IMPLEMENTATION OF POWER ELECTRONIC CIRCUITS USING PYTHON

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Abstract: *Simulation has become an integral part of the learning process of Power electronics and electrical drives. Nowadays Power electronics converters are designed by programming languages. Our objective is to simulate and implement Power Electronic converters using Python Power Electronics Simulator. This tool is developed with Python language and libraries, which can be freely distributed. Without going through complicated mathematics and software manuals, students can obtain steady-state waveforms from Python for Power Electronics Simulator.*

1. INTRODUCTION

All Electronic devices are operated some supply voltages which is generally assumed constant. The voltage regulator an electronic circuit that supporting to the constant output voltage. Various types of voltage regulators and many control methods were used to regulate output. In the DC/DC converter, the converter input is unregulated dc, and outputs are regulated dc. Several types of conversion procedures are switched-mode, electronic, magnetic, linear, and capacitive.

Every electronic device is used to change the power from one level to another voltage level is required. DC voltage conversion is extremely important in some applications, starting from lower to higher power applications. The goal of the structure is to highlight and complete the system requirement. There are used to traction motor controllers in electric automobiles. They transport fast dynamic response, smooth acceleration, and more efficiency. The DC converter is also used for regenerative braking of DC motor to the comeback energy into the supply and result save energy in the transport system

DC/DC converter is an electronic device that converts DC power from one level to another level. There are three types of converters, they are boost converter, buck converter, and buck-boost converter.

AC loads require constant or adjustable voltages at their input terminals. When such loads are fed by inverters, the output voltage of inverters must be so controlled as to fulfill the requirements of AC loads. This involves coping with the variation of the DC input voltage, for voltage regulation of the inverters and the constant voltage/frequency requirement. If the input to the inverter is a DC Voltage source, it is referred to as a voltage source inverter (VSI). If the input is a DC source, it is referred to as a Current Source Inverter (CSI). The current source inverter is commonly used for high-power applications. The voltage source inverters are further classified into single-phase and multi-phase inverters.

To ensure the effectiveness of power electronic converters, this project proposes a new simulation method for simulating Power Electronic converters. Converters are studied using Python Power Electronics simulation and hardware is also implemented using Python

2. WORKING OF POWER ELECTRONIC CONVERTERS

2. 1 BUCK CONVERTER

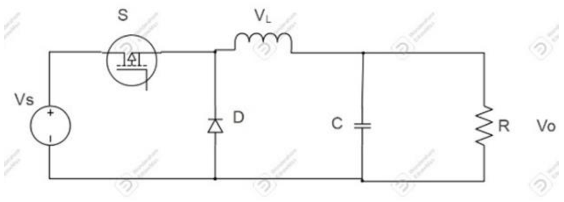

Fig-2.1: Buck Converter

The input voltage source is connected to a controllable solid-state device that operates as a switch. The solid-state device can be a power MOSFET or IGBT. Thyristors are not used generally for DC-DC converters because to turn off a Thyristor is a DC-DC circuit requires another commutation which involves using another Thyristor, whereas Power MOSFET and IGBT can be turned off by simply having the voltage between the GATE and SOURCE terminals of a Power MOSFET, or, the GATE and COLLECTOR terminals of the IGBT go to zero.

The second switch used is a diode. The switch and the diode are connected to a low-pass LC filter which is appropriately designed to reduce the current and voltage ripples. The load is purely resistive.

The input voltage is constant and the current through the load is also constant. The load can be seen as a current source.

The controlled switch is turned on and off by using Pulse Width Modulation (PWM). PWM can be time-based or frequency-based. Frequency-based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage. This leads to a complicated design for the low-pass LC filter which would be required to handle a large range of frequencies.

Mode I: Switch is ON, Diode is OFF

The voltage across the capacitance in a steady state is equal to the output voltage.

The inductor current is continuous and, this is made possible by selecting an appropriate value of L.

The inductor current in a steady-state rises from a value with a positive slope to a maximum value during the ON state and then drops back down to the initial value with a negative slope. Therefore, the net change of the inductor current over anyone's complete cycle is zero.

