The Effect Fault of Inverter Multi Levels on Asynchronous Machine

K.Mendaz, H.Bounoua, A.Bendaoud, Z. Dey

***Abstract*— The voltage source inverter has a diversity known in many industrial applications, such as the variation speed in electrical training. But the characteristic inverter recognized grace of the power electronic development can presented a structural faults, however the closed fault of semiconductors, that can provoke a serious problem for the protection of the system.**

this article presented the diagnostic of the inverters multi levels associates with the three-phase asynchronous squirrel-cage machines witch show the faults of the switches for each inverter multi levels and their influence on the answers of speed and torque.

Index Terms- —**asynchronous machine, fault, inverter five levels, inverters seven levels**

I. Introduction

THE induction machine is largely used in industry, mainly due to its reliability and relatively low cost. The control of the induction machine must take into account machine specificities: the high order of the model, the nonlinear functioning as well as the coupling between the different variables of control. The new industrial applications necessitate speed variations having high dynamic performances, a good precision in permanent regime, and high capacity of overload on all rang of speed and robustness to the different perturbation. The voltage source inverters is consisting a non-controllable function in the power electronic, it is used in the variable methods application. The strategy obtaining by this technique is based on the study of speed variation in induction machine. The strong evolution of this function was based, on the one hand, on the development of semi-conductor components entirely commendable, powerful, robust and fast, and on the other hand, on the quasi generalized use of the techniques known as pulse width modulated (PWM) [1, 2]. The multi levels inverter structural is more adapted in the ground power

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application, because the output voltage and current presented a reduction of the harmonic distortion.

The multi levels inverter can presented a structural fault, however the closed fault of semiconductor. The detection of commutation fault is very difficult because the voltage and current on each commutation fault decrease quickly as well as normally functional. These dysfunctional kinds produce a constraint that can provoke a serious problem for the protection system.

The work presented in this paper is mainly devoted to the effect of the switching fault (semiconductor, condensers) for the multi levels inverter (five and seven level inverter) on the current, torque and speed of induction machine.

II. Structure of the Inverter Five Levels

In order to go up in voltage and power, the conventional inverter on two levels starts with uses replaced by the inverters multi levels in the industrial applications most varied, requiring a great power. The judicious exploitation of the point medium of the continuous source appreciably improves quality of the wave of voltage with dimensions receiver what is advantageous to reduce the torque pulsatory and the losses in the induction machines.

An advantage which rises from this structure consists with the best controls constraints in the components voltage, the amplitude of the terminal voltage is limited to the half voltage of the source raised of has overpressure due to the commutation of the switches.

This topology is able to generate a simple voltage on five levels (between the arm of inverter and the point medium).

In this paragraph we study the structure of the inverter five levels (Figure 1).

This structure is composed of three symmetrical arms consisted each of six switches of series and two others in parallels G_7 and G_8. More two diodes, noted D_9, D_{10} allowing obtaining level zero of the voltage V_{k0} (k=R, S, T). Each one of these switches is composed of a semiconductor bi-commendable and of a diode assembled in teat digs [1, 4, 6, 8, 9].

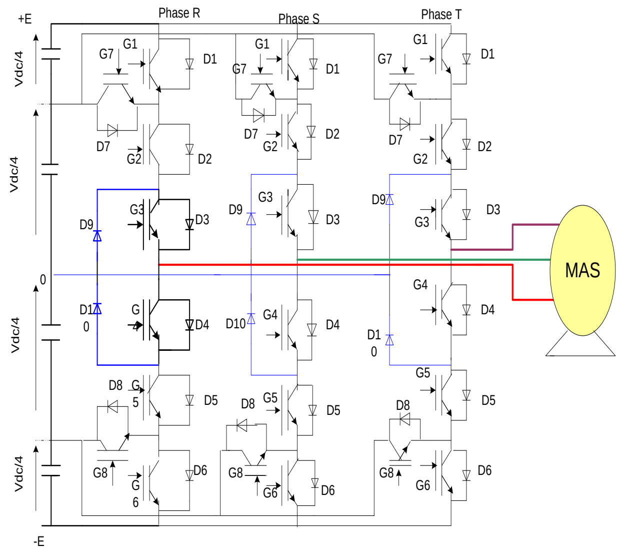


Fig.1. The five levels inverter structural associated with induction machine.

III. FONCTINNEMENT OF THE INVERTER FIVE LEVELS

The three-phase inverter on five levels is shown on the Figure 1, which represents the general diagram of the one of topologies of the three-phase inverters. The source of voltage continuous is consisted association in series of four group of condensers of filtering delivering an intermediate potential with the quarter of the input voltage ($V_{dc}/4=E/2$). A topological analysis for one arm shows five possibility configurations, to define the functional sequences for the five levels inverter, first we defining the states which can take the simple voltage(the voltage between the arm of the inverter and the fictitious point medium), for example. The simple voltage V_{R0} is defined by the state of the eight quadruplets $B_{KS}=[G_K - D_K]$ which can be a transistor, GTO or IGBT with in ant parallel diode. The possible states of only one arm of switch is the $2^5=32$ states which can represent by a quadruplet of 0 and 1 following the state of the quadruplet B_1, B_2, in B_8, only the five states following are possible.

