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DIRECT BUCK AC-AC CONVERTER BY USING PID CONTROLLER

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Abstract: Compared with the traditional AC-DC-AC convertors, the direct AC-AC convertors in which the energy-storage component is not equipped can be manufactured smaller and cheaper. The researches on direct AC-AC convertors have been an important field. The DC-modulated method, which was used in DC-DC convertors before, is used in AC-AC convertors to realize a direct AC-AC converting now. The method as regulating the duty of switch periods can control the circuit to output an acceptable sinusoid voltage wave. But this method can always bring forth a small phase shift between input and output. Compared to PWM control method, the PID can gain a smaller response time and a balance between reducing switching loss and improving quality of output.

Index Terms**—**AC-AC converter, Buck, PID, control stragety

I. INTRODUCTION

(A) BASICS OF AC-AC CONVERTERS:

The direct AC-AC convertors have been widespread concern and in-depth research for its quick response, single-stage transformation, and outputting AC voltage without low orders harmonics. Recent years, the development of Smart Grid needs smarter transformers to make the grids more controllable and more efficient. It is likely that future power generation and distribution will involve a lot of distributed renewable energy resources and power grids.

The need for power semiconductor devices with high-voltage, high-frequency, and high-temperature operation capability is growing. The AC-AC convertor can contribute more for the Smart Grid in the future. A direct AC – AC conversion has many attractive features. Most applied converter topologies in industrial electronics-voltage regulators, induction motor drives, wind power conversion systems and other.AC-AC power Converters has many applications such as power regulators, induction motor drives, direct generators and many others.

They are devices, which use a semiconductor switches in a different configuration of connection. These converters are unidirectional or bi-directional power flow compatible in function of used electric configuration, elements and application. In today of power applications high-power MOSFET or IGBT-switches are used, driven by various commutation strategies and modulation techniques.

The main aim is to obtain an high-quality power conversion, minimum losses, high efficiency and low cost.

A different converters topologies are known since 70-th and 80-th years of the last century. Some of them has an thyristor implementation with natural commutation. A today's used elements requires some kind of high performance commutation strategies to comply with the application requirements. In the present AC-AC converters are divided on two basic topologies

(b) BUCK TYPE CONVERTER

The Buck-Type AC-AC convertor. It can support a controlled output AC voltage source which is smaller than the input AC voltage source. The amplification factor K is smaller than 1.

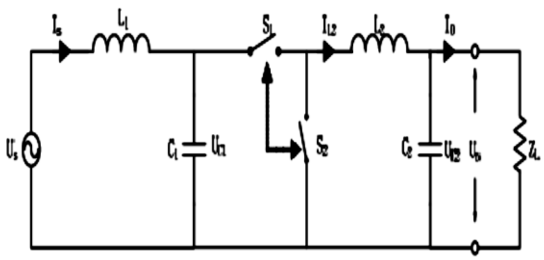


Figure 1. The Buck-Type AC-AC converter

Duty cycle (or duty factor) is a measure of the fraction of the time a radar is transmitting. It is important because it relates to peak and average power in the determination of total energy output. This, in turn, ultimately effects the strength of the reflected signal as well as the required power supply capacity and cooling requirements of the transmitter.

Although there are exceptions, most radio frequency (RF) measurements are either continuous wave (CW) or pulsedRF. CW RF is uninterrupted RF such as from an oscillator. Amplitude modulated (AM), frequency modulated (FM), and phase modulated (PM) RF are considered CW since the RF is continuously present.

The power may vary with time due to modulation, but RF is always present. Pulsed RF, on the other hand, is bursts (pulses) of RF with no RF present between bursts. The most general case of pulsed RF consists of pulses of a fixed pulse width (P W) which come at a fixed time interval, or period, (T).

For clarity and ease of this discussion, it is assumed that all RF pulses in a pulse train have the same amplitude. Pulses at a fixed interval of time arrive at a rate or frequency referred to as the pulse repetition frequency (PRF) of so many pulse per second. Pulse repetition interval (PRI) and PRF are reciprocals of each other.

Power measurements are classified as either peak pulse power, Pp, or average power, Pave. The actual power in pulsed RF occurs during the pulses, but most power measurement methods measure the heating effects of the RF energy to obtain an average value of the power.

It is correct to use either value for reference so long as one or the other is consistently used. Frequently it is necessary to convert from Pp to Pave, or vice versa; therefore the relationship between the two must be understood. Figure shows the comparison between Pp and Pave.

