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Stability of Electrical Drives Supplied by a Three Level Inverter

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***Abstract*—**The development of the power electronics has allowed increasing the precision and reliability of the electrical devices, thanks to the adjustable inverters, as the Pulse Wide Modulation (PWM) applied to the three level inverters, which is the object of this study. The authors treat the relation between the law order adopted for a given system and the oscillations of the electrical and mechanical parameters of which the tolerance depends on the process with which they are integrated (paper factory, lifting of the heavy loads, etc.).Thus, the best choice of the regulation indexes allows us to achieve stability and safety training without investment (management of existing equipment). The optimal behavior of any electric device can be achieved by the minimization of the stored electrical and mechanical energy.

***Keywords*—**Multi level inverter, PWM, Harmonics, oscillation, control.

I. Introduction

WITH the technological evolution of the electronics of the semi conductors, the non-traditional customer loads ,such as Adjustable speed drivers [5], are being applied in increasing numbers due to the improved efficiencies and flexibility that can be achieved [10].

A notable trend in power electronics in recent years has been the widespread use of power semiconductor devises such us: power transistors; gate turn off thyristors (GTO) and Mosfet transistor devises witch contribute in the improvement of power electronic quality systems by employing advanced power control strategies [12].

In fixed and variable frequency inverter power supplies, the increase of gate turn off thyristor capacity, permitted to get voltage source PWM inverter, as a variable means of power control [15],[8], providing the facility to adjust the output voltage and frequency with simultaneous attenuation of several lower order harmonics [7] .

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The DC link voltage of a conventional GTO inverter is about 2000 v. Since the DC link voltage of large capacity inverter is up 4000 v [5]; from where the incompatibility of the existing GTO with this mode of link. For the inverter configuration whose DC link voltages are up to 4000 v, we use the series connected GTO inverter [2]; of which the phase difference between the two PWM carriers in the inverters is 180°. Harmonic components of the output voltage, that is an average voltage of the two inverters, are smaller than those of the single inverter [9]. Another configuration of the high voltage inverter, is a three level inverter Fig. 1, it guarantees equal voltage sharing of series connected GTO's, and harmonic components of the output voltage is less than those of the conventional inverters (two level inverters) [6] [3].

II. Multi Level Inverter Principle

The economic considerations, of this work is the reduction of circuit control, therefore at the difference of the other works having the same orientation, we propose to use only one carrier for the three phases simultaneously, unfortunately this consideration limits us in the choice of the frequency, that must obey to the law,

$$fc=m/T \quad \text{with} \quad m=k*6 . \quad , k=1,2,3,\ldots,n$$

in order to avoid the creation of others even and non feature harmonics. The principle of GTO's switching remain the same [16], where we show on the table, the different sequences of switching as well as the corresponding three level voltages [13].

TABLE I
SWITCHING SEQUENCES OF GTOS

Bk1	Bk2	BK3	BK4	Vkm
Off	Off	On	On	-Uc/2
On	On	Off	Off	Uc/2
On	Off	On	Off	0

Bki: trigger control of the GTO Gtki of the leg k

Each breaker G_{DKS} $\left(K \in \{1,2,3\}, S \in \{1,2,3,4\}\right)$ is ordered by the function F_{KS}. This function can take two values 0 or 1, so 1 if on and 0 when off. This function can be generalised for the inverter leg as:

$$F_{kS}^{down} = \overline{F_{kS}^{up}} \text{ , k is the leg number}$$

According to these relations we found:

$$V_{AB} = V_{AM} - V_{BM} = \left(F_{11}^{up} . F_{12}^{up} - F_{21}^{up} . F_{22}^{up}\right) U_{c1} - \left(F_{13}^{down} . F_{14}^{down} - F_{23}^{down} . F_{24}^{down}\right) . U_{c2}$$

$$V_{BC} = V_{BM} - V_{CM} = \left(F_{11}^{up} . F_{12}^{up} - F_{31}^{up} . F_{32}^{up}\right) U_{c1} - \left(F_{23}^{down} . F_{24}^{down} - F_{33}^{down} . F_{34}^{down}\right) . U_{c2}$$

$$V_{CA} = V_{CM} - V_{AM} = \left(F_{31}^{up} . F_{32}^{up} - F_{11}^{up} . F_{12}^{up}\right) U_{c1} - \left(F_{33}^{down} . F_{34}^{down} - F_{13}^{down} . F_{14}^{down}\right) . U_{c2}$$

Following this development, we write the potential at point A, B and C:

$$\begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} F_1^{up} & - & F_1^{down} \\ F_2^{up} & - & F_2^{down} \\ F_3^{up} & - & F_3^{down} \end{bmatrix} E_C / 2$$

