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DESIGN OF A THREE LEGS AND PHASE SHIFT AC TO DC CONVERTER FOR TAIWAN PHOTON LIGHT SOURCE

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Abstract

A novel low voltage, high current AC/DC converter will be introduced. According to the required specification, the power converter which input is utility power supplies a low voltage DC output to load. The control strategy is fulfilled by a digital signal processor TMS32F28035 which is manufactured by Texas Instrument. By applying the phase shift control method, this novel low voltage, high current AC/DC converter has been realized. The new three legs phase shift DC / DC low voltage high current power supply [1~4], can divided to five parts: diode full bridge rectifier, three legs phase shift control circuits, transformers, double inductor circuit and feedback circuit. Circuit operates as a single-phase 110 Vrms AC mains power input three legs phase shift control mode from the diode bridge rectifier circuit, the output voltage through the transformer and the phase shift control method converts to low voltage DC 12V output and supplies to pure resistor loading, feedback circuit are using a feedback resistor across the filter capacitor voltage to product a feedback signal. Digital signal processing (DSP) control board by a feedback voltage determines the three legs phase shift displacement in order to control the output voltage keep a constant value 12V. For this circuit have a zero voltage switching characteristics of the three legs phase shift mode power supply, the input voltage for single phase 110Vac and output load power is 12V/20A.

Keyword: DSP, three legs phase shift control

INTRODUCTION

The production of three-legs phase shift power supply, three-legs phase shift structure consists of six switches and two transformers made. Phase shift controller will process signals transmitted to the switching elements to achieve zero voltage switching function (zero-voltage-switching). Use TMS32F28035 as a control circuit, which contains a set of single-chip ADC (Analog to Digital Converter), the control circuit is composed of 3 parts PWM (Pulse Width Modulation) and six power switches. 3 sets of PWM signals, PWMXH with PWMXL signals complementary program has Phase Shift function and phase shift angle limiting function, and a disturbance observation controller closed loop control loop. The circuit uses a full-bridge phase-shift control methods (Full Bridge Phase Shift) and the same conduction legs switches signal will be complementary. In order to make the output PWM signal at phase shift interval (27% to 47%), adding a group to determine the phase shift angle limits, to prevent interference caused dramatic changes in the phase shift angle, causing the circuit to produce damage. Design a PI controller (Proportional Integrate controller), thus the steady-state error correction by PI controller to increase the reliability and stability of the system.

THREE LEGS AND PHASE SHIFT AC TO DC CONVERTER

The main structure of the circuit, AC input stage by a diode bridge rectifier and a regulator capacitor to send energy to a three-legs phase full-bridge circuit, this three-legs phase shift circuit consists of two groups of six switches and transformers components. Energy flows through the three-legs phase shift full bridge circuit, measured by the secondary transformer and current doubler circuit (current doubler) circuit output to the filter capacitor, the use of inductive charging and discharging characteristics staggered to reduce the peak output voltage. Divider resistor voltage divider output, its value through LM324N control input to a digital signal (DSP) board, feedback voltage will determine the value of three-legs phase shift circuit, in order to achieve stability in the output voltage DC 12 Voltage. Table 1 has shown three legs and phase shift AC to DC converter specification.

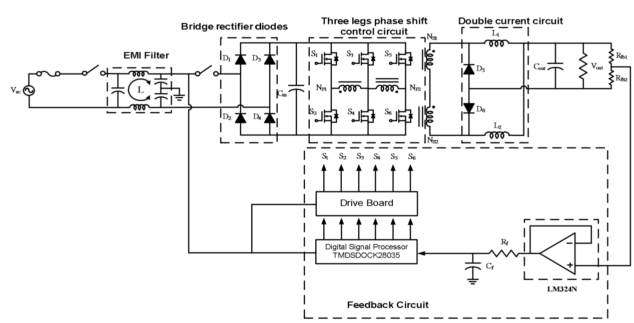

Figure 1: Three legs and phase shift AC to DC converter circuit.

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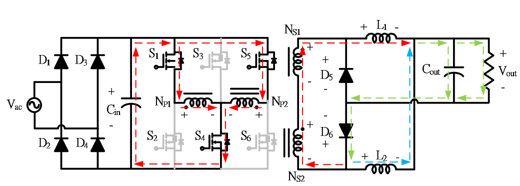
PRINCIPLES OF OPERATION