1st configuration $[1 \ \ 1 \ \ 1 \ \ 0 \ \ 0 \ \ 0 \ \ 0 \ \ 0]$:

To have the configuration of the figure (2), it is necessary to command the quadruplets B_1, B_2 and B_3 with state 1 and the others quadruplets remain to 0. The value of simple voltage V_{R0} is given by the equation (1).

$$V_{R0} = (B_2 .\ B_3 .)\frac{V_{dc}}{4} + B_1\frac{V_{dc}}{4} = \frac{V_{dc}}{4} \quad (1)$$

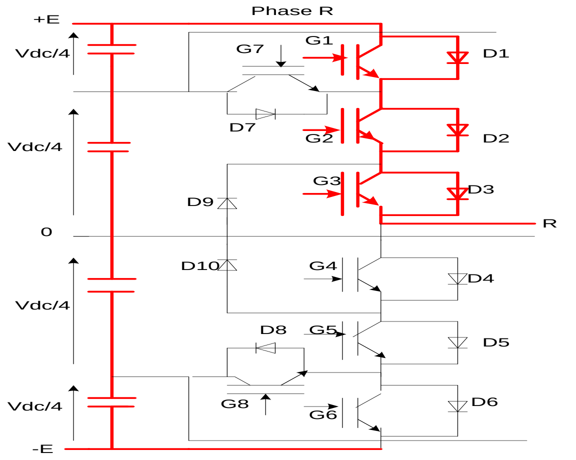


Fig. 2. 1st configuration of 1st arms

2nd configuration $[0 \ \ 1 \ \ 1 \ \ 0 \ \ 0 \ \ 0 \ \ 1 \ \ 0]$:

The figure 3 illustrates the state of the quadruplets in the state 1, necessary to provide the simple voltage V_{R0} which corresponds to this configuration. The equation (2) gives the value of voltage V_{R0}.

$$V_{R0} = (B_2 . B_3 . B_7)\frac{V_{dc}}{4} = \frac{V_{dc}}{4} \quad (2)$$

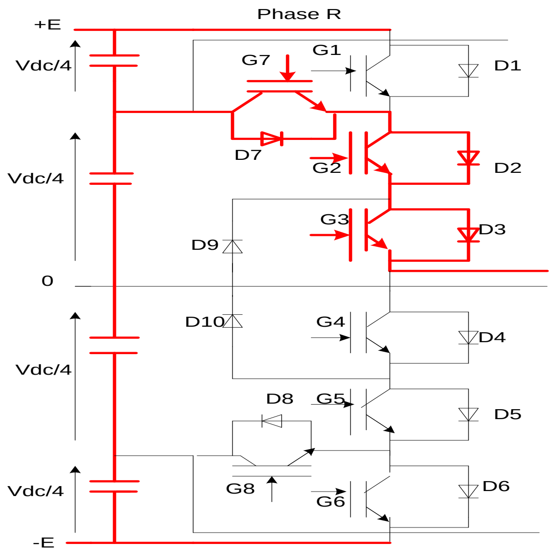


Fig.3. 2 nd configuration of 1st arms

3rd configuration $[0 \ \ 0 \ \ 1 \ \ 1 \ \ 0 \ \ 0 \ \ 0 \ \ 0]$:

This configuration is similar to the three levels inverter. The state of the quadruplets B_3 and B_4, which are in a state 1 necessary to remain the voltage V_{R0} to zero.

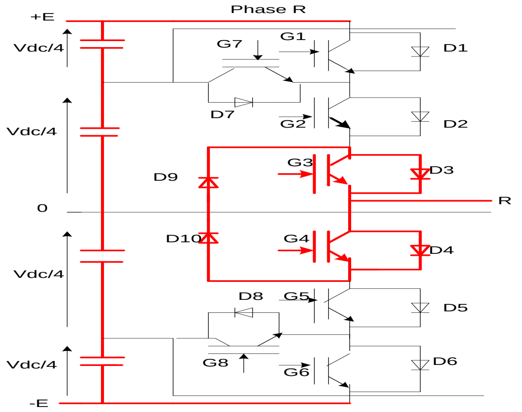


Fig.4. the setting has zero of an arm of the on five levels inverter

4th configuration $\left[0 \quad 0 \quad 0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0\right]$:

This configuration provided the negative part, defined by the state of the quadruplets B_4, B_5 and B_8, which is equal to 1. The equation (3) gives the value of V_{R0}.

$$V_{R0} = -(B_4.B_5.B_8)\frac{V_{dc}}{4} = -\frac{V_{dc}}{4} \tag{3}$$

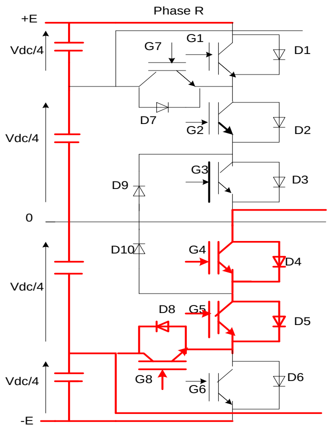


Fig.5. 4 th configuration of 1st arms

5th configuration:

The Fig.6 show the state of the quadruplets B_4, B_5 and B_6 with state 1. The value of voltage V_{R0} is given by the equation (4).

$$V_{R0} = -(B_4.B_5.)\frac{V_{dc}}{4} - B_6\frac{V_{dc}}{4} = -\frac{V_{dc}}{2} \tag{4}$$