Mode II: Switch is OFF, Diode is ON

Here, the energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current through the load.

$$\frac{Vo}{Vin} = D$$

2.2 BOOST CONVERTER

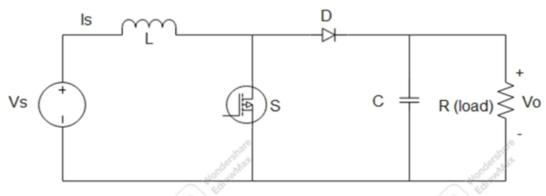

Fig-2.2: Boost Converter

The input voltage source is connected to an inductor. The solid-state device which operates as a switch is connected across the source. The second switch used is a diode. The diode is connected to a capacitor, and the load and the two are connected in parallel.

The inductor connected to the input source leads to a constant input current, and thus the Boost converter is seen as the constant current input source. And the load can be seen as a constant voltage source. The controlled switch is turned on and off by using Pulse Width Modulation (PWM).

PWM can be time-based or frequency-based. Frequency-based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage

Mode I: Switch is ON, Diode is OFF

The Switch is ON and therefore represents a short circuit ideally offering zero resistance to the flow of current so when the switch is ON all the current will flow through the switch and back to the DC input source. Let us say the switch is on for a time TON and is off for a time TOFF.

The inductor current in a steady-state rises from a value with a positive slope to a maximum value during the ON state and then drops back down to the initial value with a negative slope. Therefore, the net change of the inductor current over anyone's complete cycle is zero.

Mode II: Switch is OFF, Diode is ON

In this mode, the polarity of the inductor is reversed. The energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current in the same direction through the load and also step-up the output voltage as the inductor is now also acting as a source in conjunction with the input source.

$$\frac{Vo}{Vin} = \frac{1}{1-D}$$

2.3 SINGLE-PHASE HALF-BRIDGE INVERTER

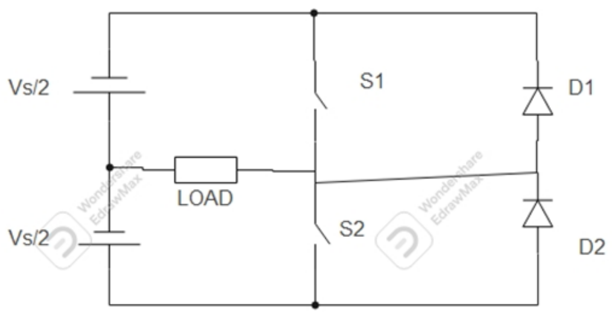

Fig-2.3: Single-Phase Half-Bridge Inverter

In Single-Phase Half-Bridge Inverter, R is the resistive load, Vs/2 is the voltage source, S1 and S2 are the two switches, i0 is the current. Where each switch is connected to diodes D1 and D2 parallelly. In the above figure, the switches S1 and S2 are the self-commutating switches. Switch S1 will conduct when the voltage is positive and the current is negative, switch S2 will conduct when the voltage is negative, and the current is negative. The diode D1 will conduct when the voltage is positive and the current is negative, diode D2 will conduct when the voltage is negative, and the current is positive.

Case 1 (when switch S1 is ON and S2 is OFF): When switch S1 is ON from a time of 0 to T/2, the diode D1 and D2 are in reverse bias condition and the S2 switch is OFF.

Applying KVL (Kirchhoff's Voltage Law)

Vs/2-V0=0

Where output voltage V0= Vs/2

Where output current i0 = V0/R= Vs/2R

In case of supply current or switch current, the current iS1 = i0 = Vs/2R, iS2 = 0 and the diode current iD1 = iD2 = 0.

Case 2 (when switch S2 is ON and S1 is OFF): When switch S2 is ON from a time of T/2 to T, the diode D1 and D2 are in reverse bias condition and the S1 switch is OFF.