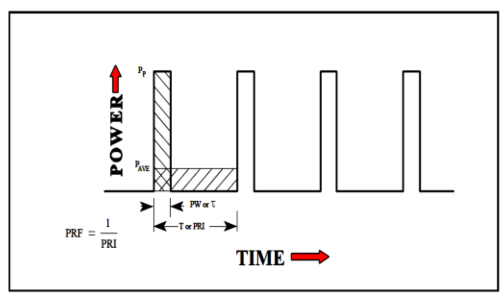


Figure2 .RF Pulse Train

The average value is defined as that level where the pulse area above the average is equal to area below average between pulses. If the pulses are evened off in such a way as to fill in the area between pulses, the level obtained is the average value, as shown in Figure 1 where the shaded area of the pulse is used to fill in the area between pulses.

The area of the pulse is the pulse width multiplied by the peak pulse power. The average area is equal to the average

value of power multiplied by the pulse period. Since the two values are equal:
(note that the symbol J represents pulse width (PW) in most reference books)
The ratio of the average power to the peak pulse power is the duty cycle and represents the percentage of time the power is present. In the case of a square wave the duty cycle is 0.5 (50%) since the pulses are present 1/2 the time, the definition of a square wave. For Figure 1, the pulse width is 1 unit of time and the period is 10 units. In this case the duty cycle is:. Thus a duty cycle of 0.001 is also 0.1%.

The duty cycle can be expressed logarithmically (dB) so it can be added to or subtracted from power measured in dBm/dBW rather than converting to, and using absolute units.
Duty cycle (dB) = 10 log(duty cycle ratio).

II.BUCK CIRCUIT MODEL

State-Space Model

The typical buck circuit is shown in the Figure. The two switches S1 and S2 are both bi-directional switch and the two realizations of bi-directional switch are given in the Figure. In the following simulation the Figure 3 is adopted.

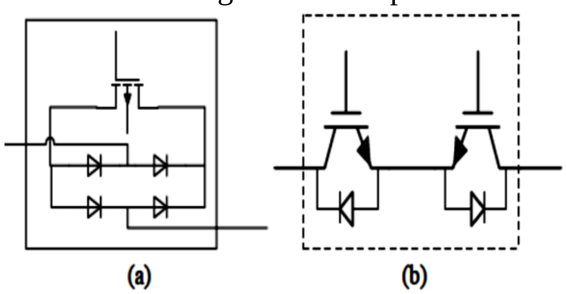


Figure 3. Bi-directional Switch

Since the dead time and the follow current problem for buck circuits have been solved perfectly, The switch S1 and S2 are ideal switches and they close complementarily. When S1 is closed and S2 is opened. The state equation of the buck circuit is equation (1).

$$\frac{dU_{C_1}}{dt} = \frac{1}{c1}(I_{L1} - I_{L2})$$
$$\frac{dU_{C2}}{dt} = \frac{1}{C2}(I_{L2} - I_O)$$
$$\frac{dI_{L1}}{dt} = \frac{1}{L_1}(U_S - U_{C1}) \qquad (1)$$
$$\frac{dL_{L2}}{dt} = \frac{1}{L_2}(U_{C1} - U_{C2})$$
$$U_O = U_{C2}$$

When S1 is opened and S2 is closed. The state equation of the buck circuit is equation (2)

$$\frac{dU_{C1}}{dT} = \frac{1}{C_1} I_{L1}$$
$$\frac{dU_{C2}}{dt} = \frac{1}{C_2}(I_{L2} - I_0)$$
$$\frac{dI_{L1}}{dt} = \frac{1}{L_1}(U_S - U_{C1}) \qquad (2)$$
$$\frac{dI_{L2}}{dt} = \frac{1}{L_2}(-U_{C2})$$
$$U_0 = U_{C2}$$

According to the state-space average method (SSAM), the state-space average model of the buck circuit is equation (3).

$$\frac{\Delta U_{C1}}{T} = \frac{1}{C_1}(I_{L1} - DI_{L2})$$
$$\frac{\Delta U_{C2}}{T} = \frac{1}{C_2}(I_{L2} - I_0) \qquad (3)$$
$$\frac{\Delta I_{L1}}{T} = \frac{1}{L_1}(U_S - U_{C1})$$
$$\frac{\Delta I_{L2}}{T} = \frac{1}{L_2}(DU_{C1} - U_{C2})$$
$$U_0 = U_{C2}$$