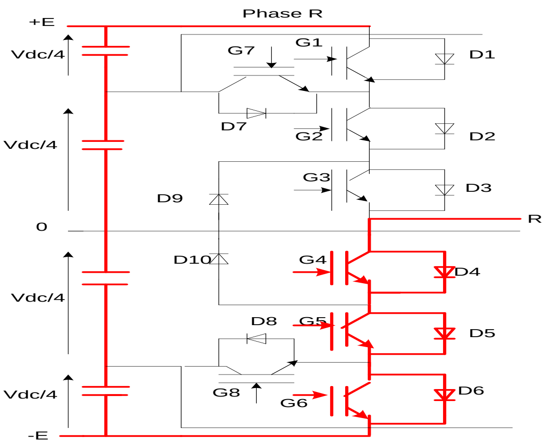


Fig.6. 5th configuration of 1st arms

IV. STRUCTURE OF THE INVERTERS HAS SEVEN LEVELS

The three-phase inverter on seven levels with structure studies in this paragraph consists of three symmetrical arms and six sources of equal continuous voltage. Each arm comprises twelve switches of which eights are in series and four in parallel, like two diodes for the zero setting of the arm of the inverter. Each switch is composed of a GTO and of a diode assembled at the head digs as it is shown in the Fig.7.

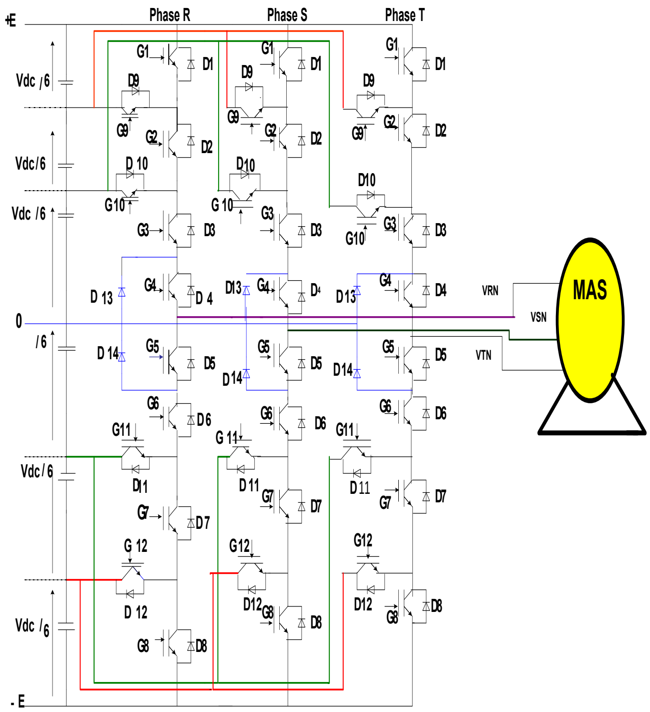


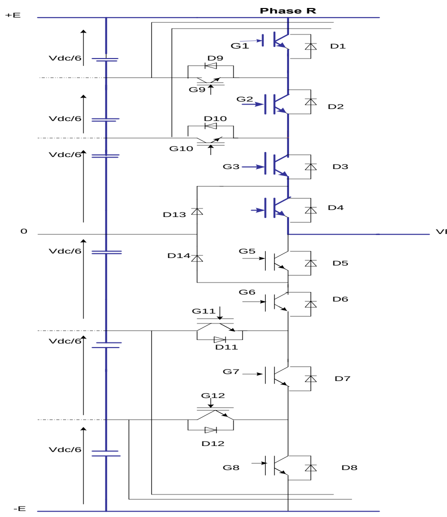
Fig.7. The seven levels inverter structural associated with induction machine.

A topological analysis of an arm of the inverter shows seven possible configurations for this last. These different configurations are represented for the figures 8 to 11.

1st configuration: $\left[1 \quad 1 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0\right]$

To obtain the configuration of the figure (8-a), we command the four switches B_{k1} to B_{k4} on state 1 and the others remain on state 0. Thus, the value of voltage V_{R0} is defined by the equation (5).

$$V_{R0} = (B_3.B_4.)\frac{E}{3} + B_2\frac{E}{3} + B_1\frac{E}{3} = \frac{V_{dc}}{2} \tag{5}$$



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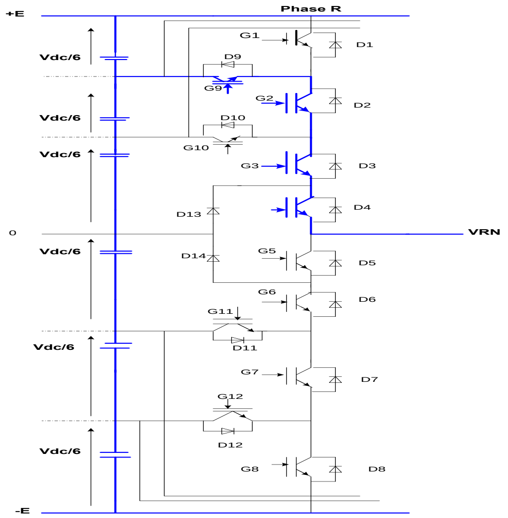
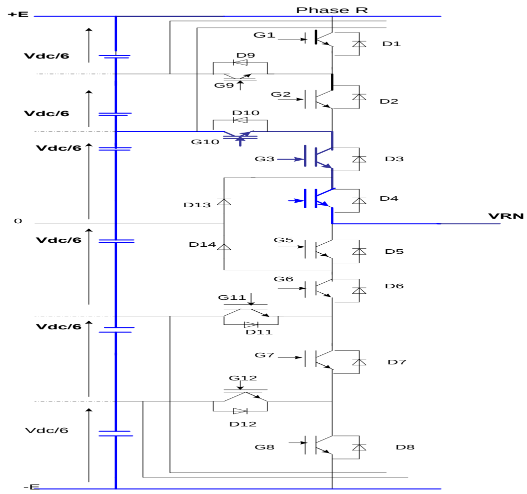


