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Control Strategy of Three Phase PWM by Three Half Bridge Topology Bidirectional DC/DC Converter and Resonant

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Abstract

This paper analyses and compares PWM control strategy of control and buffer type soft switching half bridge DC/DC converter. Finally, the soft switching condition are analyzed, and this article gets the realization of soft switching conditions of the three half bridge DC/DC converter and the influence factors of soft switching conditions of the three half bridge DC/DC converter. Characteristics of resonant converter can boost and buck, so the output voltage stable strategy of variable frequency control is more easily achieved. The paper presents control strategy of three phase PWM by three half bridge topology bidirectional DC/DC converter and resonant.

Keywords: *converter, resonant, PWM, three half bridge*

1. Introduction

Bidirectional DC/DC converter is that the polarity in the DC voltage to maintain converter at both ends of the circumstances, can be adjusted according to the direction of energy needs, to achieve power DC converter bi-directional flow. Multi port bidirectional DC/DC converter enables multiple power interconnections, the energy transmission between multiple direction multilevel powers [1]. The three half bridge bi-directional DC/DC converter is a kind of three port converter model, the magnetic coupling to different power together, through the phase shifted control simultaneously or separately to the load power supply.

In the speed control system of three-phase AC asynchronous motor, the three-phase asynchronous motor externally with the unified form, so the inverter bridge with the standard six tube structure, soft switching three-phase inverter is easy to form the corresponding to the circuit topology consistency. According to the different auxiliary resonant circuit to realize soft switching topology, soft switching three-phase inverter has two categories: one category is by adding a auxiliary power switching devices, auxiliary resonant inductance and snubbed capacitor formed by the auxiliary resonant circuit in hard switching inverter and a DC power supply, called the inverter resonant DC link.

Switching power supply is the use of modern electronic technology, the control switch transistor turn-on and turn off time ratio, maintain a stable output voltage power supplies, switching power supply from the general pulse width modulation (PWM) control IC and MOSFET. Switching and linear power supply compared, two costs are increasing with the increase in power output, but two different growth rate. Power costs in a linear output power point, rather than switching power supply, the cost of reversal. With the development of power electronics technology and innovation, making switching power supply technology in constant innovation, increasing the cost of reversal point move to the low output power end, this provides a broad development space for the switching power supply.

Half bridge DC/DC converter has the advantages of simple structure, convenient control, very suitable for small and medium power applications. The hard switching converter of high frequency switching losses, seriously affect its efficiency. Soft switching technique can reduce the switching losses and line EMI, improve the efficiency and power density, increasing the switching frequency so as to reduce the converter volume and weight. The traditional half bridge converter has two kinds of control methods, one is symmetrical control, and one is the

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asymmetric complementary control. This paper mainly analyzes the control strategy of PWM to achieve soft switching half bridge DC/DC converter. The paper presents control strategy of three phase PWM by three half bridge topology bidirectional DC/DC converter and resonant.

2. Research on Three Half Bridge Topology Bidirectional DC/DC Converter PWM

Asymmetric complementary pulse PWM control switch of the control pulse asymmetry is complementary; the traditional asymmetrical half bridge converter with this control strategy has been widely used in small and medium power applications. The primary side switches realizing ZVS in 2 ways: ZVS load current and excitation current of ZVS. Its advantages are: two switches can realize ZVS; some can improve the phase shifted full bridge converter ZVS for the lagging arm condition measures can also be used for the asymmetrical half bridge converter; oscillation problem does not exist hard switch; compared with the phase shifted full bridge converter, loop free energy.

Its disadvantages are: voltage stress of the switches and soft switching conditions inconsistent, tube is difficult to achieve soft switching; rectifier voltage stress is not consistent, and the function of duty cycle, some applications of a rectifier voltage is very high, the device is difficult to choose; light load will lose the soft opening the relevant conditions; transformer DC magnetic bias, the heavier load duty ratio is small, bias and more serious; is not suitable application occasion input or wide output voltage.

The main circuit of the isolation of three half bridge DC/DC converter contains two combination of input stage boost half bridge circuit, a three winding high frequency transformer, and an output voltage fed half bridge circuit [2]. The transformer for the equivalent model of the main circuit to replace, and it is the primary side equivalent circuit for reference.

