Volt)	Input Current (A)	Input Power (Watts)	Power Loss BUCK-BOOST (Watts)	Power Loss CUK (Watts)
10	1	10	15.386	17.457
20	2	40	64.94	70.6
30	3	90	147.3	159.45
40	4	160	270.92	284.2
50	5	250	411.85	444.3
60	6	360	594	640
70	7	490	1297.8	871.85

Performance analysis of both converters by above parameters with frequency 25KHz, Duty Cycle 0.4 and the source voltage 20 volts. Output voltage, output power, efficiency and power loss parameters are tabulated and their corresponding comparative graphs are plotted. Both converters are working in continuous conduction mode. By comparison it is concluded that Cuk converter has low switching loss making it more efficient.

V CONCLUSION

In this proposed paper DC-DC converters are designed and simulated using MATLAB/Simulink. Performance of Buck-Boost and Cuk converter are discussed and compared. The main objective of this comparison was to find the converter which efficiently converters the solar or any other renewable energy. For efficient energy transfer we are employing two DC-DC converters; Buck-Boost and Cuk converters. From that it is concluded that these converters have its own advantages and disadvantage. While when efficiency parameters is taken in account, CUK converter is chosen as good converter with maximum efficiency as compared to Buck-Boost converter.

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