INTERNATIONAL JOURNAL OF RESEARCH
In Advanced Engineering Technologies

Volume I, Issue 3 JUL 2014

DC VOLTAGE REGULATION OF A MATRIX RECTIFIER TOPOLOGY BY USING SPWM CONTROL STRATEGY

SRAVYA K

PG scholar,Balaji institute of Technology & Science, JNTUH,Warangal, Telangana, India.

SRIDHAR S

M.Tech, Asst. Professor, Balaji Institute of Technolgy & Science JNTUH,Warangal, Telangana, India

ABSTRACT-

Matrix Rectifier has evolved from the traditional three phase to three phase Matrix Converter (MC) in recent years, and inherits merits of the traditional MC. Matrix Rectifier could be divided into isolated and non-isolated two types according to using high frequency transformer or not. A kind of isolated Matrix Rectifier topology, i.e., high frequency link Matrix Rectifier (HFLMR) has been selected as the study project. Space vector modulation is the mostly focused control strategy for the HFLMR, however its algorithm and its implementation are complicated and difficulty. So a novel straightforward absolute value logic SPWM control strategy based on De-Re-coupling idea has been proposed in this paper, which could realize unit power factor and DC voltage output, and made the transformer gain volt-second balance in a high frequency switching cycle. The validity and feasibility of the proposed control strategy have been well proved by the simulation and experiment results, and a special working phenomenon named as "the dual voltage endemism" has been analyzed in detail.

Index Terms—Absolute value logic SPWM, de -re-coupling, high frequency link, matrix rectifier, the dual voltage endemism

I. INTRODUCTION

CONVENTIONAL diode rectifier and phase controlled rectifier have caused more serious harmonic pollution to the power grid, so high frequency PWM rectifiers have been paid more attention in recent years. PWM rectifiers can shape their input current as an approximate sine wave and they also can realize higher power factor, minor output voltage ripple, bidirectional flow of energy and better dynamic response.

synthesize a required wave by using of proper logic

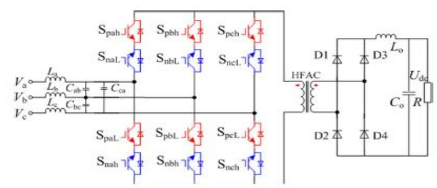


Fig. 1. The topology of high frequency link matrix rectifier (HFLMR).

However, neither voltage source kind nor current source kind of traditional PWM rectifier can be suitable for isolated single power conversion. Matrix converter (MC), since proposed by L. Gyugyi and B. Pelly in 1976 [1], has caused worldwide interest for merits of having no intermediate energy-stored link, realizing power factor in the mains side and adjustable amplitude and frequency of the output voltage.Matrix converter is a very flexible and universal power converter, and Matrix Rectifier has evolved from

the traditional three phase to three phase Matrix Converter (MC) in recent years, and inherits merits of the traditional MC. It can be used in active power filter, wind power generation, motor

drive systems, power factor correction, DC excitation, AC/DC switching mode power supply, etc. An isolated high frequency link MR (HFLMR) topology is shown in Fig. 1, it consists of several parts as input filter, MC, high frequency transformer, full bridge rectifier and output filter. According to the literature we could find, the isolating topology under virtual DC link modulation control was first proposed by Mr. Stefanos Manias in 1985 [2]–[5]. And then, more and more research working had been done on direct SVM or indirect SVM [6]–[9], but the modulation strategy is limited to SVM. To achieve SVM strategy not only needs sector partition, but also needs vector time calculation. Thus much resource is needed in DSP and SVM is not easy to be realized digitally. A novel absolute value logic SPWM (AVL SPWM) strategy based on De-Re-coupling idea has been proposed in the paper, which can control HFLMR to combination according to the absolute value of its input voltage. This modulation strategy has a plain idea and could be easily realized.Under the control of the modulation strategy, the HFLMR not only can get an input unit power factor and a steady output DC voltage, but also can contribute a maximum voltage utility and a reduced switching action within a high frequency period.

MODELING OF CASE STUDY

II. IDEA OF CONTROL STRATEGY AND PRINCIPLE

A. Topology of High Frequency Link Matrix Rectifier The high frequency link rectifier (HFLMR) shown in Fig. 1 is the heritage and development of the original high frequency link power conversion system [10], and its significant improvement is the using of fully-controlled high-frequency devices such as IGBTs instead of semi-controlled thyristors. InHFLMR, the transformer is used to achieve electromagnetic coupling and power transmission.

A matrix converter (MC) topology that has a line-frequency three-phase AC input and a high-frequency single-phase AC output is connected to the transformer primary side. An “H” diode bridge AC/DC part is placed at the secondary side for rectifying.

So the matrix converter part can be named as “primary MC”. In the primary MC one bi-directionally-controlled switch cell was made up of two uni-directionally-controlled IGBT devices. For this special structure character, the HFLMC can be controlled to work as well as a conventional inverter based on De-Re-coupling idea. And the “H” diode bridge part can be named as “secondary rectifier” also. Compared with the conventional rectifier, a high frequency transformer has been added into the HLFMC, so it would increase a joint to achieve coupling and conversion of electromagnetic energy, and also produce additional loss in the energy transfer process, thus this situation led to some new design thinking and requirements. Compared with a traditional non isolated rectifier circuit (Such as the classic 2L-VSC), double times controllable switching power devices and extra non-controllable diode devices have been both added in the topology of the high frequency link matrix converter, thus not only the power loss would increase, but also the difficulty of modulation and control would be picked up [13]. But if appropriate control strategy could be applied to the HFLMR, a single-stage power conversion can also be achieved as a conventional rectifier. And seen from another perspective, the high frequency transformer can perform ohm isolation between input and output, can match the impedance between the power supply and load, can also be effective to reduce the common mode current in the rectifier [14], [15], and can make freely control to the output voltage amplitude to be increase or decrease. Especially, the high frequency transformer can boost the output voltage of the Buck type current source rectifier (CSR), and also can buck the output voltage of the Boost type voltage source rectifier (VSR).