(b)

Fig.8. Different configurations from an arm of levels inverter seven



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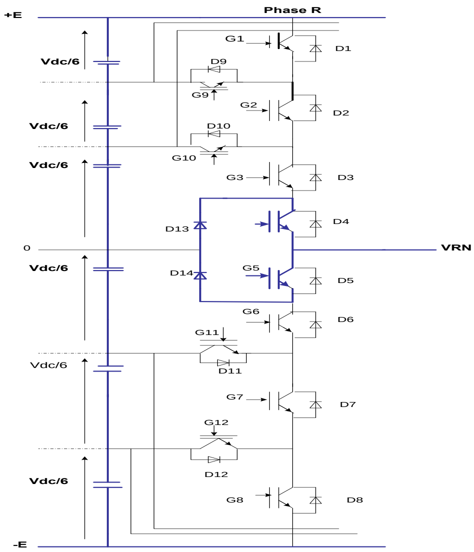

(b)

Fig.9. Different configurations from an arm of seven levels inverter

2[nd]configuration: $\begin{bmatrix}0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\end{bmatrix}$

This configuration is represented by the figure (8-b), which you can command the switches B_2, B_3, B_4 and B_9, on state 1 and others on state 0. The equation (6) gives the value of voltage V_{R0} as follows.

$$V_{R0} = (B_3.B_4.)\frac{E}{3} + (B_2.B_9)\frac{E}{3} = \frac{2E}{3} = \frac{V_{dc}}{3} \qquad (6)$$

3[rd] configuration :

$\begin{bmatrix}0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0\end{bmatrix}$

This configuration is represented by the figure (9.a), which the switching's B_3, B_4 and B_{10} was command on state 1 and the other switches on state 0. The value of voltage V_{R0} is given by the equation (7).

$$V_{R0} = (B_3.B_4.B_{10})\frac{E}{3} = \frac{E}{3} = \frac{V_{dc}}{6} \qquad (7)$$

4[th] configuration : $\begin{bmatrix}0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0\end{bmatrix}$

It is the setting zero phase of the arm for the inverter, where the diodes D_{13}et D_{14} return in conduction to secured the streaming of the current. Voltage V_{R0} takes value 0.

5[th] configuration : $\begin{bmatrix}0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0\end{bmatrix}$

The configuration of the figure (10-a) necessary the command of switchers on state 1 for formed the negative part of voltage V_{R0}, this configuration is translated by the equation (8).

$$V_{R0} = (B_5.B_6.B_{11})(-\frac{E}{3}) = -\frac{E}{3} = -\frac{V_{dc}}{6} \qquad (8)$$

6[th] configuration: $\begin{bmatrix}0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1\end{bmatrix}$

The configuration of the figure (10-b) necessary the command of switchers B_5, B_6, $B_7$and B_{12}; they must be on state 1 and the other on state 0. The equation (9) gives the value of voltage V_{R0} as follows.

$$V_{R0} = (B_5.B_6)(-\frac{E}{3}) + (B_7 B_{12})(-\frac{E}{3}) = -\frac{2E}{3} = -\frac{V_{dc}}{3} \qquad (9)$$

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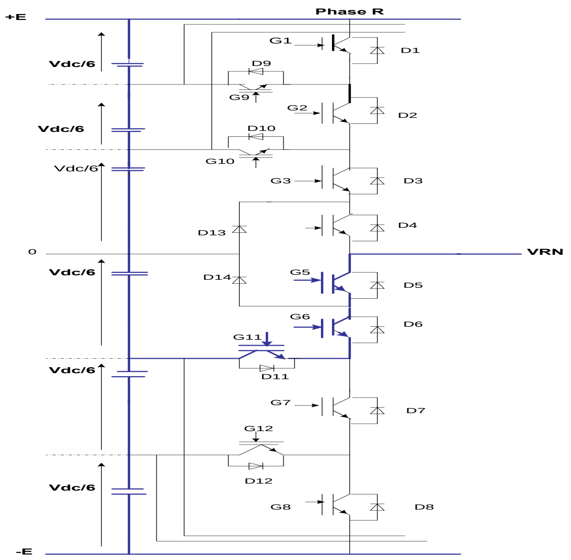