In the equation (3), D is the duty of one switch period and T is the switch period. When the L1, L2, C1 and C2 are large enough, the UC1, UC2, IL1, IL2 can be seen as constant or change a little in one switch period. Then the equation(4) can be seen right.

$$I_{L1} - DI_{L2} = 0$$
$$I_{L2} - I_0 = 0$$
$$U_S - U_{C1} = 0 \qquad (4)$$
$$DU_{C1} - U_{C2} = 0$$
$$U_0 = U_{C2}$$

In fact, the equation (4) is just an approximatively correct equation.
Because the switch frequency is much higher than the frequency of AC voltage source (50Hz), it is assumes that the input voltage can be seen as a DC source in several switch periods time.

In the other hand, the parameters of L1, L2, C1 and C2 are must be large enough. So the ripple waves of UC1, UC2, IL1 and IL2 can be small enough to be ignored.

SIMULATION RESULTS

Simulation circuits

(a)constant duty

The traditional control strategies are based on duty controlling. The switch frequency is set and the duty is controlled. In this place, constant duty control and PID control are discussed simply to show the characteristic of traditional control strategies.

A. Constant Duty

Base on the equation (4), when the D is a constant value between 0 to 1, 0<D<1, equation (5) can be gained.

$$\begin{aligned} I_{L2} &= \frac{1}{D} I_{L1} \\ U_{C1} &= U_S \\ I_0 &= I_{L2} \\ U_0 &= U_{C2} = DU_{C1} = DU_S \end{aligned} \qquad (5)$$

This is the most fundamental direct AC-AC converter.

The Figure 4 is shown the model of Simulink.

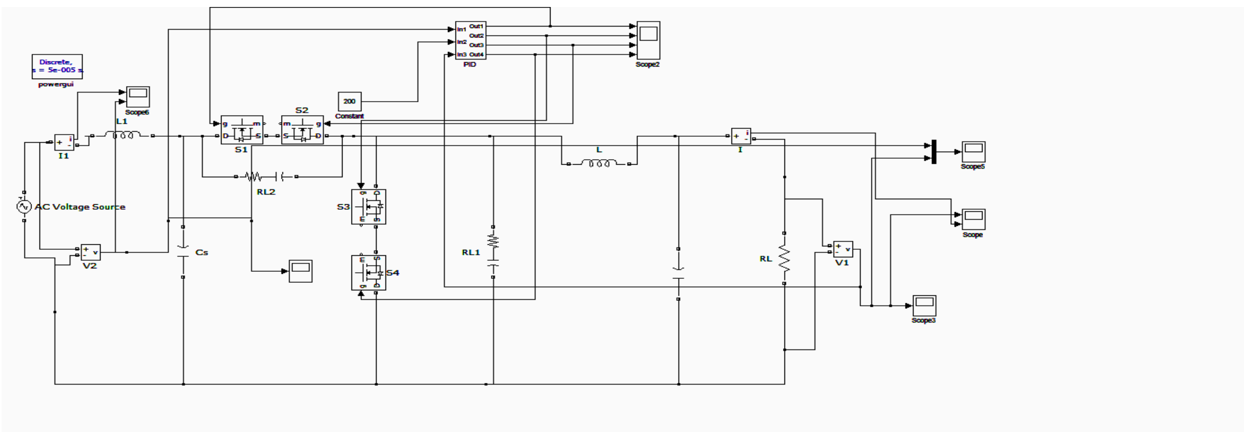
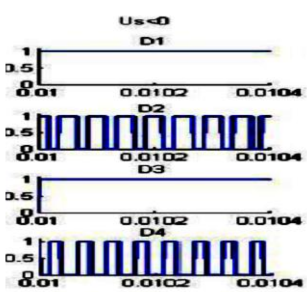


Figure4.The Simulink Circuit about Constant Duty Control Strategy

The control pulse when the US<0, D2 and D4 was closing alternately, D1 and D3 kept closing of D1~D4 is shown in Figure 5.



The Figure 5 is the result of the simulation for constant duty.

According to the equation (5), the relation between US and UO is linear. But from the Figure 5 it is can be seen that there is a phase difference between UO and US.

Because the trace in Fi]gure6 is moved anticlockwise, the phase of UO lagged the phase of US. This phase shift can be explained by equation (1)(2) (3).