HFLMR can be widely used as a general-purpose rectifier like a traditional converter, and can also be used in special occasions such as electric vehicles, submarines and aerospace, etc . For example, if the HFLMR was applied to electric vehicle charging system, the conventional conductive charging mode could be changed to a contactless charging mode. In this way, not only the charging function was achieved, but also the security of the charge was greatly improved. And, if the diode output stage is replaced by controllable switches, bi-directional AC-AC power transfer can be directly implemented without DC electrolytic capacitor that was widely required in an AC-DC-AC power conversion system. So the high frequency link matrix converter can operate at even more than 300C high temperature environment, which can not be achieved by conventional converter with DC electrolytic capacitors. It was thought that matrix converter could be applied to any electrical field of the electric warship, and taking the advantages of high frequency link into account, the isolated matrix converter topology was evaluated for the power distribution system of the NASA orbiting space station which will have an initial power capability of 75 kW, and eventually growing to 300 kW.

B. Realization of Unit Power Factor and the Duty Cycle Ratio Control of HFLMR

Assuming the output current I av of the HFLMR is constant, then the average phase current in a whole switching period is equal to the product of the switching-on current Iout and the duty cycle ratio D :

Iav=I out*D

To realize unit power factor, one phase average current should be sine wave and in phase with the corresponding input voltage, so the expected phase average current I exp is proportioned to the input voltage:

Where, V con is a control voltage related to the duty cycle ratio k1, is a constant.

As the current Iout in the switching-on interval is the expected phase average current I exp, so get the (3).

Where, d (l) is the duty cycle ratio K2, is a coefficient C con, is the integral coefficient Ts, is switching period. The relation between the input current and input voltage can be derived from the (1)–(3).

Where, k3=k1*k2 .

Finally the output power Pout can be calculated as the (5):

From the above analysis, it can be seen that if the output power is constant, the expected input phase current is sinusoidal and it can be in phase with the input voltage. And, the expected current also can be controlled through controlling the duty cycle ratio.

C. Fundamental of De-Re-Coupling Idea

De-Re-coupling is a synthesis of De-coupling and Re-coupling, and the De-Re-coupling idea also has these two meanings. When the HFLMC is operating as a DC/AC converter, the solution result based on De-Re-coupling idea is conventional inverter using uni-directionally-controlled power devices. And

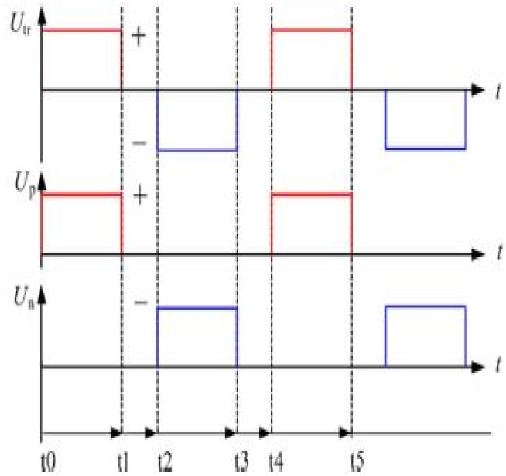


Fig. 2. De-coupling to AC power.

When the HFLMC is operating as an AC/DC converter, the solution result is conventional rectifier

1) Fundamental of De-Coupling:

De-coupling" aims at analysis to HFLMC circuit and the physical connection. De-coupling of HFLMC can be performed in two ways, the first one is to decouple an AC power source into two DC power sources: that is, the single phase high frequency AC source can be seen as a coupling of DC pulse sources that have same period but complementary and opposite polarities. Fig. 2 shows an AC power source De-coupling, in which, AC power " " is the input of high-frequency transformer, and also is the output of MC, and it could be decoupled into two DC pulse power supplies " " and " " with respective positive and negative polarity.

And the second one is to decouple a MC into a conventional inverter or rectifier, that is: three uni-directionally-controlled switches that are in same connected direction and polarity from

MC upper arms, and also three switches from MC Lower arms can be selected, to combine a three-phase half-bridge inverter or rectifier, and then a MC can be divided into two inverter or rectifier that have same topology but opposite position. So the study can benefit from referring and applying many existed abundant research achievements for conventional inverter or rectifier to MC.

2) Fundamental of Re-Coupling:

Re-coupling" focuses on the syntheses implementation of the logic and control. Re-coupling

Works are mainly to determine switching laws and logic relationships for the MC power devices, by using of a modulation and output control characteristics for conventional inverter or rectifier. The diversity of modulation and control will cause different logical Re-coupling syntheses. "De-coupling" creates conditions for the analysis and design to HFLMC; "Re-coupling" can ensure the MC finally run as a conventional inverter or rectifier.

D. Decoupling Classification of HFLMR

From the above analysis it can be seen that the result of MC De-coupling is a traditional rectifier as shown in Fig. 3 as voltage source rectifier (VSR) or current source rectifier (CSR). Based on the idea of De-Re-coupling and separated control, a bidirectional switch cell can be triggered by "integrated control" or by "separated control" [19]. A integrated control takes the bidirectional switch as a whole, and gives only one drive signal

