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Study of different triangulo – sinusoidal strategies of two five – levels of cells overlapped VSI. Application to double star induction machine drive

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Abstract : This paper presents a model and control strategy of the two five levels of cells overlapped voltage source inverter. In the first part, we present the knowledge model of this inverter by using the switches and half arms connection functions. Then, we propose a control model of this converter by using the generating functions. In the second part, we develop a model of this machine (DSIM) by using a Park transformation. In the last part, we develop triangulo-sinusoidal strategy with four carries. The performances of the drive of double star induction machine fed by the two five levels of cells overlapped VSI controlled by these algorithm are presented and analysed. The results obtained are full of promise to use this multilevel inverter in high voltage and great power applications as electrical traction.

Keywords: DSIM, cells overlapped, VSI, five levels, connection function, field oriented control , drive.

1 Introduction

The development of the semiconductors and digital processors has let to develop new static converters more efficient and control algorithms more sophisticated. In this paper, we will study a new multilevel voltage source inverter: five levels of cells overlapped voltage source inverter.

We present in the first part the knowledge and control models of this new converter. Then, we propose two PWM algorithms [4] [5] [9]:

- Triangulo-sinusoidal strategy with four carries
- Space vector modulation associated to the triangulo-sinusoidal strategy with four carries.

In the last part, we analysis the performances of the indirect field oriented control of the DSIM fed by two five levels of cells overlapped VSI controlled by the proposed these two strategies.

As application, we will study the performances of the indirect field oriented control of the DSIM [1] [2] [3] [9] fed by two five levels of cells overlapped VSI. The performances obtained are full of promise to use this system in high voltage and great power applications as electrical traction.

2 Knowledge model of the five levels of cells overlapped VSI

In this paper, we will present the three phases five levels to cells overlapped. It is composed of three symmetrical arms corresponding to the three phases.

Every arm is constituted of overlapped four cells, every cell carries two switches whose working is complementary and a source of tension (Uc).
Each of the two switches is composed of a semi driver and a diode gone up in head spade (fig 1).

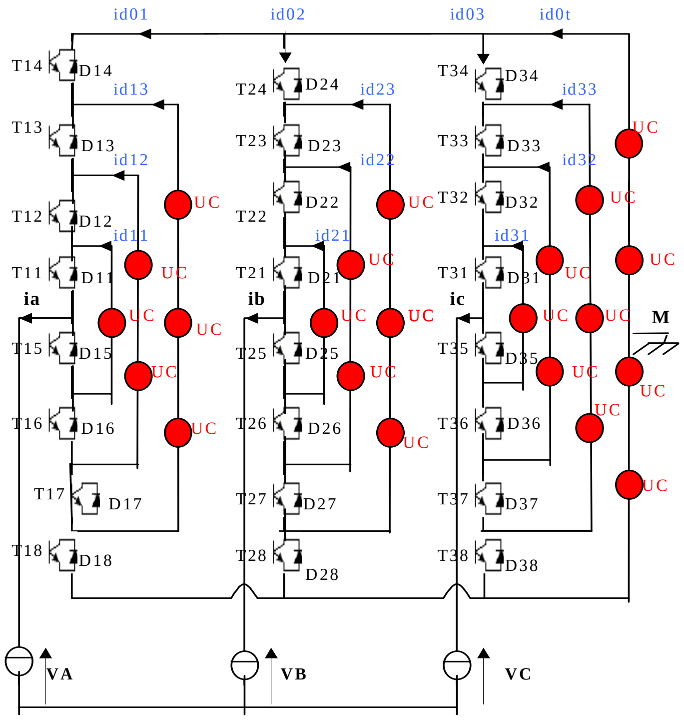

Fig 1:Three phases five levels of cells overlapped voltage inverter

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3 Control model of the five levels of cells overlapped VSI