The three single voltages of output inverter are:

$$V_A = \left(2V_{AM} - V_{BM} - V_{CM}\right)/3$$

$$V_B = \left(-V_{AM} + 2V_{BM} - V_{CM}\right)/3$$

$$V_C = \left(-V_{AM} - V_{BM} + 2V_{CM}\right)/3$$

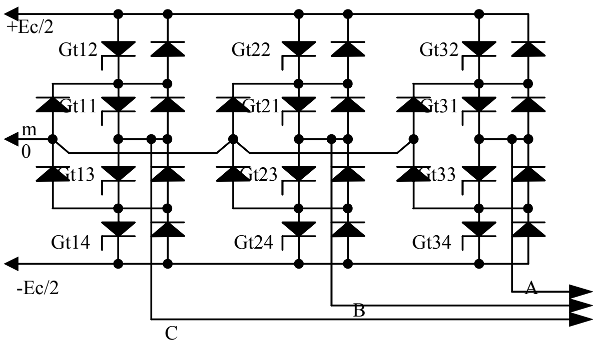


Fig. 1 Three level inverter Configuration

The simulation model Fig. 2 of the inverter supplying an induction motor (IM) see Annex is done by varying r & m. This type of inverter offer 27 possible out put voltage levels [4] Fig. 2, the time of its application define the RMS inverter out put voltage Fig. 4.

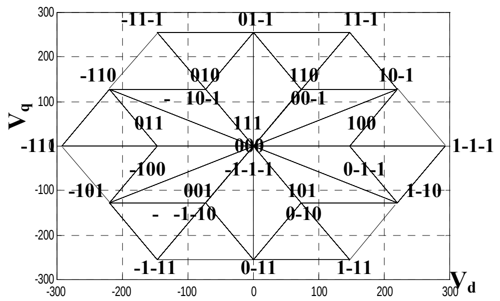


Fig. 3 Voltage sequences of a three level inverter in DQ

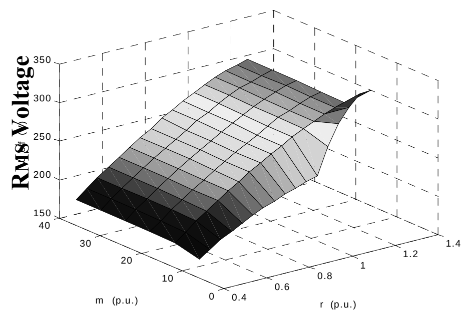


Fig. 4 Variation of RMS the inverter output voltage according to r and m

III. SIMULATION RESULTS

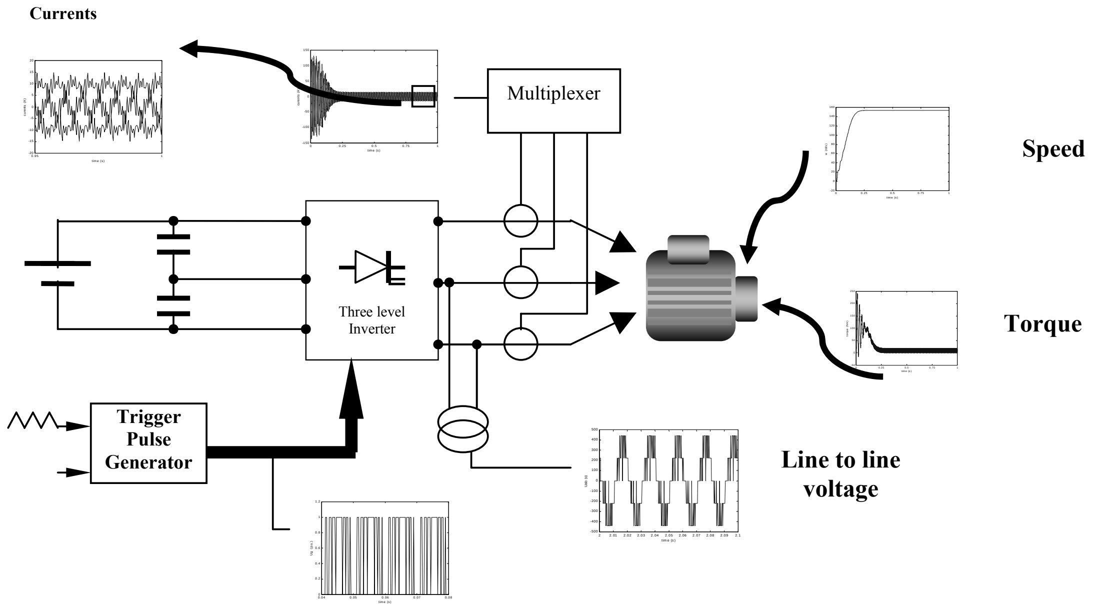


Fig. 2 Model simulation

The other inverter improvements is the Total Harmonic Distortion (THD) witch depends on the choice of r and m simultaneously Fig. 5.