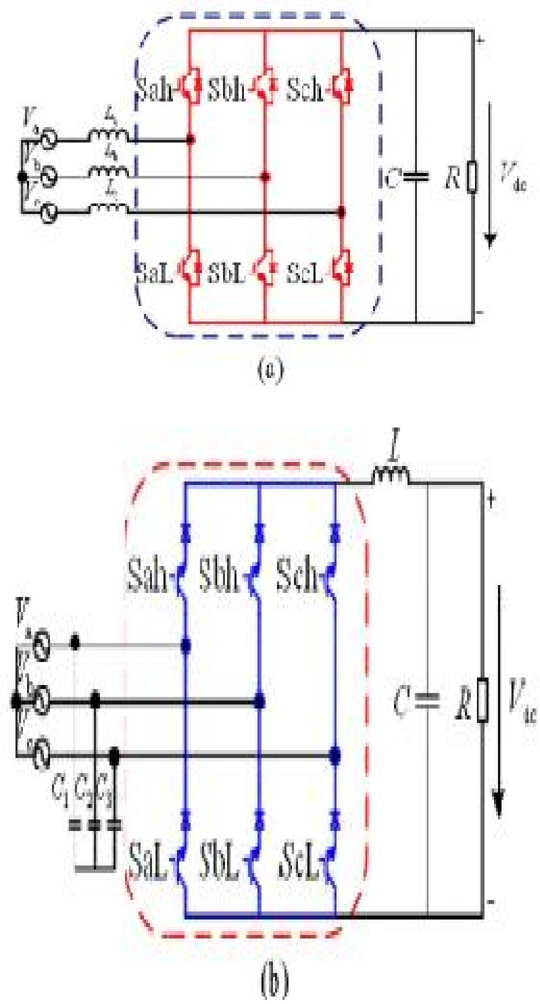


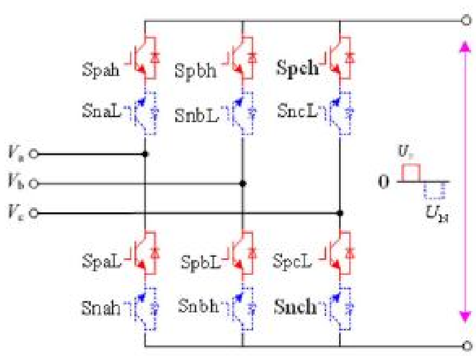
Fig. 3. Conventional three-phase VSR and CSR. (a) Voltage source rectifier- VSR; (b) Current source rectifier-CSR.

To the cell, it is a commonly used control method. A separated control takes the bidirectional switch as two uni-directionlly- controlled switches, and gives them two drive signals in same train or not. The separated control has a greater flexibility than the integrated control. So two kind of De-coupling results can be gotten as following, firstly, the MC can be de-coupled as two equivalent VSRs as show in Fig. 4(a), and secondly a conventional CSR de coupling results of MC can be gotten as Fig. 4(b), and this class would be selected as the controlled object in this paper.

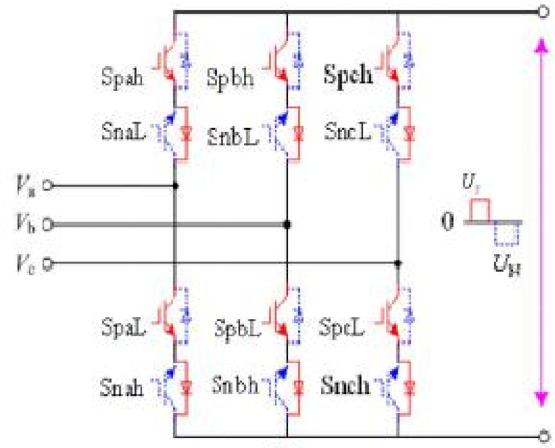
E. Basic Idea of Absolute Value SPWM

The book (*static Power Frequency Changer*) [1], narrated by L. Gyugyi and B. Pelly in 1976, showed that three-phase to three-phase matrix converter can realize output function from the amplitude and frequency of one input to another, and can output random frequency waves in theory, which was called high frequency synthesis theory.

Based on this theory, in three-phase-to-single-phase matrix converter, the input three phase sine wave with low frequency can be chopped into a series of high frequency AC waves. So the absolute value logic (AVL) SPWM idea for could be proposed, first we can get three absolute values of the three phase input voltages, and judge the relation among their values. Then according to the absolute value and suitable logic, the principle of the phase voltage conduction can be determined as: in a high frequency switching period, the phase with the maximum absolute value should be always in a conduction state both in former and latter half period; and the phase with the intermediate value should firstly be in a conduction state to match the phase with the maximum absolute value in a time slicing of the period; and then the phase with the minimum absolute value should secondly be conducting to match the phase with the maximum absolute value. For instance, see “section 1” in Fig. 5, A-phase voltage has the maximum absolute value, B-phase voltage value is lesser, and C-phase voltage value is minimum. Then the switches



(a)



(b)

Fig. 4. Decoupling classification to HFLMR. (a) Conventional VSR de-coupling of MC; (b) Conventional CSR de-coupling of MC.

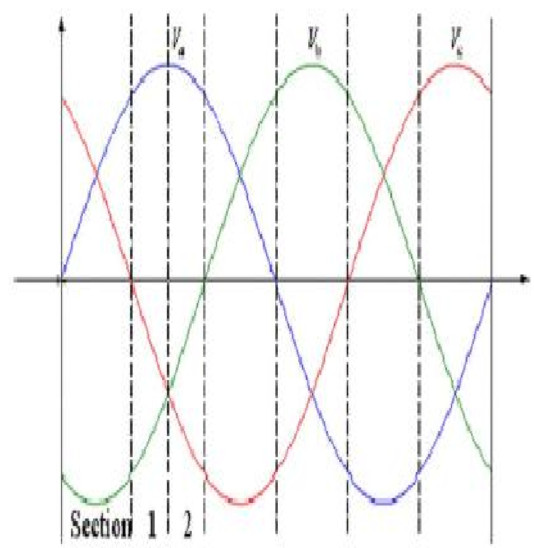


Fig. 5. The relation of three phase input voltage amplitude.

Connected to A-phase are on all in a high frequency period, B-phase switches firstly prefer to synthesize the output voltage with A-phase’s, and then C-phase switches to be the second synthesizer. Because switching frequency is much higher than the grid voltage frequency, the input voltage amplitude could be approximately considered as a constant in a high frequency switching period. Then in the former half high frequency period, A phase and B phase voltages firstly synthesize the line voltage Vab (seeing Fig. 6), after that A phase and C phase secondly synthesize the line voltage Vac . Similarly, in the latter half period, A phase and B phase voltage firstly synthesize the minus line voltage -Vab, A and C secondly synthesize the minus line voltage -Vac . So a high frequency AC voltage meeting the volt-second balance has been gained at the output port of MC.