To achieve the output DC voltage U0 regulator, known as the pulse frequency modulation (PFM) switching power supply. Since the switching frequency is not fixed, so the design of output filter circuit is not easy to achieve the optimization. Change TON; change T, pulse duty ratio adjustable voltage mode called PWPF way [3]. In all kinds of switching power supply, more than three kinds of pulse duty ratio control method with application.

Therefore, parallel resonant converter does not exist in light load voltage regulation. The main advantages of parallel resonant converter: can open load operation; due to the inductance filter, filter capacitor to ripple current bear is very small, suitable for low voltage, high output current applications. A significant disadvantage of parallel resonant converter for light load conditions still generates a lot of wattles power. Because of the parallel resonant converter, parallel structure is between load resonant capacitor. This makes even in no-load condition, the input voltage square wave, impedance of series resonant cavity is still small. Even when the output current is zero, no power energy will have certain.

Symmetrical PWM control ZVS half bridge converter is proposed in the literature, a symmetrical PWM control ZVS half bridge converter, as compared with the conventional half bridge circuit, ZVS converter symmetrical PWM control increased composed of an auxiliary switch and a diode branch. The main switch is not only in the symmetric state, and the tube and the auxiliary switch can be in the full load range is ZVS; the tube can also be implemented ZVS wide load range, the additional loss caused by very small. The converter device is the stress of small, high reliability, which is more suitable for the MOSFET switch, less used in high voltage, high power applications. As shown in Figure 1, the asymmetrical half bridge converter analysis of resonant mode PQRDCL circuit as an example, a single chopping mode, considering the control process of winding of Lph1: V2 opened in PWM, V1.

The saturated push-pull converter, switch tube VT1, VT2 must choose the larger ICM. Because when the magnetic flux to saturation, pulse transformer equivalent inductance also began to decrease, the magnetic flux completely saturated inductance is zero, the switch tube collector current surge.

Symmetrical PWM control ZCS half bridge converter, on the side of traditional asymmetrical half bridge circuit transformer adds an auxiliary switch, a resonant capacitor and a resonance inductor in series auxiliary branch. The main switch is not only in the symmetric state, and the converter can realize ZVS. and symmetrical half bridge ZCS of all switches and diodes in the whole load range, the auxiliary switch in each half cycle break over time, resonant with resonant capacitance and the leakage inductance of the transformer for full load range all

the switches ZCS ZVS and all the diodes to create the conditions, overloading is difficult to achieve soft switching.

The work principle of the three half bridge bidirectional DC/DC converters in the positive direction mode, and the commutation process and single input ZVS double bidirectional DC/DC converter is similar. Switch the device off, which will be in the current transfer to the clamping capacitor corresponding with the leakage inductance of the transformer resonance, charge and discharge and the switch tube is connected with the two on the same bridge arm of the clamping capacitor voltage respectively, linear rise and fall, in order to achieve zero voltage switching off. Realization of zero voltage switch, the switch has been applied is positive driving signal tube opened in anti parallel diode conduction.

Switch V1 to the right of the dashed box V6, diode VD1 ~ VD6 to form a control circuit asymmetry half bridge SRM phase windings, each phase switch is connected in parallel with a buffer capacitor from C1 to C6. Each phase switch parallel capacitance, mutation for capacitor voltage can not, so they at any time off are zero voltage soft switching. Insert the PQRDCL circuit is designed for the phase switch opening provides zero voltage gap, the requirements of the circuit is must ensure that the circuit can be controlled resonant at any time, and is not influenced by the phase switch status effects, the bus voltage zero crossing time is easy to control, convenient control strategy with phase switch synchronization.

Switch power supply is composed of the following four basic links, which are power converter with DC/DC converter, is the core of the switching power supply; the driver is part of switch signal amplification, shaping and amplifying, the switch signals from the signal source, in order to adapt to the switch tube driving requirements; signal source generates control signals, generated by it. Or self excitation circuit, can be a PWM signal, and can also be PFM or other signals; a comparison amplifier for a given signal and the output feedback signal comparison operation, amplitude, control switch signal frequency, waveform, the driver to control the duty ratio of the power devices, to stabilize the output voltage value of the objective. In addition, switching power supply and auxiliary circuit, including starting circuit, over current and over voltage protection, input filter, output sampling, function instructions.