Applying KVL (Kirchhoff's Voltage Law)

Vs/2+V0=0

Where output voltage V0= -Vs/2

Where output current i0 = V0/R= -Vs/2R

In case of supply current or switch current, the current iS1 = 0, iS2 = i0 = -Vs/2R and the diode current iD1 = iD2 = 0.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 08 | August - 2022 Impact Factor: 7.185 ISSN: 2582-3930

3. SIMULATION WORK

In our project, we used a new simulation tool called "Python Power Electronics". It is an open-source software where we can use simulate various power electronics converters.

3.1 SIMULATION DIAGRAMS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	wire	Ammeter	wire	Switch_S1	wire	wire	wire	Ammeter	wire	Resistor_L	wire	Inductor_f	wire	wire	wire	wire	wire	wire	wire	wire	
2	wire					wire								wire			wire			wire	
3	wire					wire								wire			wire			wire	
4	wire					wire								wire			wire			wire	
5	wire					Ammeter_diode								Resistor_Cfilter			wire			wire	
6	wire					wire								wire			wire			wire	
7	wire					wire								wire			wire			wire	
8	VoltageSource_input					Diode_d1								Capacitor_filter			Ammeter_load			Voltmeter_output	
9	wire					wire								wire			wire			wire	
10	wire					wire								wire			Resistor_load			wire	
11	wire					wire								wire			wire			wire	
12	wire					wire								Ammeter_capacitor			wire			wire	
13	wire					wire								wire			wire			wire	
14	wire					wire								wire			wire			wire	
15	wire					wire								wire			wire			wire	
16	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	
17																					
18																					

Fig-3.1: Simulation diagram of the Buck converter

The above is an excel sheet diagram of a buck converter which should be uploaded in the python power electronics simulator.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Ammeter	wire	wire	Ammeter	wire	wire	wire	Ammeter	wire	Diode_D1	wire	wire	wire	wire	wire	wire	wire	wire	wire	
2	wire					wire									wire		wire		wire	
3	Inductor_L1					wire									wire		wire		wire	
4	wire					wire									wire		wire		wire	
5	Resistor_R1					wire									Resistor_Cout		Ammeter_load		wire	
6	wire					wire									wire		wire		wire	
7	wire					wire									wire		wire		wire	
8	VoltageSource_Vin					Switch_S1									Capacitor_Cout		Resistor_load		Voltmeter_Vo	
9	wire					wire									wire		wire		wire	
10	wire					wire									wire		wire		wire	
11	wire					wire									Ammeter_Cout		wire		wire	
12	wire					wire									wire		wire		wire	
13	wire					wire									wire		wire		wire	
14	wire					wire									wire		wire		wire	
15	wire					wire									wire		wire		wire	
16	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	
17																				
18																				

Fig-3.2: Simulation diagram of the Boost converter

The above is an excel sheet diagram of a boost converter which should be uploaded in the python power electronics simulator.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire				
2	wire					wire						wire				
3	wire					wire						wire				
4	wire					wire	wire	wire				wire	wire	wire		
5	wire					wire		wire				wire		wire		
6	wire					wire		wire				wire		wire		
7	wire					Switch_S1		Diode_D1				Switch_S3		Diode_D3		
8	wire					wire		wire				wire		wire		
9	VoltageSource_Vin					wire		wire				wire		wire		
10	wire					wire	wire	wire				wire	wire	wire		
11	wire					wire						wire				
12	wire					wire						wire				
13	wire					wire	wire	wire	Jumploadp			wire	wire	wire	Jumploadn	
14	Resistor_R1					wire						wire				
15	wire					wire						wire				
16	wire					wire	wire	wire				wire	wire	wire		
17	wire					wire		wire				wire		wire		
18	wire					wire		wire				wire		wire		
19	wire					Switch_S2		Diode_D2				Switch_S4		Diode_D4		
20	wire					wire		wire				wire		wire		
21	wire					wire		wire				wire		wire		
22	wire					wire	wire	wire				wire	wire	wire		
23	wire					wire						wire				
24	wire					wire						wire				
25	wire					wire						wire				
26	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire	wire				
27																
28																

Fig-3.3: Simulation diagram of single-phase half-bridge Inverter

The above is an excel sheet diagram of a single-phase half-bridge Inverter which should be uploaded in the python power electronics simulator.