3.1 Connection function:

The connection function F_{kS} defines the state (switch on or off) of each switch:

$$\begin{cases} F_{KS} = 1 & \text{TDKS on} \\ F_{kS} = 0 & \text{TDKS off} \end{cases} \qquad (1)$$

TDKS represents every pair transistor-diode, and k is number of arm (or phase).
For the five levels VSI, several complementary laws are possible, the optimal one is defined as follow:

$$\begin{cases} B_{k1} = \overline{B}_{k5} \\ B_{k2} = \overline{B}_{k6} \\ B_{k3} = \overline{B}_{k7} \\ B_{k4} = \overline{B}_{k8} \end{cases} \qquad (2)$$

Then for connection functions, we write:

$$\begin{cases} F_{k1} = 1 - F_{k5} \\ F_{k2} = 1 - F_{k6} \\ F_{k3} = 1 - F_{k7} \\ F_{k4} = 1 - F_{k8} \end{cases} \qquad (3)$$

The output voltage of the inverter can be written as follow:

$$\begin{cases} V_{AM} = (F_{11} + F_{12} + F_{13} + F_{14}).U_C - 2U_C \\ V_{BM} = (F_{21} + F_{22} + F_{23} + F_{24}).U_C - 2U_C \\ V_{CM} = (F_{31} + F_{32} + F_{33} + F_{34}).U_C - 2U_C \end{cases} \qquad (4)$$

3.2 Conversion functions:

The output voltage vector of the nine levels voltage inverter is:

$$\begin{bmatrix} U_{AB} \\ U_{BC} \\ U_{CA} \end{bmatrix} = \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} F_{11} + F_{12} + F_{13} + F_{14} \\ F_{21} + F_{22} + F_{23} + F_{24} \\ F_{31} + F_{32} + F_{33} + F3 \end{bmatrix} Uc \qquad (5)$$

4 Strategies of five levels of cells overlapped VSI

4.1 Triangulo-sinusoidal strategy using four carriers

This strategy uses four bipolar carriers $(U_{p1}, U_{p2}, U_{p3}, U_{p4})$ shifted each others by $(T_p/4)$. T_p is the carrier period. (Fig 2)
This strategy is characterised by two parameters[8] [9]:

modulation index **m** and the modulation rate **r**

m=fp/f and r=Vm/(2*Upm)

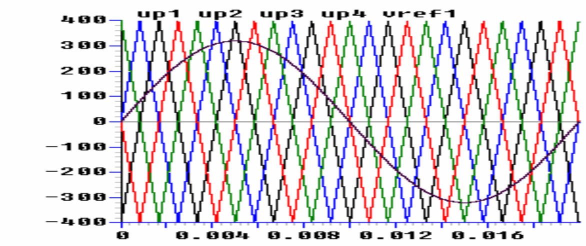


Fig 2: The reference signal and the Carriers (m= 6, r = 0.8)

Figures 3 and 4 show the performances of this PWM strategy

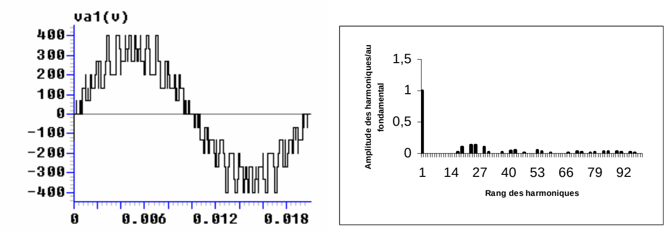


Fig 3: The simple output voltage Va and its spectrum (m= 6, r= 0.8)

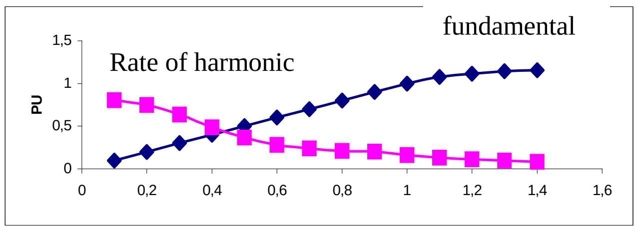


Fig 4 : characteristics of The simple output voltage Va of the three phases five levels of cells overlapped VSI