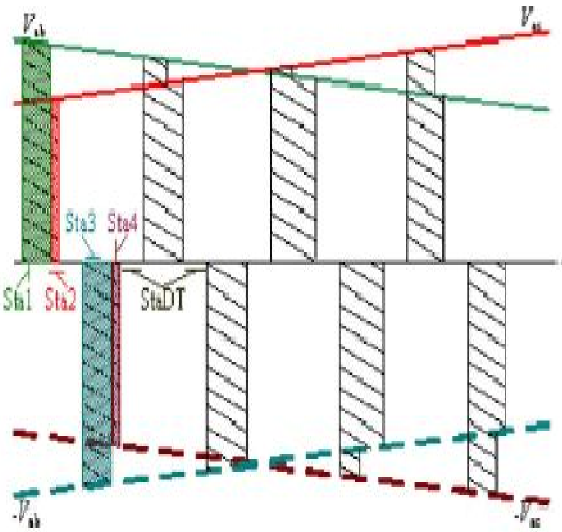


Fig. 6. Voltage synthesis in high frequency switching periods.

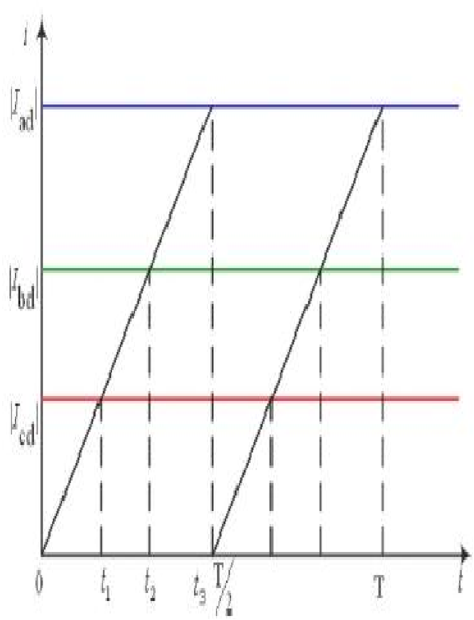


Fig. 7. Themodulation relationship of switching times among different phases.

F. The Core Modulation Algorithm for Absolute Value SPWM

The modulation relationship of switching times among different phases is shown in Fig. 7. Where, assuming the period is in some one high frequency switching cycle; among the three phase grid voltages and , there exists the following relationships Va,Vb,Vc and > and = + three-phase expected current are be in line with the expression

Based on the geometric relations, it can be found that:

T3=t1+t2

And because:

So combined with expression (6) and (7), the following expression
Can be obtained:

From the expression (9), it can be found that every phase current is also proportional to the corresponding conduction duty time. And the expression (2) has shown that the proportion of the three phase voltage value was equal to the proportion of the duty cycle, i.e., , so:

In order to achieve the unit power factor in the input side of the HFLMR, the modulation voltage can be chosen as the one that is synchronous with the input grid voltage. This is the core theoretical control algorithm for absolute value SPWM, and the actual switches driving signals used in the experiment are shown in Fig. 15(c).

G. Analysis of Working States under AVLSPWM Control

The main circuit of HFLMR is shown in Fig. 1, in which every bidirectional switch cell is composed of two unidirectional switches. As all switches have four-quadrant conduction ability, the matrix converter can output either plus or minus voltage and current, i.e., a kind of single phase high frequency AC square-wave voltage could be achieved by MC from the three phase AC grid mains. The specific working states are analyzed in the following by assuming A-phase voltage has the maximum absolute value, B-phase voltage has an intermediate absolute value, and C-phase voltage has the minimum absolute value.

1) State 1:

(See Fig. 8, the following Stat2 state4 are similar to this one.) The current flows from A-phase , through the bidirectional switch cell "Sah" in the upper of MC A-phase leg, then to the transformer's primary side, and pass by the bidirectional cell "SbL" in the lower of MC B-phase leg, finally the current flows back into B-phase . Thus, the plus voltage , which was shown as "Sta1" in Fig. 6, is formed in the

INTERNATIONAL JOURNAL OF RESEARCH
In Advanced Engineering Technologies

Volume I, Issue 3 JUL 2014

primary side. At the same time, the current of second side flows through diode VD1, the output filter, and the load. Finally, it flows back into the transformer second side by VD4. So the state meets the equation:

Where R, is the total resistance that includes resistances in the inductance, the switches and wires; is the current in phase A L; is the primary inductance of the high frequency transformer; is the total inductance that includes the primary side leakage inductance of the transformer and parasitic inductance of wires.

2) State 2:

The current flows through from A-phase, through the bidirectional switch cell "Sah" in the upper of MC A-phase leg, then to the transformer's primary side, and pass by the bidirectional switch cell "ScL" in the lower of MC C phase leg, finally the current flows back into C-phase. Thus, the plus voltage, which was shown as "Sta2" in Fig. 6 is formed in the primary side. The secondary side current is as same as state 1. The state meets the equation:

3) State 3:

The current flows from A-phase, through the bidirectional switch cell "SaL" in the lower of MC A-phase leg, then to the transformer's primary side, and pass by the bidirectional switch cell "Sbh" in the upper of MC B-phase leg, finally the current flows back into B-phase. Thus, theminus voltage, which was shown as "Sta3" in Fig. 6, is formed in the primary side. At the same time, the current of secondary side flows through diode VD3, the output filter, and the load. Finally,