3.3 SIMULATION PARAMETERS

Table-3.1: Parameters of Buck Converter

PARAMETERS	VALUES
Capacitor	**0.0005 F**
Inductor	**0.001 H**
Load Resistor	**5Ω**
Voltage Input	**12V**

Table-3.2: Parameters of Boost Converter

PARAMETERS	VALUES
Voltage Source 1	100V
Voltage Source 2	100V
Load Resistor	100Ω

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 08 | August - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Table-3.3: Parameters of Single-Phase Half-Bridge Inverter

PARAMETERS	VALUES
Capacitor	0.0002 F
Inductor	0.001 H
Load Resistor	5Ω
Voltage Input	24V

3.4 SIMULATION RESULTS

3.4.1 BUCK CONVERTER

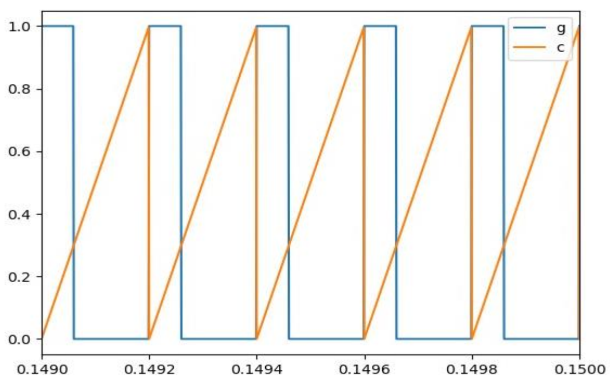

Fig-3.4: PWM Signals

Fig-3.4 represents the PWM Signals which is generated by the controller attached to the buck converter.

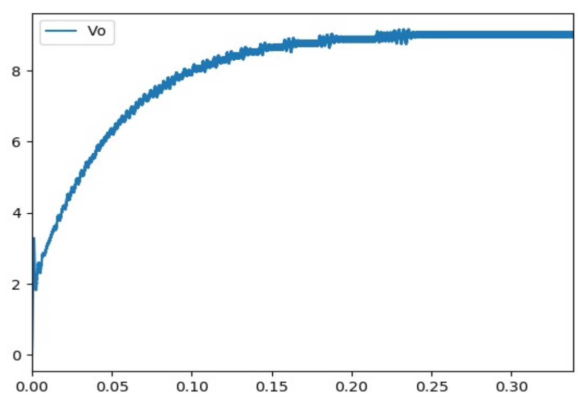

Fig-3.5: Controlled Output Voltage (Closed Loop)

Fig-3.5 represents the controlled output voltage for a closed-loop buck converter which is around 9V.

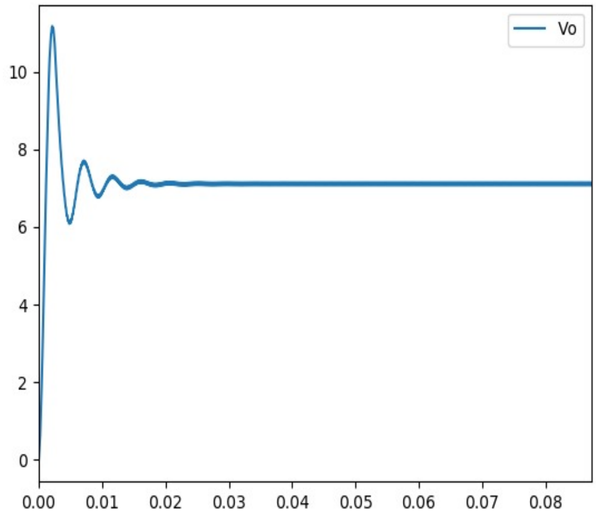

Fig-3.6: Output Voltage (Open Loop)

Fig-3.6 represents the output voltage for an open-loop converter which is around 7V