4.2 Space vector modulation associated to the triangulo-sinusoidal strategy with four carries.

Figures 6 and 7 show the performances of this PWM strategy [9]

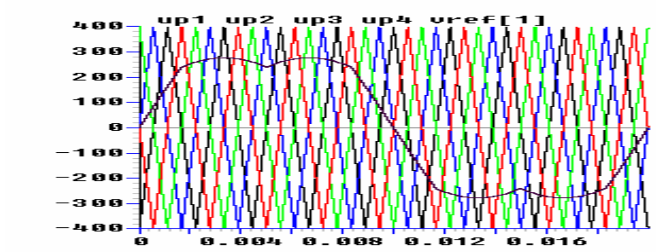


Fig 5: Space vector modulation with four bipolar carriers (m=6, r=0.8).

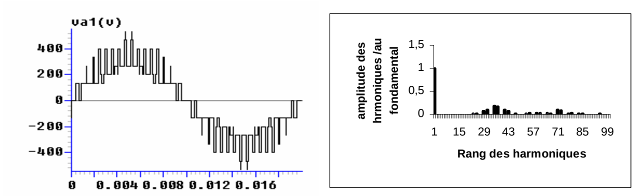


Fig 6: The simple output voltage Va and its spectrum (m= 6, r= 0.8)

We note :
-There is no symmetry for the output voltage. Then, all harmonics exist.
-The harmonics to gather by families centred around frequencies multiples of $4mf = 4f_p$ (with f_p : carrier frequency).
-The first family centred around $4mf$ is the most important in view of amplitude. The rise of the modulation index m lets to push the harmonics towards the high frequencies.

5 Association inverters - DSIM

The figure show a structure of association

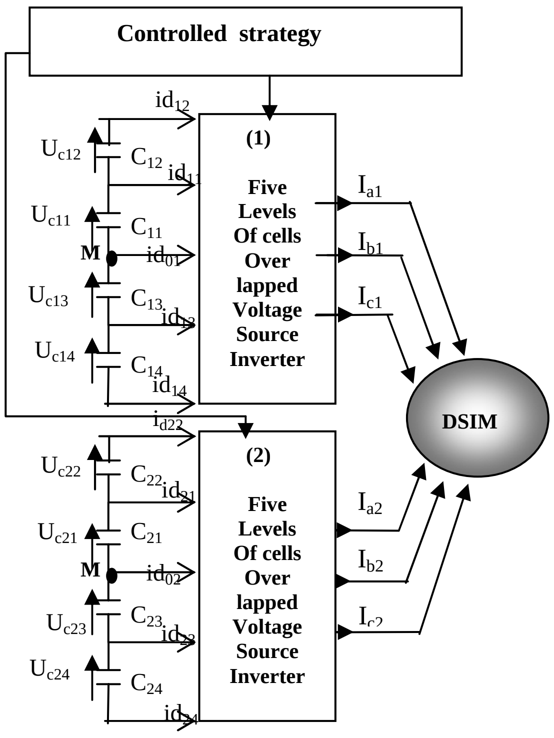
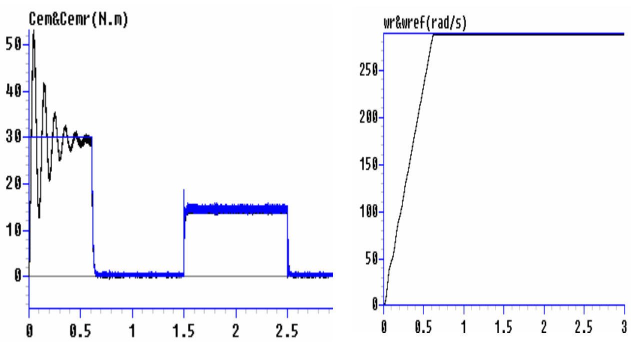


Fig 7: Two five levels of cells overlapped VSI-DSIM.