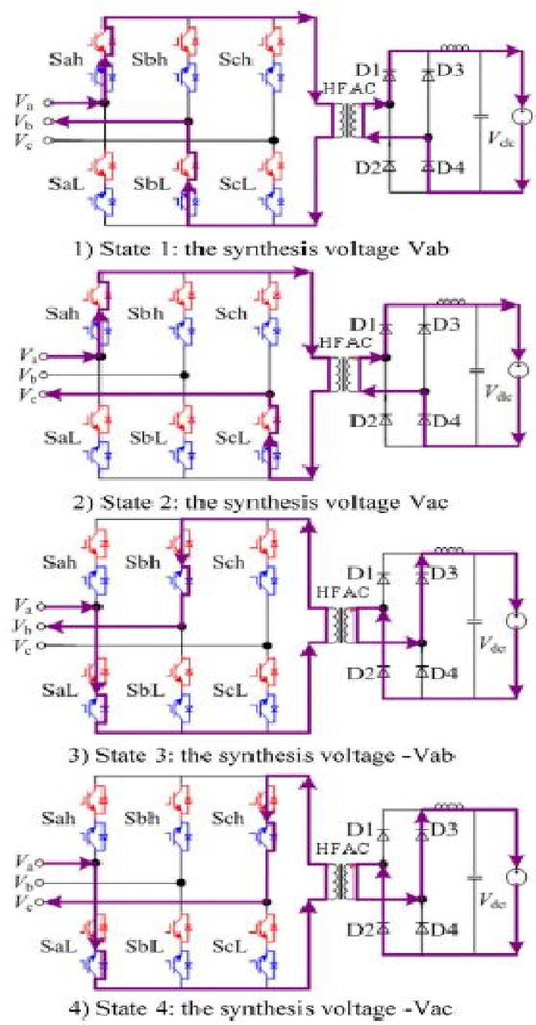


Fig. 8. The working states of matrix rectifier in a switching period.

it flows back into the secondary side by VD2. The state meets the equation:

4) State 4:

The current flows from A-phase, through the bidirectional switch "SaL" in the lower of MC A-phase leg, then the transformer's primary side, and pass by the bidirectional switch cell "Sch" in the upper of MC C-phase leg, finally the current flows back into C-phase . Thus, the minus voltage , which is shown as "Sta4" in Fig. 6, is formed in the primary side. The circulating of secondary side current is as same as state 3. The state meets the equation:

From the above working states,we can see the high frequency single phase AC voltage at the secondary side was rectified and filtered to be a DC voltage, this means that the high frequency link matrix rectifier has achieved the desired converting function.

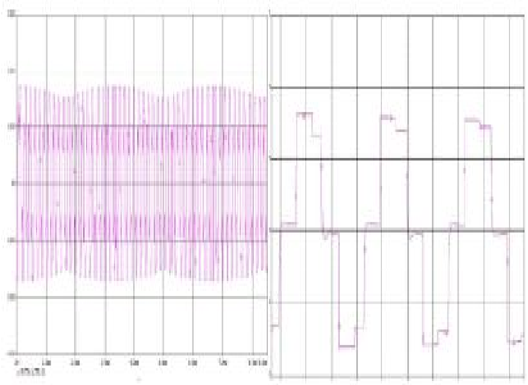


Fig. 9. The primary voltage of the transformer.

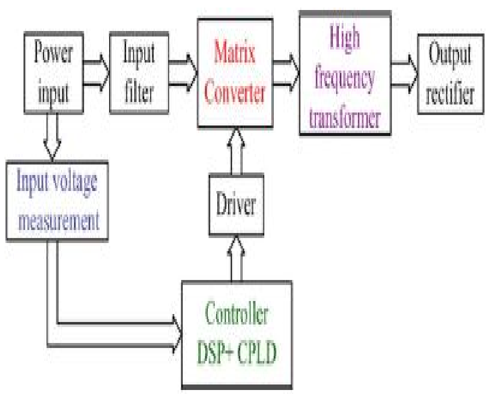


Fig. 10. Block diagram of the absolute value control system.

III. SIMULATION AND EXPERIMENT

A. The Basic Validation of the AVLSPWM Principles and the HFLMR Characteristics

1) Simulation by

To validate the correctness of the proposed control strategy, simulations have been done by using general circuit simulation software. Voltage wave of the transformer primary side are shown in Fig. 9, the left one was gained at a low grid voltage frequency rating and the right one was gained at high switching frequency rating. To verify the feasibility of the AVLSPWM strategy, a HFLMR platform has been built up, and some experiments had been done by using digital controller. And the following show block diagram of the absolute value control system, components and design of the hardware, key functions and resource allocation of the controller, program flow chart about absolute value judgment and the SPWM signal generation.

2) Block Diagram of the Absolute Value Control System:

The block diagram is shown in Fig. 10, in which, Matrix converter is in the operating condition with low-frequency three-phase input and high-frequency single-phase output, and the controller is in form of a combination of DSP and CPLD.

3) Components and Design of the Hardware:

a) Bi-directional switch for matrix converter:

It has been made up by two FGA25N120ANTD IGBT in common-collector series connection. And then six bi-directional switches could constitute a matrix array as shown in Fig. 1.

b) Driver circuit:

An optical isolation IC named TLP250 has been selected to be a driver. The IC has dual functions such as an optical isolation and power device driving, and the specific application circuit of it is shown in Fig. 11, where “Gin” and “Ein” are input port to the driving signal and “Gout” and “Eout” are output port

c) High frequency transformer:

Taking the turns ratio of transformer as 5:1, the matrix converter switching frequency as

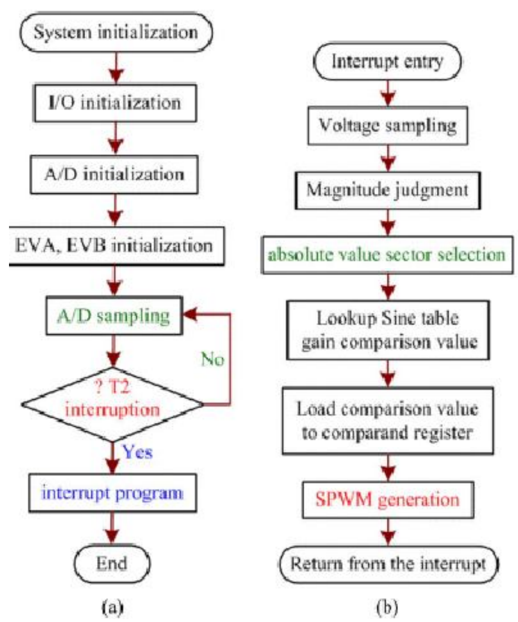


Fig. 12. The flowchart of software program. (a) Flowchart of main program; (b) flowchart of interrupt program.