The above analysis and comparison of the series resonant converter, parallel resonant converter and the basic principle of series parallel resonant converter, so they are not suitable for operation in the condition of wide voltage range input. High input voltage corresponding to a high working frequency will bring the conduction and switching loss is very high. In order to obtain the converter more efficient, need to find the right topology. LLC resonant converter is suitable to work over a wide input voltage range soft switching topology. In fact it has been around for a long time, but due to its characteristics of misunderstanding, refer to the series resonant converter [4]. In recent years, people found that it also has superior characteristics of some traditional resonant converter does not have, such as a wide range of input voltage, the frequency adjustment range of small, simple topology, easy to implement integrated magnetic, as is shown by Equation (1).

$$Z_i = \frac{\left(Z_B + n^2 Z_L\right)^2}{2(Z_B + n^2 Z_L)} = \frac{Z_B + n^2 Z_L}{2} \tag{1}$$

Where Z_i and Z_B are Symmetrical PWM control ZCS half bridge converter, n is the side of traditional asymmetrical half bridge circuit transformer adds an auxiliary switch, a resonant capacitor and a resonance inductor in series auxiliary branch. The main switch is not only in the symmetric state, and the converter can realize ZVS. and symmetrical half bridge ZCS of all switches and diodes in the whole load range, the auxiliary switch in each half cycle break over time, resonant with resonant capacitance and the leakage inductance of the transformer for full load range all the switches ZCS ZVS and all the diodes to create the conditions, overloading is difficult to achieve soft switching.

In the forward (Boost) mode, a complete switch cycle according to the condition of different can be divided into t0 to T19 a total of 19 intervals. The steady state corresponding here before assuming T1 time to switch S1 is switched on, the switch tube S5 and the S3 anti parallel diode D5, D3 by forward bias and conduction.

A series of principle of switching is power supply box. Power switch transistor VT is connected in series between the input and output. When in normal work, power switching

transistor VT control pulse is periodically pass, by alternating between in the guide drive in the switch between input and output, so that the closed cycle and disconnected. DC input voltage instability of the power switching transistor VT output for the periodic pulse voltage, and then after filtering, can be smooth DC output voltage U0. Pulse U0 and power switching transistor VT is related to space than D.

In the common switch circuit, the switch SRM the signal of rotor position is controlled by the lower frequency, the public switch Vc controlled by the PWM signal of high frequency. Because the burden of the public switch is heavy, in order to reduce the burden of public switch, to avoid the motor winding stream continued through the public switch, Vc control signal the final by each phase switch control signal and the PWM signal according to the initial speed required to produce CO generation. This ensures that only the phase switch public switch can be conducted during the period, so the public switch topology of each phase winding only two continued flow path [5].

$$\dot{u} = \frac{\dot{u}_B}{R + R_i + n_2^2 Z_i} \times n_2^2 Z_i \tag{2}$$

In the Equation (2) where u is PWM signal of high frequency, R is traditional half bridge resonant converter; n_B is composed of two parts of the inverter and the rectifier. The series and parallel resonant circuit mainly contains only the inverter resonant converter part. The rectifier part half bridge resonant converter is usually full wave rectifier; a secondary center tap full wave rectifier structure is widely used in the topology with isolated transformer.

Half bridge circuit is defined as two switches off the bridge circuit, half bridge converter circuit. Streamlined bridge circuit phase winding freewheeling path, only two switches per phase winding on simultaneous conduction to winding power supply, so that each arm switch respectively and the two one arm (or switch with each arm switch are respectively matched with the two arm switch) control of two phase winding, can achieve time division multiplexing each switch, the switch to halve the number. But each of the two switch control method of one phase winding control mode and asymmetrical half bridge topology is same, commutation process and the chopping process continued flow rules similar to it.

The control strategy of the half bridge also known as dual active bridge [6]. The control strategy and the traditional phase-shift full bridge topology similar, difference is phase two bridge arms on each side of the distribution transformer. This topology, the leakage inductance of the transformer is the intermediate energy storage element. Each side of the half bridge generates a 50% duty cycle Fang Bo, to control the transformer leakage inductance energy by phase shift between the two bridge output regulations to regulate the output voltage. Soft switching full load range of this topology can be output at the same time, but also can obtain the synchronous rectifier. Its disadvantages are: energy is very large, large output current ripple.