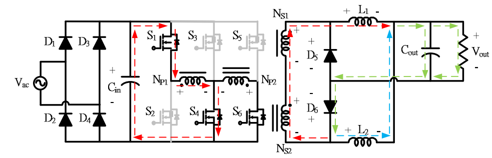
The circuit operation is divided into six operating stages. Fig. 2 (a) ~ (f) has shown stage1~stage6 operation mode of three legs and phase shift AC to DC converter. State1 [t_1~t_2, Fig. 2 (a)]: switch S_1, S_4 and S_5 turn on, transformer stress voltage V_{Tx1} and V_{Tx2} =$V_{cin.}$ V_{Tx1}+V_{Tx2}=2nV_{cin}, V_{D5}=2nV_{cin},V_{D6}=0. Inductor L_1 charge energy and L_2 discharge energy, voltage L_1 and L_2 are $V_{L1} = 2nV_{c_{in}} - V_{out}$ and $V_{L2} = -V_{out}$. State2 [t_2~t_3, Fig.2 (b)]: switch S_1, S_4 and S_6 turn on, transformer stress voltage V_{Tx1}=V_{cin}; V_{Tx2} =0; V_{Tx1}+V_{Tx2}=nV_{cin}, V_{D5}=nV_{cin},V_{D6}=0. Inductor L_1 charge energy and L_2 discharge energy, voltage L_1 and L_2 are $V_{L1} = nV_{c_{in}} - V_{out}$ and $V_{L2} = -V_{out}$. State3 [t_3~t_4, Fig.2 (c)]: switch S_1, S_3 and S_6 turn on, transformer stress voltage V_{Tx1}=0, V_{Tx2}=-V_{cin}, V_{Tx1}+V_{Tx2} =-nV_{cin}, V_{D5}=0,V_{D6}= nV_{cin}. Inductor L_1 discharge energy and L_2 charge energy, voltage L_1 and L_2 are $V_{L1} = -V_{out}$ and $V_{L2} = nV_{c_{in}} - V_{out}$. State4 [$t_4$~$t_5$, Fig.2 (d)]: switch S_2, S_3 and S_6 turn on, transformer stress voltage voltage V_{Tx1}=-V_{cin}, V_{Tx2} =-V_{cin}, V_{Tx1}+V_{Tx2} =-2nV_{cin}, V_{D5}=0, V_{D6} =2nV_{cin}. Inductor L_1 discharge energy and L_2 charge energy, voltage L_1 and L_2 are $V_{L1} = -V_{out}$ and $V_{L2} = 2nV_{c_{in}} - V_{out}$. State5 [$t_5$~$t_6$, Fig. 2 (e)]: switch S_2, S_3 and S_5 turn on, transformer stress voltage voltage V_{Tx1}=-$V_{cin,}$ V_{Tx2}=0, V_{Tx1}+V_{Tx2}=-nV_{cin}, V_{D5}=0, V_{D6} =nV_{cin}. Inductor L_1 discharge energy and L_2 charge energy, voltage L_1 and L_2 are $V_{L1} = -V_{out}$ and $V_{L2} = nV_{c_{in}} - V_{out}$. State6 [$t_6$~$t_7$, Fig.2 (f)]: switch S_2, S_4 and S_5 turn on, transformer stress voltage voltage V_{Tx1}=0, V_{Tx2}=$V_{cin,}$ V_{Tx1}+V_{Tx2}=nV_{cin}, V_{D5}=n$V_{cin,}$ V_{D6}=0. Inductor L_1 charge energy and L_2 discharge energy, voltage L_1 and L_2 are $V_{L1} = nV_{c_{in}} - V_{out}$ and $V_{L2} = -V_{out}$. According to system analysis of six operations mode in the proposed base on volt-second balance can show the relationship by $V_{out} = 2n\phi V_{c_{in}}$, Phase shift can be used to change the voltage value that phase shift angle will increase the voltage to rise.

Table 1: Specification of Three Legs and Phase Shift AC to DC Converter

V_{out}	12 V
P_{out}	240 W
I_{Full}	20 A
I_{BCM}	8 A
v_{ac}	110 V_{rms} @ 60 Hz
f_s	100 kHz
n(=N_S/N_P)	0.129



(a)



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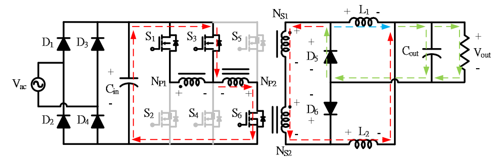

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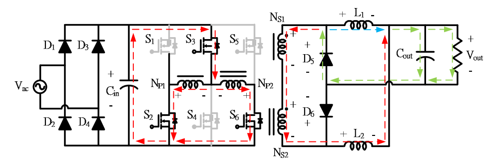

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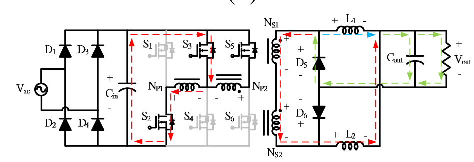
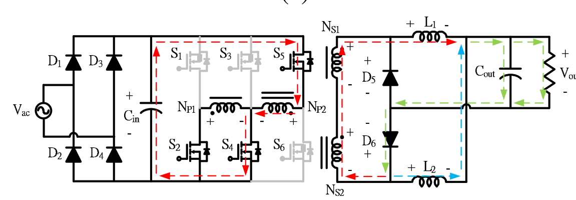


(e)



(f)

Figure 2: Operation mode of the proposed converter (a) mode 1 [t_1~t_2], (b) mode 2 [t_2~t_3], (c) mode 3 [t_3~t_4], (d) mode 4 [t_4~t_5], (e) mode 5 [t_5~t_6], (f) mode 6 [t_6~t_7].