So for the voltage inverter out put

$$THD_V = 100.\sqrt{\sum_{H=2}^{n} U_H{}^2} / U_1\%$$

And for the load current

$$THD_I = 100.\sqrt{\sum_{H=2}^{n} I_H{}^2} / I_1\%$$

Where:

- I_1 and U_1 are respectively the fundamental current and voltage
- I_H and U_H are respectively the harmonic current and voltage

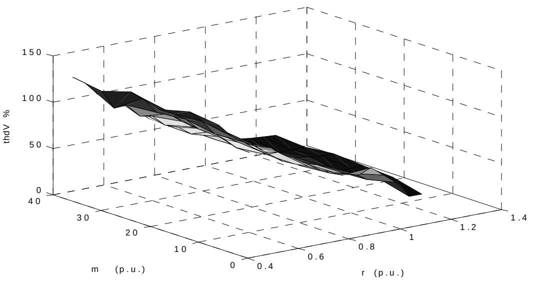


Fig. 5 Harmonic spectrum voltage

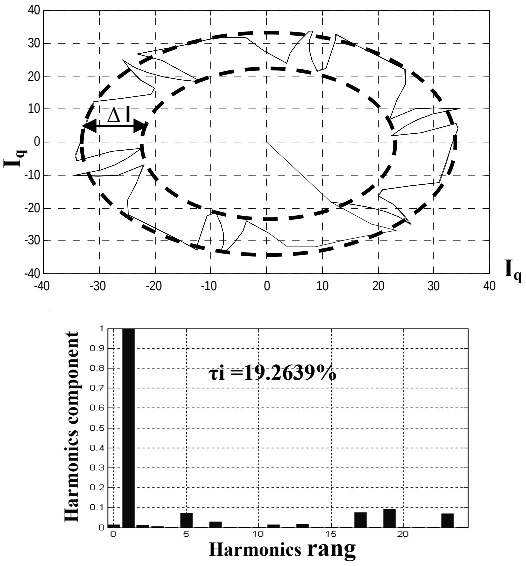


Fig. 6 Current and corresponding harmonics delivered by three level inverter to an IM

The Fig. 6 is a very important representation because it informs us directly and clearly, about the harmonics content that is proportional to the thickness of the ring ΔI, which delimits the superior and lower values, since in sinusoidal operation this one is perfectly circular or elliptic, according to the working mode of the load.

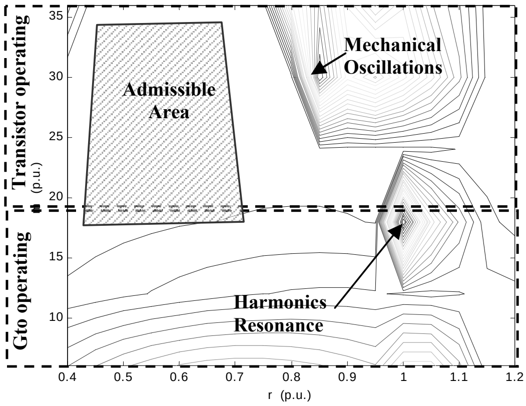


Fig. 7 Influence of the regulating indexes on speed oscillations of the IM rotor

The mechanical characteristics are also influenced by the variations of r and m Fig. 7, where the working without intolerable friction is delimited in the hatched domain that goes imposed us another restriction of r which depends on the technological process where the motor is submitted [11].