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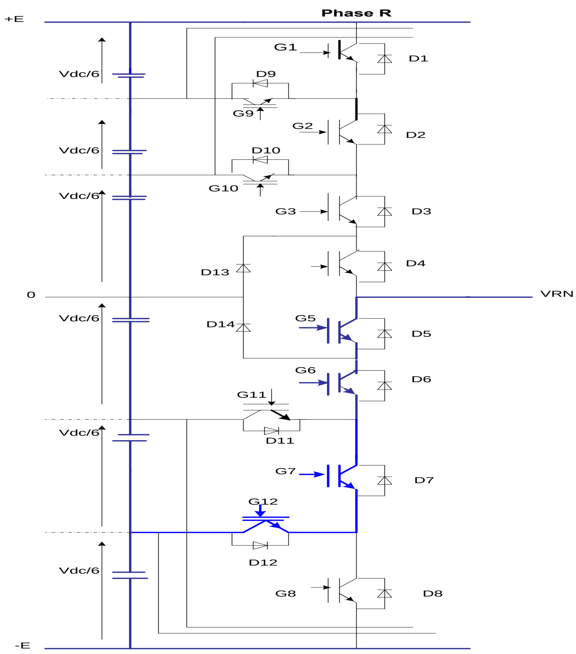


(b)

Fig.10. Different configurations from an arm of seven levels inverter

$$7^{th}\text{ configuration}: \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

This configuration produced the filled up voltage - E, the conduction switchers was B_5, B_9, B_7 and B_8, but remainder switchers was on blocked state and the voltage V_{R0} is given by the equation (10).

$$V_{R0} = (B_5.B_6)(-\frac{E}{3}) + B_7(-\frac{E}{3}) + B_8(\frac{-E}{3}) = -E = -\frac{V_{dc}}{2} \tag{10}$$

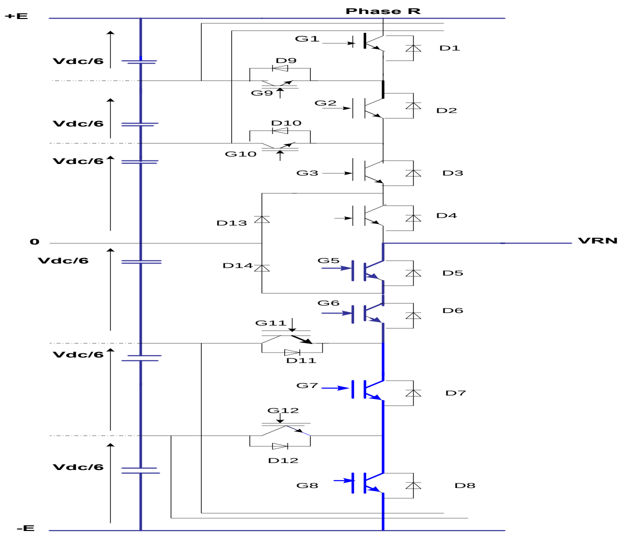


Fig.11. Application of a complete and negative voltage

V. DIAGNOSTICS FAULTS OF INVERTER MULTI LEVELS

The application domains of the three-phase inverters of voltage most known in industry are undoubtedly that of the electric drives at variable speed. The three-phase inverters, in spite of their qualities, which have pusses to reach thanks to the development of the power electronics, and the use quasi-generalized of the techniques known as of "pulse width modulation", can present a structural fault such as the fault of closing of the semiconductors. This type of induced dysfunction of the constraints can be damages for the systems of production if the personnel are not informed and that a spurious shutdown is produced. Since, the equipment of protection intervenes only at the last stage of fault; it is thus obvious, that the investment in the field of the detection of the dysfunctions appears a solution impossible to circumvent. Many faults of the inverters multi levels is detected by using overpressures and the over currents of current system. However, the detection of fault of the elements of commutation is very difficult because the voltage and the current according to each fault of commutation decrease quickly compared to the normal functioning. The disequilibrium of the continuous voltage at the input of the inverter multi levels, as the faults occur, causes serious problem for the protection and the reliability of the system [2,3,5].

A) - DIAGNOSTICS FAULTS OF INVERTER FIVE LEVELS

In the inverter five levels, the phases voltage have fifteen levels under symmetrical functional, but their voltage levels seem to be different with each fault commutation. The phase voltage for the positive period has only five levels because the phase current transits the switch K_{17} replacing the switch k_{11} in the positive state (P). In the event of commutation fault of switch k_{12}, the phase voltage for the positive period has only three levels because the phase current transits the switch K_{13} in the positive state. Consequently when each commutation

fault occurs, the fictitious phase voltage was differently between them.
The fault of K_{17} and K_{12} induces a disequilibrium in the three phases, which translates by the discharge of the lower condensers of the arm R for the five levels inverter. [2,3,5,7,8]
K_{12}: the switch of first arm (phase R) composed for $[G_2, D_2]$
K_{11}: the switch of first arm (phase R) composed for $[G_1, D_1]$
K_{13}: the switch of first arm (phase R) composed for $[G_3, D_3]$
K_{17}: the switch of first arm (phase R) composed for $[G_7, G_7]$

B) - DIAGNOSTICS FAULTS OF INVERTER SEVEN LEVELS

In the seven levels inverter, the phase voltage represented twenty and one levels under symmetrical functional, but their levels of voltage identical to be different for each commutation fault. The phase voltage in the positive period has only eight levels because the phase current transits the switch K_{19} replacing K_{11} in positive state. In the event commutation faults of K_{110}, the phase voltage for the positive period has only six levels because the phase current transits the switch K_{110} in positive state. In the event of commutation faults of K_{13}, the phase voltage for the positive period has only four levels because the phase current transits the switch K_{14} in the positive state. Consequent the production of each commutation fault make the fictive phase voltage differently with them [2,5,6].
K_{110}: the switch of first arm (phase R) composed for $[G_{10}, D_{10}]$
K_{11}: the switch of first arm (phase R) composed for $[G_1, D_1]$
K_{13}: the switch of first arm (phase R) composed for $[G_3, D_3]$
K_{14}: the switch of first arm (phase R) composed for $[G_4, D_4]$

VI. RESULT SIMULATION

For showing the performance of multi levels inverter (five and seven level inverter), a simulation was elaborated on Matlab/Simulink for the induction machine associated with multi levels inverter.