3.4.2 BOOST CONVERTER

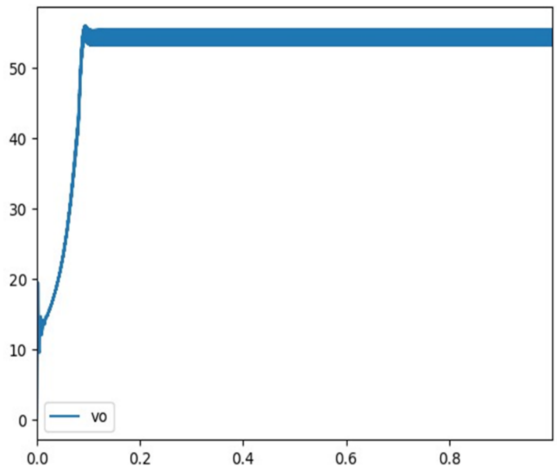

Fig-3.8: Output Voltage

Fig-3.8 represents the output voltage of the boost converter which is around 57V.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 08 | August - 2022 Impact Factor: 7.185 ISSN: 2582-3930

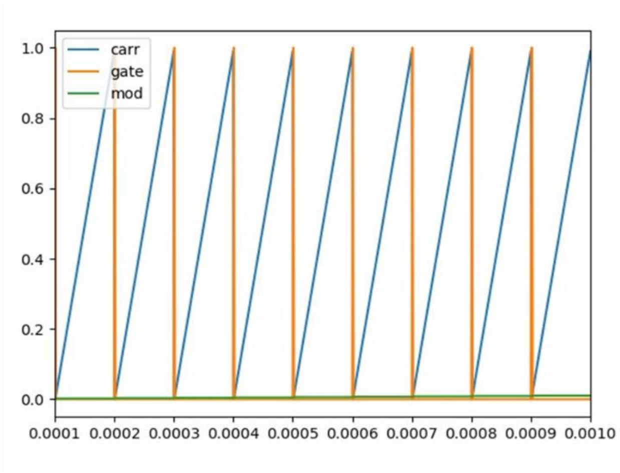

Fig-3.9: PWM Signals

Fig-3.9 represents the PWM Signals which is given to the boost converter from the controller.

3.4.3 SINGLE-PHASE HALF-BRIDGE INVERTER

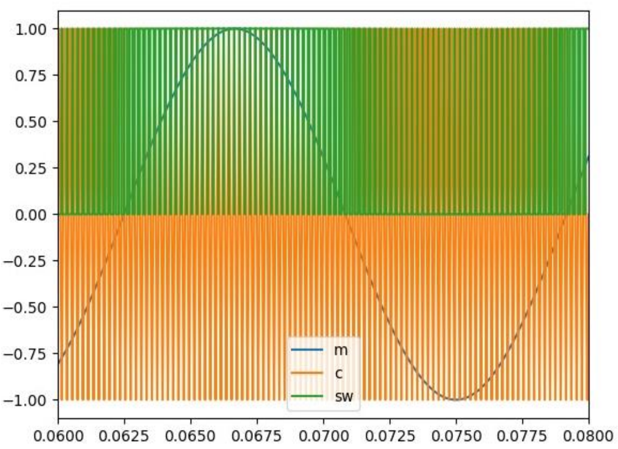

Fig-3.10: PWM Waveform

Fig-3.10 represents the PWM Signals which is given to the single-phase half-bridge converter from the controller.

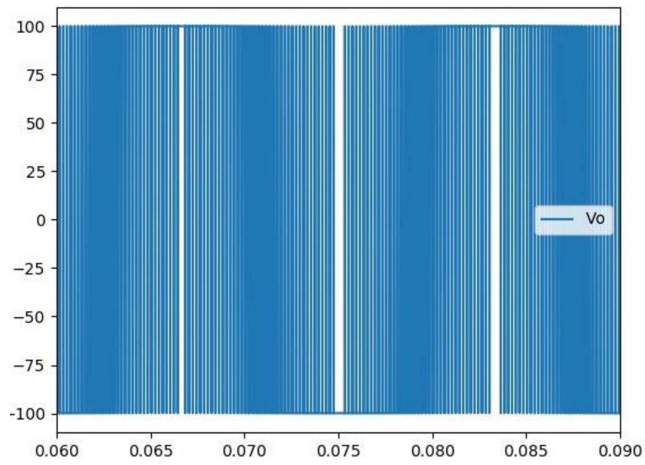

Fig-3.11: Output Voltage

Fig-3.11 represents the output voltage from the single-phase half-bridge converter.