12 kHz, and in accordance with the Area-Power law, the specific design expressions are the following:

Where, is the apparent power and set to 1 kVA; is the window area of transformer; represents the magnetic core cross-sectional area, and should be calculated for additional 10% margin than the calculation result. is the core window utilization factor, generally taken as 0.4. is the waveform

INTERNATIONAL JOURNAL OF RESEARCH
In Advanced Engineering Technologies
Volume I, Issue 3 JUL 2014

factor, when there is sine wave it is 4.4, and when square wave it is 4. is the working core flux density, usually taken to be 0.3 or 0.4 T. is the current density factor, usually taken to be 2 5 A/mm2, the unit of it should be translated into A/m2 when calculating. is the operating frequency.

c) Measured parameters of the transformer

In the primary winding, inductance, L p=41.9 m H leakage inductance, L p =0.18Mh Resistance R p= .And in the secondary winding, inductance Ls=1.52 mH , leakage inductance Ls , resistance Rs=0.4

.d) Designation for input filter:

The input filter of matrix converter is usually required to meet the following requirements: a) The cutoff frequency of the filter is much smaller than the switching frequency. b) To ensure the power supply has a possibly max power factor. c) To keep the filter has a possibly min volume.d)Tomin

imize the voltage drop on the inductance in the case of a rated current. So the cutoff frequency was selected as 1.2 kHz, at the same time inductance and capacitor of the filter were selected as 4mH and 4.4F *.4) Main Functions and Resource Allocation of Controller:*

a) Measurement of three-phase input voltage:
The DSP samples three phase voltages through three ports of A/D converter, and distinguishes the absolute value sector, then judges the absolute value relationship of magnitude, and sends the corresponding signals through I/O ports to CPLD. For example, When the grid voltage magnitude relationship could meet the condition that A phase voltage has the largest absolute value, B phase magnitude is lesser and C phase magnitude is the minimum, a high level signal will generated by the I/O port IOPA7 and sent to the CPLD. And this high level signal could be found in Fig. 13 with a 'ABC' identifier.

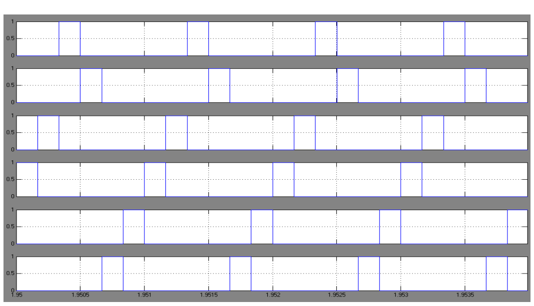


Fig. 13. Grid voltages and their absolute value in order.

TABLE I
THE I/O CORRESPONDING RELATION BETWEEN DSP AND CPLD

Signal	I/O pin	PWM port	CPLD pin
ABC	IOPA7	PWM2	8
ACB	IOPB1	PWM4	10
BAC	IOPB3	PWM6	14
BCA	IOPE2	PWM8	2
CAB	IOPE4	PWM10	7
CBA	IOPE6	PWM12	16

b) Basic signals generated by DSP

The so-called basic signals are the signals fed to the CPLD such as the three phase uni polar SPWM signals and the absolute value signals to index the three phase input voltages magnitude relationship.

c) Logic processing by CPLD:

After receiving the abovementioned basic signals, the CPLD will generate the specific driving signals for bi-directional switches. Also take the above 'ABC' condition as an example, the A phase leg of matrix converter will be assigned a whole turn on driving signal in the half of the switching period at first, and B phase leg will be priority assigned one part turn on driving signal, and then the C phase leg will be assigned anther part turn on driving signal at last. The geometric algorithms relationship is shown in Fig. 7, and the actual driving signals are shown in Fig. 15(c).

d) Controller resource allocation:

a) SPWM generation

The unipolar three phase SPWM signals were generated by Timer T1 in DSP, and the signals are issued by the PWM1, PWM3 and PWM5 ports to the 6,9,13 pins of the CPLD.

b) Absolute value signals

The A/D sampling to voltage was started by the T2 timer of the DSP, and the one to one relationship between the three phase voltages and the A/D converter is as the following: the ADCIN10 pin of DSP corresponds to phase A voltage, the ADCIN11 corresponds to phase B, the ADCIN12 corresponds to phase C.

The specific interface resources are shown in Table I, where the signal identified by "ABC" means that the grid voltage magnitude meets the situation as the voltage of phase A has a maximum magnitude, then phase B is lesser,

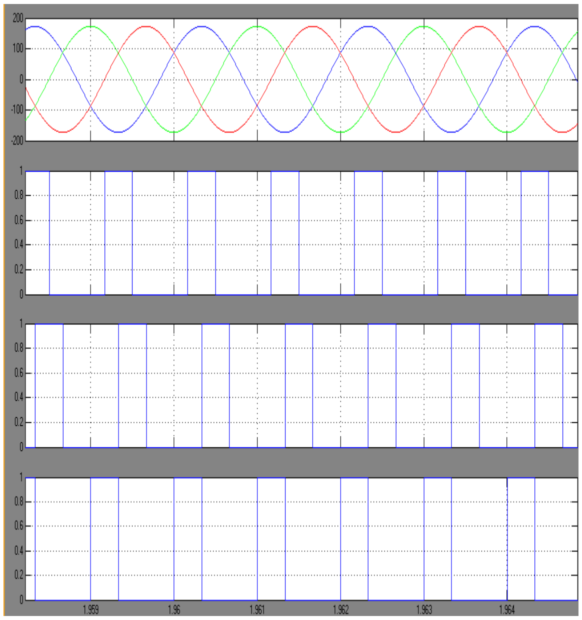


Fig. 14. SPWM of A-phase and its corresponding wave (blue). and the phase C is minimum. The rest identifiers may be deduced by analogy.