For the inverter five levels the form of V_{an} voltage and the current of the arm I_R illustrated by the Fig.12 that notice how the faults of this switcher K_{12} induces an disequilibrium on these currents and voltage.
The currents I_{sa}, I_{ra} resulting from the faults of the switcher K_{12}, illustrated by the figure 14, which shows the effect of these faults on disequilibrium of the currents. During the fault of the switcher K_{12} we remark an augmentation of speed and oscillations of the torque but after this oscillation the speed decreased, which illustrated by the Fig.13.

For the inverter seven levels the form of V_{an} voltage and the current of the arm I_R In the faults of the switcher K_{19} at time (1s, 1.5s) represented by the Fig.15., that shown the disequilibrium of these voltages and current. The currents I_{sa}, I_{ra} of induction machine resulting from the faults of the switcher K_{19} for seven levels inverter illustrated by the Fig.17., that notice how the faults of this switcher K_{19} induces an disequilibrium on these currents. The Fig.16. show the conduit of the asynchronous machine, during and after the fault which are translated by an incensement of speed and oscillations of the torque. After this fault we have a decreasement of speed. If they have a production of the fault in the seven and five levels inverter, the current deporting in the medium point caused a ground effect in the charge/discharges condensers variation. The fault in high switchers, produce an incensement in lower discharges condensers and the voltage level appear to be different for each switching fault, this disadvantage of seven and five levels inverter have an influence on the induction machine (effect of the fault on speed, electromagnetic torque, statoric current and rotoric current of induction machine).

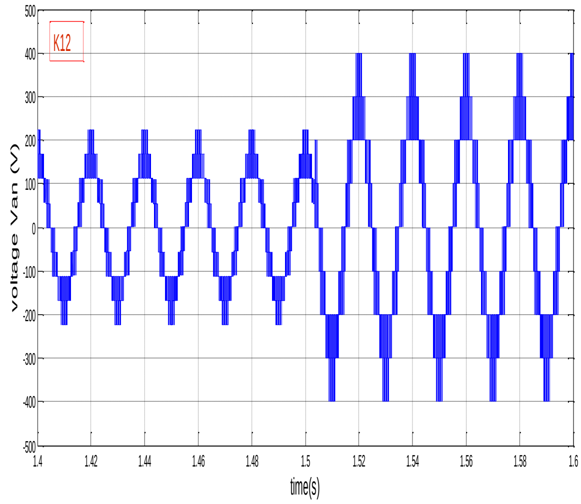


Fig.12. the voltage results Van of inverter five levels with fault in switch K12 a t (1.4, 1.5)

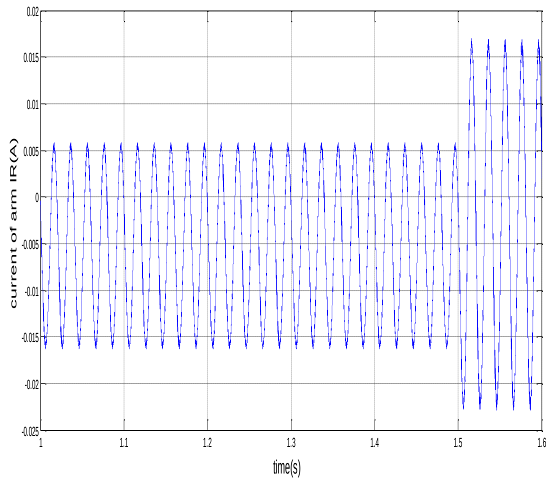
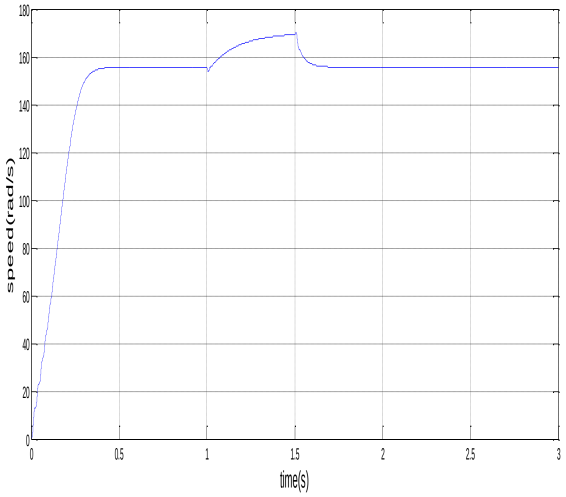


Fig.13. the current arm I_R results of inverter five levels with fault in switch K_{12} at t (1, 1.5)