PROPOSED CONTROL SCHEME

The control circuit using TMS32F28035 as a control unit, which generates a set of single-chip ADC (Analog to Digital Converter) and group 3 PWM (Pulse Width Modulation) control the six power switches. The control block diagram is shown in Fig. 3, the feedback voltage analog into digital signals, signals collected 10 times to average. V_o greater than V_{ref} will decrease phase to reduce output voltage;. Opposite will increase phase shift if V_o is less than V_{ref} voltage, this operation mode compare to V_o=V_{ref}. Phase controller clamp the phase shift at 27% to 47% of the cycle, shift phase is greater than 47% will be clamped to 48% and less than 27% will be clamped to 27%.

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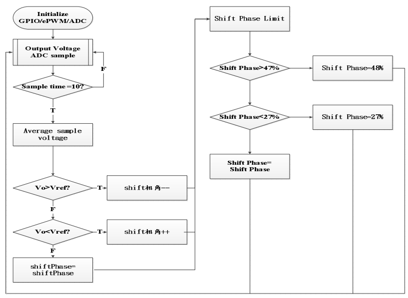

Figure 3: Control function block.

EXPERMENT RESULT

The three legs and phase shift AC to DC converter is characterized by a reduce stress of power switches and sequence to turn on the power switches. Fig.4 has shown power switches S1, S3, S5 PWM waveform at full loading output current 20A testing. V_{gs1} leading V_{gs3} 35% and V_{gs5} 70%. The phase shift limit controlled has make the output PWM signal at phase shift interval (27% to 47%). Fig. 5 has shown secondary transformer stress voltage and inductor stress voltage, thus the output state is used by current double circuit, inductor L1 and L2 will interact with the charge and discharge. $V_{sec1}+V_{sec2}$ stress is $-2nV_{cin}$ to $2nV_{cin}$ and V_{L1}, V_{L2} stress voltage is $-V_{out}$ to $2nV_{cin}-V_{out}$. Secondary inductor current waveform are shown in Fig. 6, rechargeable inductor current to reduce the current peak value, low current peaks will be designed smaller inductance, in order to reduce the volume and saving, I_{L1} and I_{L2} current is 7.2A to 11.5A.

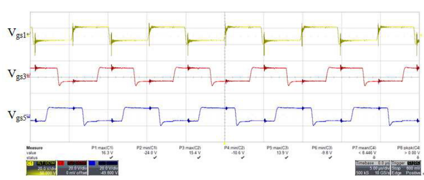

Figure 4: V_{gs1} 、V_{gs3} and V_{gs5} (output current 20A).

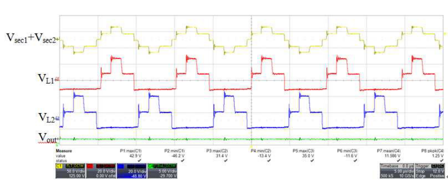

Figure 5: Secondary transformer stress voltage and inductor stress voltage.

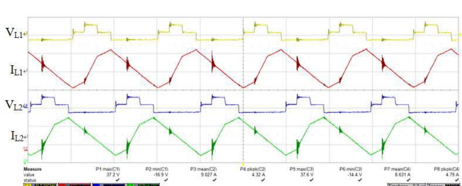

Figure 6: Secondary inductor current waveform.

Figure 7 has shown power system dynamic response waveform, the output current light load (6A) to full load (20A) to measure the output current. Disturbance output voltage is 2.73V, recover time is 0.5s. Efficiency testing is output current 6A to 20A has shown in Fig.8, all of the output current efficiency high than 75% and maximum efficiency at output current 15A that has 81.43% performance.

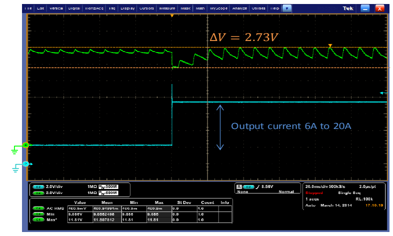

Figure 7: Dynamic response of three legs and phase shift AC to DC converter.

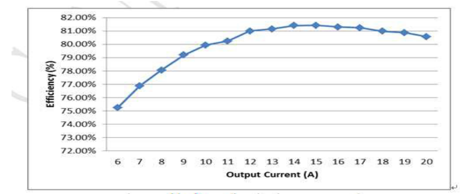

Figure 8: Efficiency of the power supply.

CONCLUSION

This paper presents a three legs and phase shift AC to DC converter, the proposed control scheme is based on DSP controlled and phase shift control algorithm. The low current distortion and stable capacitor voltage are implemented from the experiment result. The advantages of the proposed are using a digital controller will be increased flexibility parameters varies and confidentiality. Interleave output circuit can be reduces the peak current flowing through the inductor.

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