Figures 8, 9 show the performances of the drive of the DSIM fed by this inverter controlled by the triangulo-sinusoidal and space vector modulation strategies.



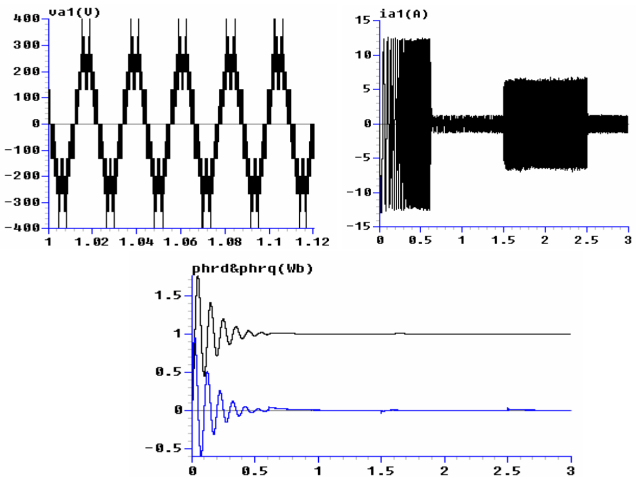


Fig 8: Two five levels of cells overlapped- inverter controlled by triangulo-sinusoidal strategy -DSIM

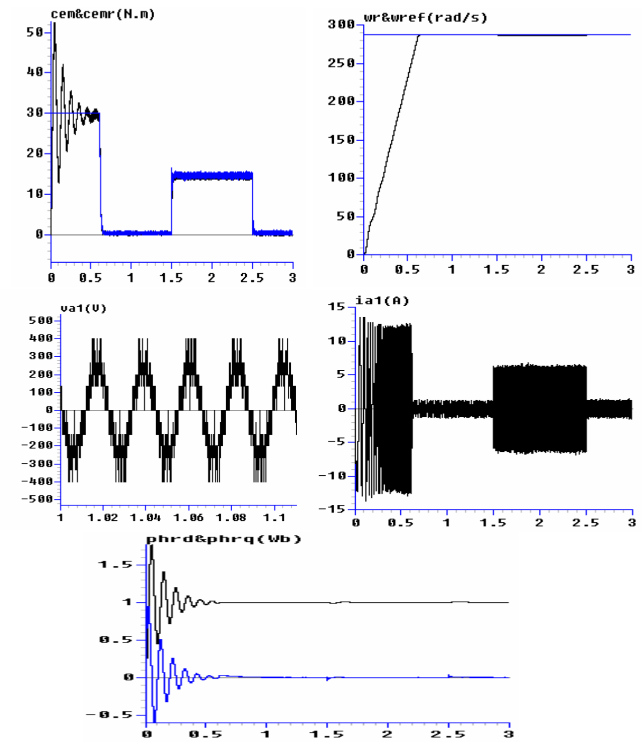


Fig 9: Two five levels of cells overlapped- inverter controlled by space vector modulation strategy -DSIM

for these two strategies, we note:
-The speed and the torque follow quietly their references after 0.62s.
-The voltage and current are practically sinusoidal.
-The flux phrq is practically null, and the flux phrd follow its reference.

6 CONCLUSION:

In is paper, we have developed in the first part the knowledge and control models of the three phases five levels of cells overlapped VSI. We have

proposed two strategies for the control:
-Triangulo-sinusoidal strategy with four carries
-Space vector modulation associated to the triangulo-sinusoidal with four carries.
With the two strategies, the harmonics to gather by families centred around frequencies multiples of 4mf.
The harmonics rate decreases when **r** increases.
The performances obtained with the studied system are full of promise to use it in high voltage and great power applications as electrical traction.

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