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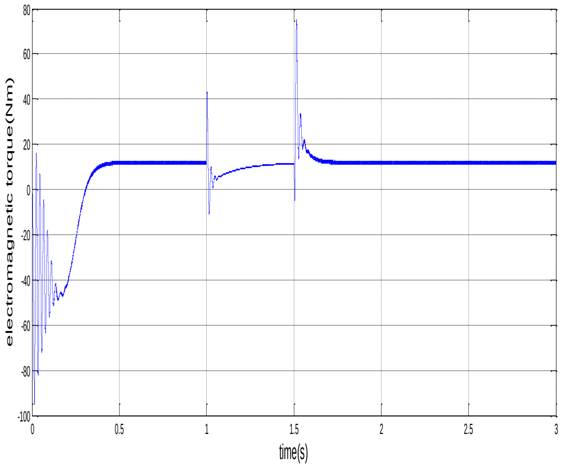

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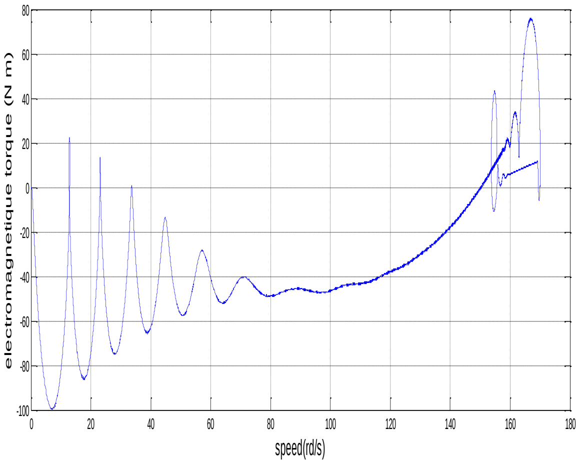
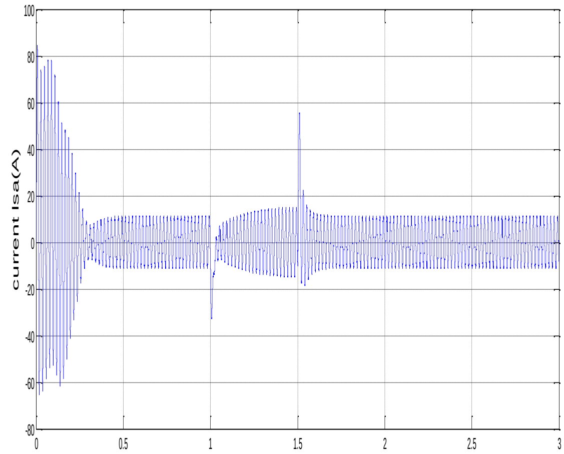


(c)

Fig.14. Speed, electromagnetic torque and speed according to torque results of association induction machine -inverter five levels with fault in switch K_{12} at t (1, 1.5) of



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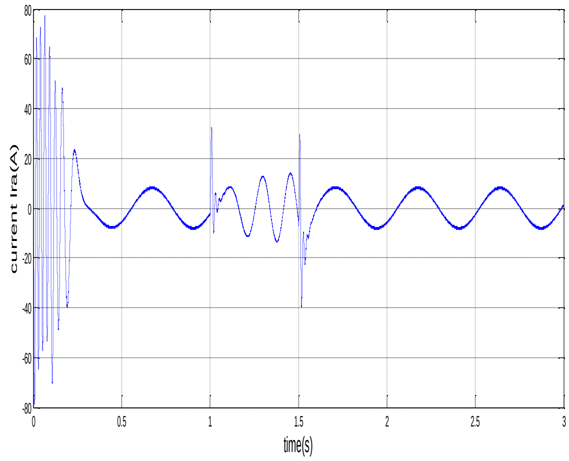

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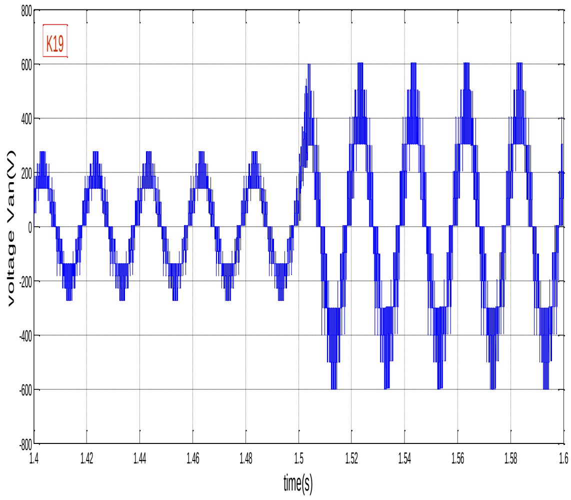
Fig.15. the current I_{sa}, I_{ra} results of association induction machine inverter five levels with fault in switch K_{12} at t (1, 1.5)



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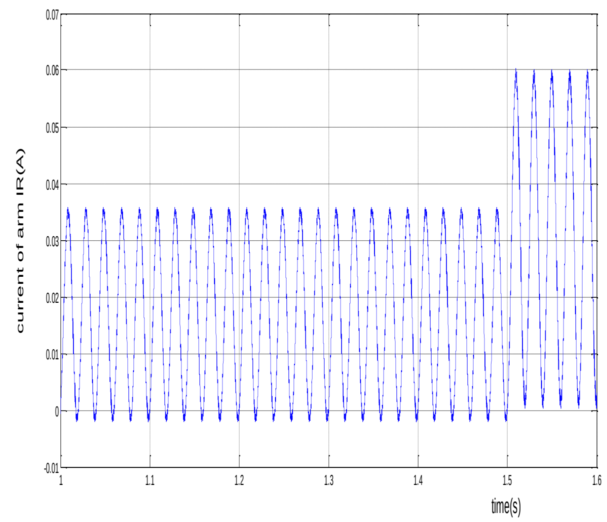