5) Flowchart of Absolute Value Judgment and the SPWM Signal Generation:
The key work is to detect the input voltage and to lookup sine table and to issue SPWM signals based on the magnitude relationship among the three phase voltages.
6) Waveforms of Experiment:
The main experimental parameters are: three phase voltages input with 220 V effective value, 12 kHz switching frequency, 4 mH inductance of input filter, 4.4 capacitor of input filter, 1mH inductance of output filter, 220 capacitor of input filter, and 1–10 resistance load. Fig. 13 shows the relationship between three-phase input voltages (grid voltages) to MR and the absolute values. In the figure the sign “ABC” denotes phase A is the phase with the maximum absolute value of voltage, phase B is the lesser and phase C is the minimum. Other signs such as “ACB,” “BAC,” “BCA,” “CAB” and “CBA” have the similar changing trends as the “ABC” one. Fig. 14 shows two waveforms, the upper one is a square wave signal synchronizing with A-phase voltage, and the lower one is its correspondent usual SPWM signal. The extensive transformer primary voltage wave at grid frequency trend is shown in Fig. 15(a), and its local and magnified wave is shown in Fig. 15(b). And it can be found that the character of the waves in Fig. 9 and Fig. 15(b) are consistent. And the relationship of the driving signals to the three phase leg of HFLMR is shown in Fig. 15(c), where the identifier “Sah,” “SbL” and “ScL” denote the driving signals to the switches in same identifiers. It can be found that the width of ‘Sah’ pulse is the total sum width of “SbL” and “ScL” pulses, it means that the distribution of the PWM signals is consistent with the abovementioned pulse generation principle and algorithm.
The extensive and local waves of transformer secondary voltage are shown in Fig. 16 when the HFLMR had engaged a capacitor filter. Fig. 17 shows the DC output voltage of HFLMR, and Fig. 18 shows the A-phase input voltage and the current of MC. So we may find that the HFLMR can achieve high power factor.

B. A Special Working Phenomenon and Its Genetic Analysis
A special working phenomenon named as “the dual voltage endemism” under AVLSPWM control is shown in Fig. 19.

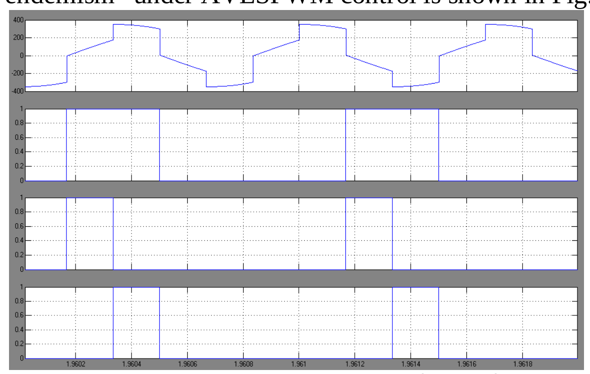
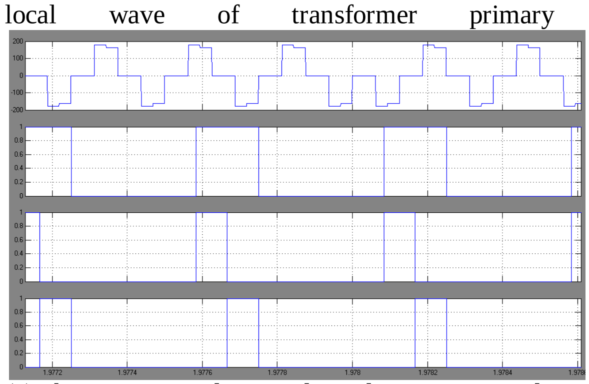


Fig. 15. Extensive and local wave of transformer primary side. (a) Extensive wave of transformer primary side; (b) local wave of transformer primary side;



(c) the primary voltage side and its corresponding switch pulses

Fig. 15. Extensive and local wave of transformer primary side. (a) Extensive wave of transformer primary side; (b) local wave of transformer primary side; (c) the primary voltage side and its corresponding switch pulses. It could be found both in simulation or experiments of the HFLMR. Unlike traditional waveform, it is special and interestingthat there were two periodic consecutive negative or positive voltage pulses in the high frequency transformer AC voltage wave. It could be analyzed that “the dual voltage endemism” is a normal working state which may make no harmful influence to the volt-second balance of the high frequency transformer. For, in a line frequency cycle, every 60 electrical degrees, the phase with maximum absolute value

INTERNATIONAL JOURNAL OF RESEARCH
In Advanced Engineering Technologies
Volume I, Issue 3 JUL 2014

would have a cycle variation as orderliness as B-A-C-B-A-C. And in the every same 60 electrical degree interval the absolute value of the second largest were transformed twice as orderliness asCA-BC-AB-CA-BC-AB.

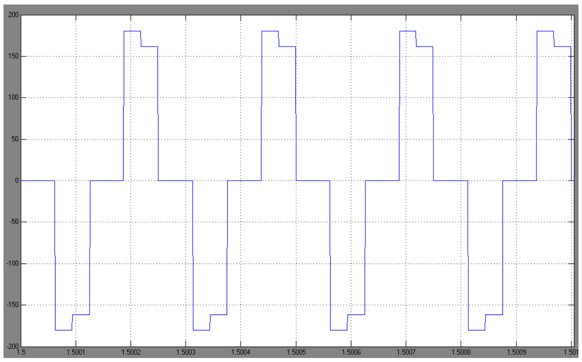


Fig. 16. Extensive and local wave of transformer secondary side. (a) Extensive wave; (b) local wave.