The three half bridge DC/DC converter in Boost and Buck two kinds of mode of operation, low side and high side switch voltage and current waveforms. In Boost mode, the low side switch tube S5 as an example, in the S5 off, leakage current Ir56 reaches the maximum value and greater than that of Idc2, Ids5<0, S5 anti parallel diode conduction, S5 off when Vds5=0, realizes zero voltage switching. In the S5 before conducting, reverse Ids5 less than 0, the anti parallel diode freewheeling switch tube, and in the t time, Ids5 from diode commutation to switch S5, realizes zero voltage turn-on of the S5. Similarly, in the Boost and Buck two kinds of work mode, the low side switches tube S1, S2, S5, S6 and high side switch tube S3; S4 can achieve zero voltage turn-on and turn off (ZVS).

According to the winding current control PWM duty cycle, the combination of 6 student success rate converter required driving signal, controls the power switching; resonant temporal logic and driving module according to the driving signal from the phase switch signal generating circuit of PQRDCL control logic and the driver module required for the resonant circuit, control action.

From a low voltage DC conversion high voltage AC must boost scheme design. In the power supply design after considering various boost scheme from different angles. The different position by the boost, mainly considering the pre boost and post boost two methods. The so-called pre boost, that will boost in before the first inverter, 12V low voltage DC input for DC-DC conversion, to the required high DC voltage, the high voltage DC as the subsequent inverter

circuit, the high voltage DC inverter, direct voltage sinusoidal alternating current needed by filtering wave. The so-called post boost, that will boost after inverter, filter, such that 12V low voltage DC power of thermoelectric generator input of inverter, filter, get the low voltage AC, then AC boost signals on the desired AC output.

3. Half Bridge Resonant Converter and Quasi Parallel Resonant with Switching Power Supply

In this paper, the auxiliary resonant circuit in the inverter bridge output hard switching inverter terminal, called the resonant pole inverter. But in the switched reluctance motor speed regulating system, because the types and forms of a variety of SRM diversity, power converter corresponding is all kinds of, so, in view of universality, extremely similar resonant inverter that is inserted into the auxiliary resonant network between the converter and the motor is undesirable [7]. Further studies showed that, in various forms of SRD power circuit.

TL494 is a fixed frequency pulse width modulation circuit, built-in linear saw tooth oscillator, the oscillation frequency can be adjusted by an external resistance and a capacitor, the output pulse width is through positive saw tooth voltage capacitance on the CT and the other two control signals are compared to achieve. Power output tube Q1 and Q2 is controlled by gate.

When the input voltage is low, and it is the converter frequency nears the resonance frequency. When the input voltage is increased, in order to keep the output voltage constant, converter working frequency to stay away from the resonance frequency is increased in the direction of. But the impedance resonator is also accompanied by an increase in operating frequency increases. This means more energy to non power stored in the resonator, and not delivered to the converter output. Here mentioned no power energy can be defined switch back to that part of the energy input power cycle for each. Each switch cycle feedback more energy to the input end of the switching device, power transmission in the total amount is larger, can cause higher conduction loss.

Therefore, when the input voltage range is large, high input voltage corresponding to low efficiency. The main advantages of series resonant converter for: the use of series capacitor, isolation of the DC component, avoiding the transformer saturation; current through the switching devices and decreases with the decrease of load current, so in the whole load range can get the win.

At the same time can make the UCr ≥ Ud to complete the resonant charging for Cr. Visible, the size of I1 is closely related with the motor winding current, load current requirement of the I1 value should be greater than the phase switching transient value and set aside to charge capacitor Cr margin, but I1 is the lead switching auxiliary resonant circuit conduction loss increase, but also makes the Lr capacity and loss increase, in Lr. The case will make the Δ T1 increases, the highest frequency of direct expense. Therefore, the size of the I1 needs to consider the frequency of main switching device, the motor capacity requirements (current) and resonant circuit efficiency factors. In order to simplify the control, I1 can take a value greater than the current maximum value, to be resonant after the completion of the excess energy feedback power and transmitted to the motor windings.