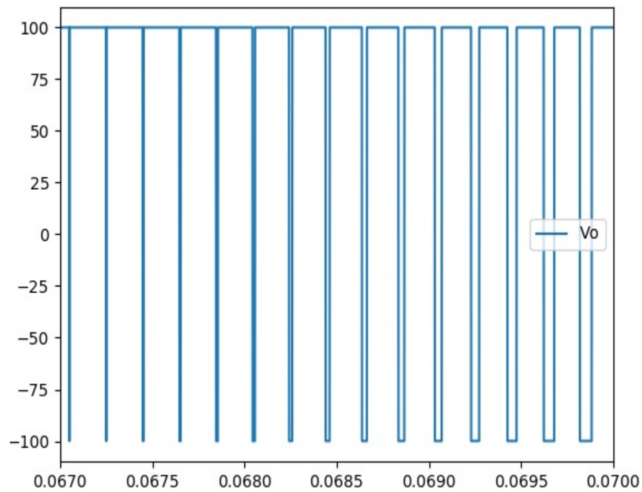

Fig-3.12: Width of signal change in reference with the modulation signal

Fig-3.12 represents the output voltage from the single-phase half-bridge converter with signal change about the modulation signal

4. HARDWARE IMPLEMENTATION

In this project, we are implementing Python code as an input to the Arduino UNO for generating pulse to the controller of a BLDC motor and to drive the BLDC motor using it.

4.1 REQUIRED COMPONENTS

- Arduino UNO
- Brushless DC Motor
- Controller for BLDC motor
- 11.1V Battery
- 10K Resistor Pot

4.2 CIRCUIT DIAGRAM

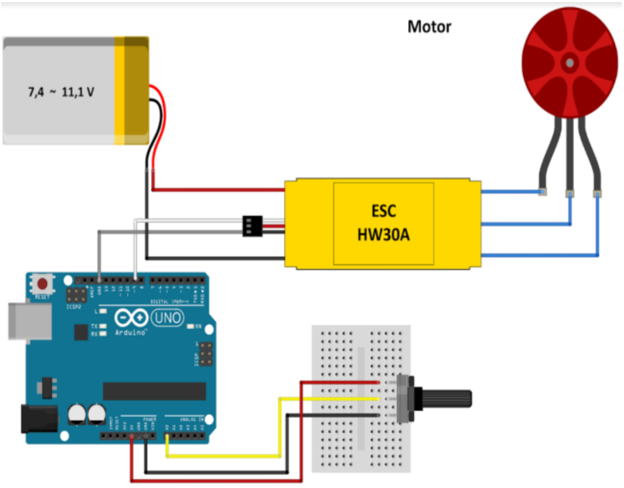

Fig-4.1: Circuit diagram

4.3 WORKING OF THE HARDWARE SYSTEM

The Brushless DC motor is connected to the controller which is supplied by the 11V battery. The pulse of the controller is given to the Arduino UNO pin 9 which has PWM support in it.

Python code is given to the Arduino for pulse generation to the controller. When the code is dumped to the Arduino, it generates the pulse to the controller and the controller drives the motor. The resistor pot is used to vary the speed of the motor.

We are also working on implementing a GUI where the speed of the brushless DC motor can be controlled by the user in the computer.

5. CONCLUSION

In our project, we used a new simulation tool called "Python Power Electronics" and created a buck, boost converter, and single-phase half-bridge inverter using it. We also implemented python in Arduino to generate pulses for Brushless DC motor controller and to drive a brushless DC motor

6. REFERENCES

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