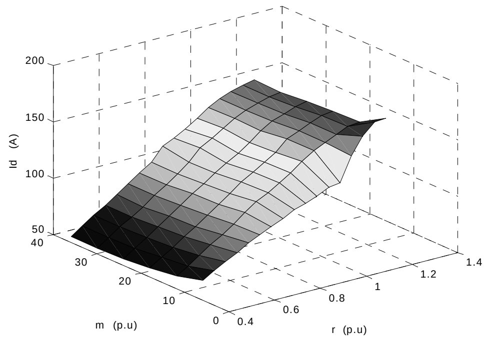


Fig. 8 Variation of the starting current of the IM according to r and m

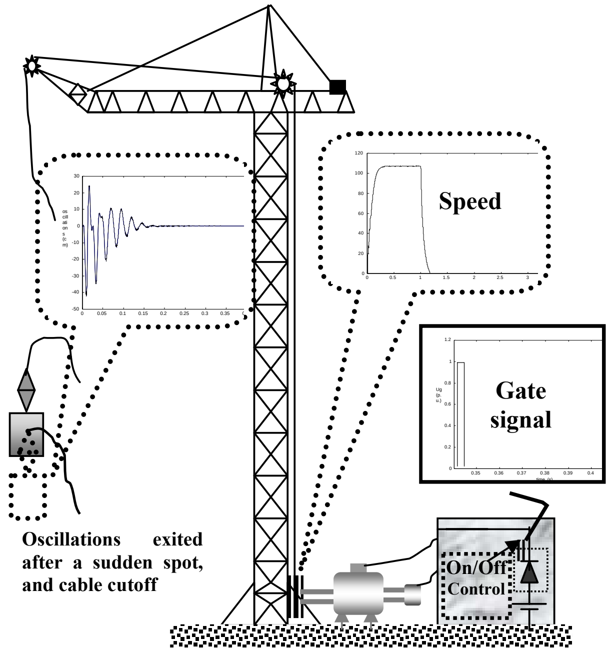
IV. Progressive Starting & Braking

A. Starting of the Large Power Engine

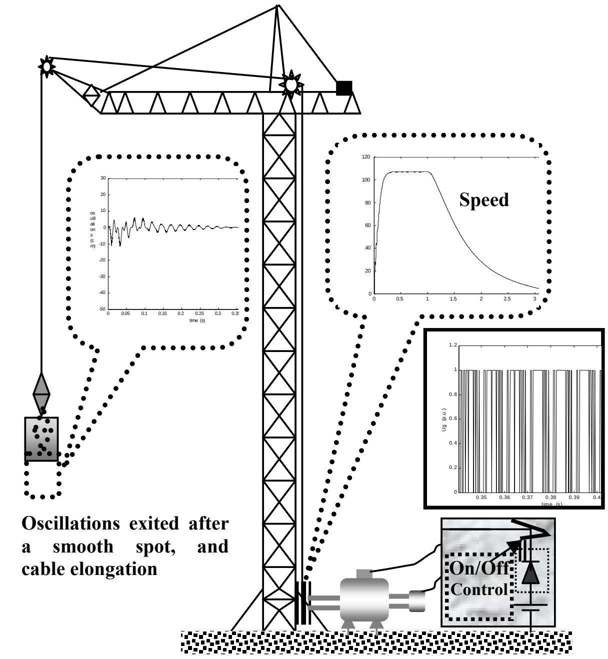
Sweet starting can be obtained with r control, for asynchronous machines of large power [1], beyond 100 kw the Y/Δ starting would be impossible, because of the strong commutation current, therefore one often uses the starting resistors, which reduces the efficiency and requires more space [11]. From where it is judged useful to orient these techniques toward the progressive starting that allows us more efficiency and flexibility Fig. 8 (adjustment of the starting time, and starting voltages if need be). According to Fig. 8 we show, that the dependence of Id in relation with r is important from where the idea of the progressive starting.

B. Braking of Heavier Load

The principle of the progressive starting explained higher can be as well very useful in the starting that in the braking of the lifting facilities; whose brusque braking can cause some incidents engraves the side facilities and personal Fig. 9, because the sudden stop of a load suspended by steel cables stimulates oscillations that risk either: the rupture of the cables, or the laxity of the load in free fall.



a/ sudden braking



b/ smooth braking

Fig. 9 Lifting of heavier load process

V. Conclusion

The operating mode of a three level inverter is limited in [0,8: 0,95] for regulating index r and for modulation index m not passing 18 p.u., what corresponds well to the superior limits of the GTOs, currently marketable.

The optimum for every inverter depends as well as r and m indexes, characterizing the law of control that the technological process in witch the machine is submitted. So the control area given by r & m is limited according to the devise sensitivity.

Hence the excitation or the attenuation of frictions (whose tolerance depends on the load nature) can be adjusted by the simultaneous choice of r and m. The magnification of these frictions can be seen in different zones: the first peak corresponds to the weak values of m (GTOs operation) can be explained by the interference of harmonic currents. On the other hand the corresponding peak to the high values of m (transistors operation) doesn't have the same reason because the rate of harmonic is reduce, therefore, in this case, it brings closer the electromechanical resonance.

This study also allowed us to show as well the limits of three level converter supplying an asynchronous machine, that the influence of r, on the progressive starting, lifting heavy loads, can give economic and safety in industry works.

Appendix

Squirrel Motor features: 400 V, 50 Hz, 2.24 Kw, 1500 Rpm, R1=0.435Ω, L1=1,6 mH, R'2=0.16 Ω, L2=2,4 mH, Lm=59,31 mH.

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