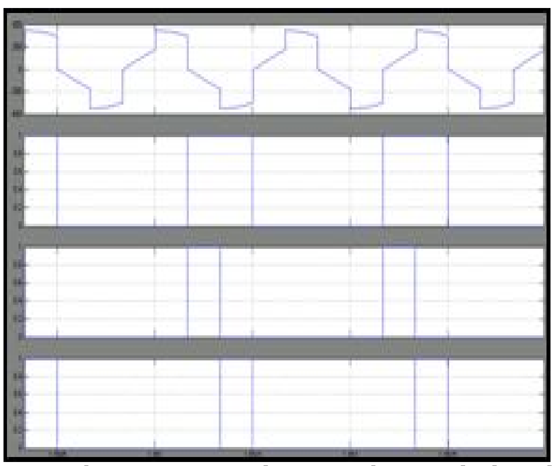


Fig. 19. The primary voltage with its dual voltage endemism. (a) Simulation waves; (b) experiment waves.

value magnitude relationship among the phases is , so the synthesis voltages that input to the high frequency transformer are and in turn, and so the zero-crossing point of B-phase voltage is the appointed place for the maximum value owner variation. After the variation, C-phase voltage gains the maximum absolute value (actual polarity was negative), and the absolute value magnitude relationship among the phases is changed into , then the synthesis voltage are and in turn. Because the switching frequency is much higher than the grid frequency, and based on the magnitude relationship among the three phase sinusoidal voltage value it can be considered that, before and after the variation of maximum absolute value owner, phase A and C are with equal voltage amplitude; and it also can be considered that the B-phase voltage amplitude remains unchanged at the same time. So there are two equations as and , and so it can be seen that the dual voltage pulses with almost identical characteristic come forth consecutively periodically. The periodicity interval of the above dual voltage pulses is 60 electrical angle, the frequency of these dual voltage pulses is 300 Hz, and the polarity of the pulses alternately changes to be positive and negative. And especially, these adjacent two voltage pulses in same polarity do not belong to a same switching cycle, but belong to two different cycles before and after the switching point for maximum absolute value of phase voltage, So it will not cause the transformer volt-second imbalance. Seeing the Fig. 15 we can find there were two successive negative pulse voltages, before and after absolute maximum value owner variation of the A-phase and C-phase voltages. The first one of these two negative voltage pulses, belongs to the after half switching cycle in the place before the maximum absolute value owner variation; and the second voltage pulse belongs to the previous half switching cycle in the place after the maximum absolute value owner variation; so the transformer volt-second balance can be guaranteed by the integrity and reciprocity of the high frequency AC switching cycle.

IV. CONCLUSION

A kind of absolute value logic (AVL) SPWM strategy based on DE-RE-coupling idea has been proposed for HFLMR. Compared with the direct and indirect SVM control strategy proposed by the references, the AVL SPWM control strategy is simple and easy to implement. Some results of simulation and experiment have all proved the validity and feasibility of the new kind of AVL SPWM control strategy. And a special working phenomenon named “the dual voltage endemism” ofthe HFLMR under the control strategy has been analyzed, it showed that it is a normal working states, and the volt-second balance can still be assured in a high frequency period and unit power factor can also be realized by the HFLMR.

REFERENCES

[1] L. Gyugyi and B. Pelly, *Static Power Frequency Changers [M]*. NewmYork: Wiley, 1976.

[2] S.Manias and P. D. Ziogas, “A novel sine wave in AC to DC converter with high-frequency transformer isolation [J],” *IEEE Trans. Ind. Electron.*, vol. 32, no. 4, pp. 430–438, 1985.

[3] Z. Y. Yan, K. Zhang, M. L. Jia, and W. Y.Wu, “SPWM modulation strategy study of AC/DC matrix converter with high frequency isolation [C],” presented at the ICEMS, Oct. 2008.

[4] P. D. Ziogas, S. I. Khan, and M. H. Rashid, “Some improved forced commutated cycloconverter structures [J],” *IEEE Trans. Ind. Applicat.*, vol. 21, pp. 1242–1253, 1985.

[5] P. D. Ziogas, S. I. Khan, and M. H. Rashid, “Analysis and design of forced commutated cycloconverter structures

with improved transfer characteristics [J]," *IEEE Trans. Ind. Electron.*, vol. 33, pp. 271–280,
1986.
[6] V. Vlatkovich, D. Boroyevish, and F. C. Lee, "A zero-voltage switched, three-phase isolated PWM buck rectifier [J]," *IEEE Trans. Power Electron.*, vol. 10, no. 2, pp. 148–157, 1995.
[7] S. E. Joung and S.H.Huh, "A soft-switched DSP based isolated three phase PWM buck rectifier [C]," in *Proc. IEEE INTELEC*, 1997, pp. 338–343.
[8] R. García-Gil, J. M. Espí, E. J. Dede, and E. Sanchis-Kilders, "A bidirectional and isolated three-phase rectifier with soft-switching operation [J]," *IEEE Trans. Ind. Electron.*, vol. 52, no. 3, pp. 765–773, 2005.
[9] S. Ratanapanachote, H. J. Cha, and P. N. Enjeti, "A digitally controlled switch mode power supply based on matrix converter [J]," *IEEE Trans. Power Electron.*, vol. 21, pp. 124–130, 2006.
[10] P. M. Espelage and B.K. Bose, "High frequency link power conversion [J]," *IEEE Trans. Ind. Applicat.*, vol. 13, no. 5, pp. 338–394, 1977.
[11] Z.Y.Yan, J.X.Li, X.L. Li, andW. Y.Wu, "Modeling and de-re-couple idea proving of matrix converter in high frequency link inverter [J]," *Trans. China Electro technSoc.*, vol. 22 (Extra), pp. 57–63, 2007.
[12] Z. Y. Yan, C. J. Zhang, W. Y. Wu, M. L. Jia, and K. Zhang, "De-decouple SPWM strategy for single-phase high-frequency link matrix inverter [J]," *Trans. China Electrotechn. Soc.*, vol. 27, no. 02, pp. 59–67, 2012.

SRAVYA K currently pursuing her M. Tech in Power Electronics in Balaji Institute of Engineering and Sciences Warangal, Telangana, India affiliated to JNTU University, Hyderabad. She has done her B. Tech degree from Balaji Institute of Engineering and Sciences, affiliated to JNTU University, Warangal, Telangana, India in 2011 and her fields of interest include Renewable Energy Sources, Power Electronics and Control Systems.

SRIDHAR S has completed his M.Tech in Power Electronics from JNTUH, Telangana, India in 2009 and B.Tech in 2003. He has worked as Asst. professor in Electrical & Electronics Engineering department in Balaji Institute of Technology & Science. His fields of interest include PWM dc-dc and dc-ac inverters, power semiconductor devices, renewable energy systems, Distributed generation system level simulations of the same. He had published a paper in 2012 national conference on prototype design of wind generation system.