In each switch period, the instantaneous value of US can only decided the next switch period value of IL1, so the IL1 changed behind the US. And so on, the UC1 changed behind the IL2 and the UO changed behind the IL2. In another word, the UO needs a response time to follow the changing of US.

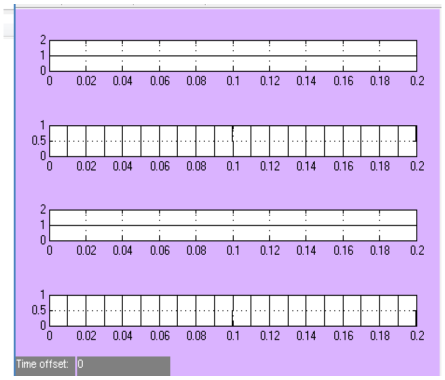


Figure6.The Result of Simulation about Constant Duty

It can be seen from the equation (3) that the duty D and the input US decide the output UO together. Even when the instantaneous value of US is closed to zero the PID controller can hardly reduce the error. So the error between Utarget and UO is divided by the absolute value of US to get a more reasonable error value.

The duty D is comprised of two main parts. One part is the ratio between US and UO, the other part is the output of PID controller with error inputting.

At the same time, when the Duty is a constant value, the amplification factor between US and UO is also a constant value. It means that, when the US is unstable, the UO would be unstable too, just like the simulation results in figure 10.

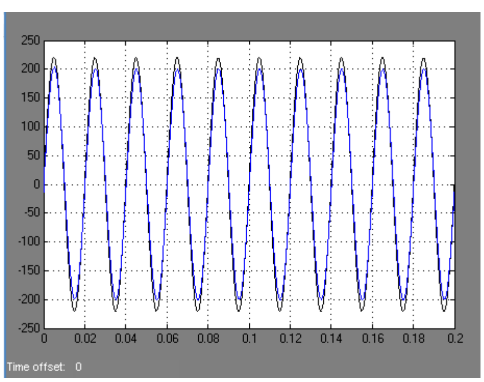


Figure7. The Simulation Results of a Unstable Input US.

From the Figure 10, the input source US contains a 11- order harmonic. This 11-order harmonic can transmit from the input port to the output port directly.

B. PID Control

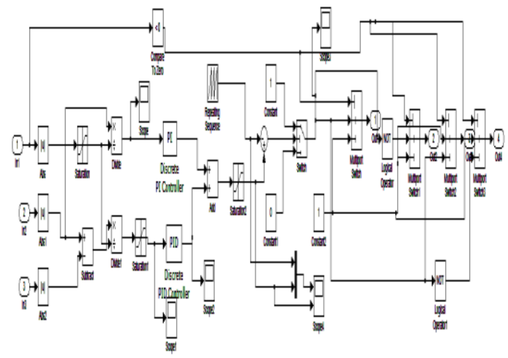


Figure 8. simulink PID Controller

Based on above analysis, the PID converter control the duty D dynamically instead the constant duty to get a better output wave. PI or PID control based on traditional control theory is used to control the D. Since D is no longer a constant, the system][is converted into a time-varying system.] The Figure 11 is the simulation model. The PWM1H is the control pulse of D1, the PWM2H is the control pulse of D2; the PWM1L is the control pulse of D3; the PWM2L is the control pulse of D4.

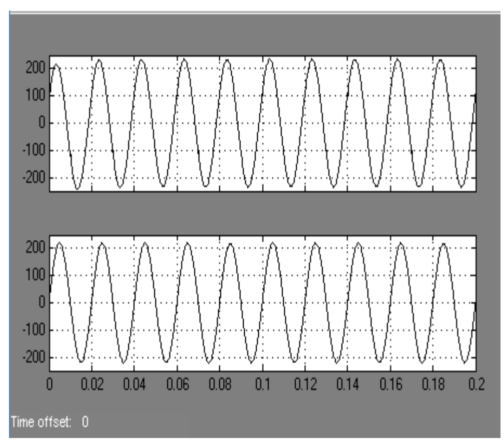


Figure 9.simulink voltages US and UO

V. CONCLUSION

The simulation results of different control strategies based on the Simulink platform for Buck-Type converter . The comparing and analysis of these results shows that the PID controller is more effective and can almost eliminate the phase shift between input and output.

In the other hand, the switch period can be regulated following the error. So a balance between reducing switching loss and improving quality of output and a smaller response time can be gained. At the same time, the PID controller can filter the high order harmonic contained in AC source effectively.

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