The DC/DC converter has a variety of circuit, wherein the control waveform is a square wave PWM converter and working form resonant converter using quasi sine wave is more common. Compared with linear power supply, transient transformation input more performance in the output, improve the switching frequency at the same time, because of the frequency characteristic of feedback amplifier is improved, the transient switching power supply response index can also be improved. Determining the characteristics of the transient response is load transformation mainly by the output LC filter. So can improve the switching frequency, reduce the output LC filter to improve the transient response characteristics.

Although called parallel resonant converter, the resonant cavity is still connected in series, but the relationship between parallel load resonant capacitor. More precisely for parallel load series are resonant converter output [8]. Due to the topology of the primary side of the transformer is connected in parallel with a capacitor, transformer secondary to an increase in the output inductor, so as to achieve the impedance matching.

Forward circuit principle diagram as shown in Figure 3, the working process of the electric circuit are as follows: the VT switch is opened, the voltage transformer winding N1 at

ends of the positive and negative voltage N2, winding and coupling is positive and negative. Therefore, V1 is in on state, off state current V2, inductance L increase gradually; VT off, the inductance L flow continued through the V2, V1 off. VT off exciting current of a transformer with N3 winding and V3 flows back to power. Figure 3 is in the mode of GS domain computing model of PQRDCL circuit.

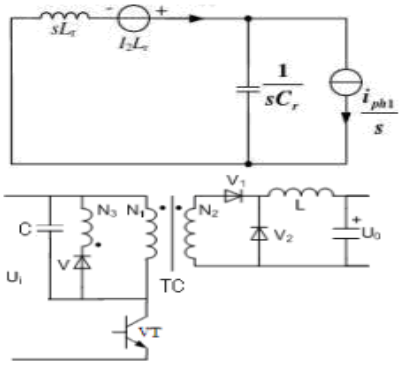

Figure 3. Forward Circuit Principle and PQRDCL Circuit Diagram

Half bridge resonant converter topology is a series parallel resonant cavity structure, which consists of three resonant elements, the intrinsic resonance frequency (i.e. DC gain is the biggest change along with the change of load point) [9]. Therefore, when the load is increased from zero to infinity in the process (i.e. the full load range), LLC exigent resonant frequency of two boundaries: first, when the load is zero, secondary short circuit equivalent transformer, the characteristic frequency resonant capacitor Cr resonant inductance L_r series resonant cavity for the maximum LLC eigen resonant frequency second, the; when the load is infinite, equivalent transformer secondary open circuit, resonant capacitor Cr and the inductor (Lr + Lm) characteristic frequency series resonant to its minimum value. Experiments show that when the half bridge switching frequency in the near resonant frequency change, will show some characteristics of very attractive.

Converter primary by three element voltage fed series parallel resonant structure, secondary adopts the center tap of the full wave rectifier topology, with full load range of zero voltage switching characteristics. It has a DC voltage gain characteristics better, improve the traditional series resonant converter input voltage range is narrow, wide frequency range, disadvantages of light load adjustment characteristics etc. Compared with the traditional parallel resonant converter, which element is fewer, light load efficiency is higher, is a kind of soft switching resonant converter topology is simple and practical.

4. Control Strategy of Three Phase PWM by Three Half Bridge Topology Bidirectional DC/DC Converter and Resonant

The work principle of the three half bridge bidirectional DC/DC converter in the forward mode and commutation process and single input dual ZVS half bridge DC/DC converter is similar, but the soft switching condition and the influencing factors of soft switching and single input dual ZVS half bridge DC/DC converter. Therefore, the condition of soft switching of three half bridge bi-directional DC/DC converters is very meaningful.

Output power output power main switch for power supply is an auxiliary power supply, power line output stage two times bigger. It will be a DC input voltage 220V AC input directly rectifying, filtering is about 300V, after the switch to adjust the switching regulator to adjust the link in the pipe, the switch transformer, voltage regulator control circuit, pulse generating circuit for DC voltage of about 300V to DC-DC converter, the DC voltage stable output various required. Main switch for power supply mainly provides DC voltage 110 ~ 145V load circuit. Remote control standby function is realized by controlling the main switch power supply, the main power switch once to stop working; the corresponding power amplifier stage will also stop working, so the main load lost DC power supply [10].