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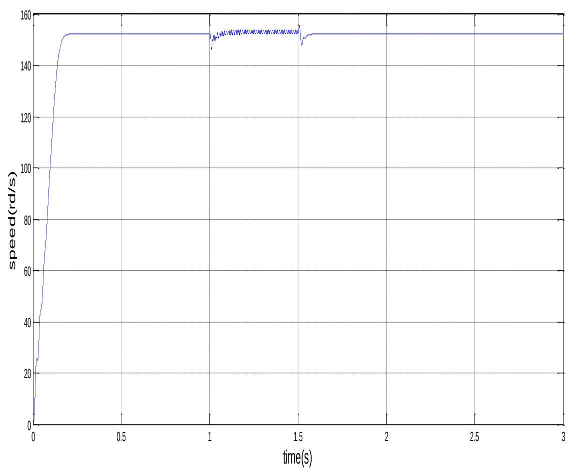
Fig.16. the voltage and current results V_{an}, I_R (current of the arm R) of inverter seven levels with fault in switch K_{19} a t (1, 1.5)



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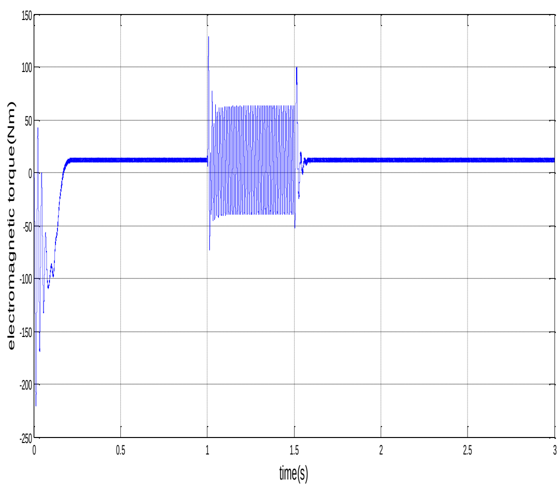

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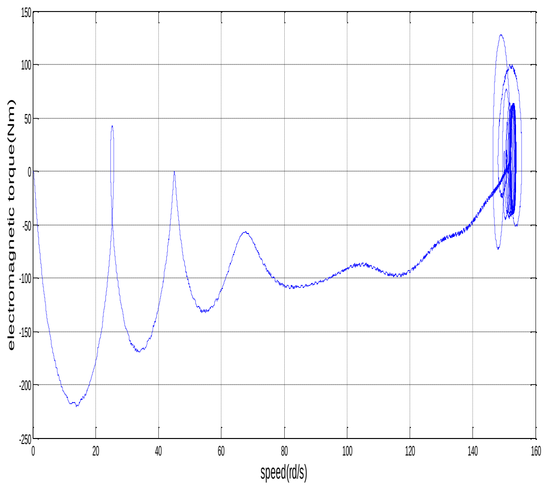
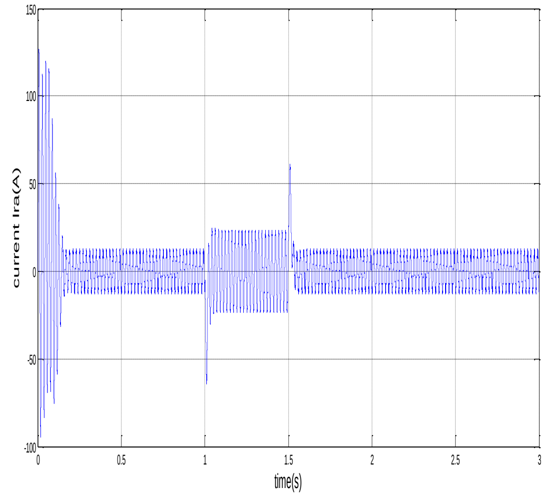


Fig.17. Speed, electromagnetic torque and speed according to torque results of association induction machine -inverter seven levels with fault in switch K_{19} at t (1, 1.5)



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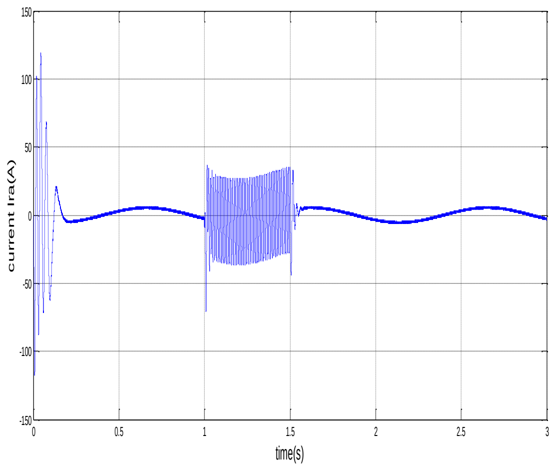

(b)

Fig.18. the current Isa, Ira results of association induction machine inverter seven levels with fault in switch K19 at t (1, 1.5)

VII. CONCLUSION

We elaborate a new functional model of the three-phase inverter with five and seven levels. That shows the contribution of the inverters multi levels for the improvement of the performances of the asynchronous machine.

The presented fault of the inverter five and seven levels proposes the following advantage; the diagnostic of fault can easily identify each fault of commutation.

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