The series parallel resonant converter resonant cavity can be regarded as a complex series resonant cavity and parallel resonant cavity. Similar and parallel resonant converter and it is in order to impedance matching, a need to increase the output filter inductor. Series parallel resonant converter has the advantages of series resonant converter and parallel resonant converter. Compared with the parallel resonant converter, increased by the Lr and Cs series resonant cavity in series with the load current loop, effectively limits the reactive energy generation; compared with the series resonant converter, the parallel capacitance Cp, and makes the series parallel resonant converter in the no-load condition can well realize the adjustment of output voltage.

According to the definition of control type soft switching half bridge DC/DC converter, and summarizes the variety of control type soft switching half bridge DC/DC converter PWM control strategy and the snubbed type soft switching half bridge DC/DC converter symmetric PWM control strategy. The control strategy of PWM are analyzed and compared, which provides the basis for choosing the specific applications.

Through the analysis of the work in the Boost and Buck two kinds of mode of operation principle of the three half bridge DC/DC converter, the realization of soft switching conditions of the three half bridge DC/DC converter, and the soft switching condition are analyzed, the influence factors of soft switching conditions of the three half bridge DC/DC converter.

Saturation type converter is the output of the pulse transformer magnetic saturation phenomenon that the switch tube by guide is changed into the globe, so that two switch push-pull tube wheel circulation/off. Pulse transformer for converting the output power, cross-sectional area of core become larger, and to achieve greater flux required for saturation of the magnetization current, the switching loss. So in the design of saturation type transformer, try to choose pipe working state switch at the start of the magnetization curve of pulse transformer into the saturated state at the beginning of, first of all let into the saturated zone switch, the switch circuit to reduce the switch flips, large current transformer magnetic saturation in later growth, reduce the switching loss. But both the design and debugging, to maintain the close relationship is very difficult. So this kind of transformation is often used double transformer circuit form.

The main disadvantage of series resonant converter for light load conditions the output voltage can not adjust the main drawback: parallel resonant converter for light load conditions the converter resonant current is still large, resulting in light load efficiency. While the use of three resonant components resonant cavity of the series parallel resonant converter, showed more excellent than LC resonant cavity.

The traditional LC series or parallel two element resonator topology has its defects, so on this basis derived from the LLC type three element cavity of the series parallel resonant converter topology. Its main feature is the converter resonant frequency will change with the change of load, but also can achieve zero voltage switching over a wide frequency range.

Properties can boost type LLC half bridge resonant converter and buck, so the output voltage stable strategy of variable frequency control is more easily achieved. The three element series parallel resonant topology and the two element series resonant topology is similar, but with a voltage adjustment range wide, soft switching characteristics is better.

5. Conclusion

The paper presents control strategy of three phase PWM by three half bridge topology bidirectional DC/DC converter and resonant. Buffer type soft switching control strategy of PWM is symmetry control half bridge converter core bidirectional magnetization, utilization rate is high, and there is no bias. Convenient controls can linear control characteristic. Power tube voltage stress is low, suitable for high input voltage applications, but the half bridge converter is difficult to achieve soft switching; it is difficult to improve the efficiency of the converter. The three half bridge DC/DC converter, an input circuit soft switching conditions are affected by the control variable of another in the input stage, according to the mutual influence between the two input level converter circuit control variables, reasonable selection of phase shift value.

Self-excited switching power supply using a switching transistor and high frequency pulse transformer in power supply circuit form a positive feedback loop, and it is to complete the self-excited oscillation, the switching power supply output DC voltage. In the display of PWM switching power supply equipment, self-excited oscillation frequency synchronization in

frequency pulse, even if the failure of line scanning circuit, power supply circuit can still maintain self-excited oscillation and the DC output voltage. The fly back switching power supply, the switch mode power supply must have an oscillator; the switch pulse to control the switch tube is used to, switching power supply, the output DC voltage.

Because the voltage characteristics of LLC half bridge resonant converter can boost and buck, and it is compared with the series resonant converter which can withstand a wide input voltage range and the smaller the frequency adjustment range. Experiments show that the frequency is near the highest converter efficiency. So will usually be rated input converter working frequency voltage conditions set in the vicinity of the resonant frequency of FR, and it is to achieve high efficiency.

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