STUDY FOR A MECHANISM AIDED BY ASYNCHRONOUS ACTUATOR POWERED BY ASYNCHRONOUS DIESEL GENERATOR

H.Meglouli [a] , B. Ikhlef [b]

[a] Research Laboratory of industrial electrification
[b] Research Laboratory of applied automatic
Faculty of hydrocarbons and chemicals.
University of Boumerdes

[a]hmeglouli@yahoo.fr, [b]blm_ikhlef@yahoo.fr

ABSTRACT

The modern electric facilities are equipped by a great number of different mechanisms and devices activator by Asynchronous electric Motor (ASM), the power of these motors is equal to the power of the generating devices, where their most complicated working regime is the starting when their power is equal to the power of the generating devices.

In this regime we can have an overcharge of the generating devices by the active and reactive power.

For this reason, this article is dedicated to the study of the starting methods of asynchronous motors that action the mechanisms and that are powered by Asynchronous Generating Diesel (AGD) with a limited capacity of DRY value and a given couple of resistance.

Keywords: Reliability, Autonomous asynchronous generator, starting of the asynchronous motors, Tension converter.

1. INTRODUCTION

There are several factors that considerably influence the characteristics of the asynchronous motors starting process from a AGD, amongst these factor:

-The initial conditions of the process,

- The oscillation of frequency and amplitude of the AGD tension, - The non linear character of the electric machines parameters used as an activator motor for the generator,

-The mechanisms resistant couple.

If we take into account these factors, the study of the transient regime in the AGD-ASM system using analytical methods will be complex and will induce high calculations uncertainties. In this article, we will study the analysis of the regimes dynamics of the starting from AGD of mechanisms with asynchronous electric activator using a numerical method to achieve a given precision of the calculations.

2. MATHEMATICAL MODEL OF THE STARTING REGIME OF MECHANISMS WITH ASYNCHRONOUS ACTIVATOR POWERED BY AGD

2.1. General characteristic of the model

Studies performed previously have shown that for a complete analysis of the common operating regime of AGD and ASM, it is necessary that the mathematical model takes into account the review of the transient regimes for the direct starting of the motor, the starting through an auxiliary resistance in the statoric circuit as well as the starting through the Tension Converters with Thyristors (TCT). In addition to considering the electromagnetic systems properties, the supplying of the consumers by a three-phased tension under neutral line, the necessity in a large interval of the regulation of the key elements starting angle value (because the activating mechanisms has the same power that the generator) In the mathematical model, the functioning of the TCT of 3TT type that is composed of two thyristors connected head to foot in every phase of the supplying line is described.

2.2. Mathematical model of the asynchronous motor with short-circuited rotor.

In order to study the operating regime of ASM with the auxiliary elements connected to its statoric coil, we have to write the composed differential equations in relation to the statoric current and to the rotoric hooking flux in a simple shape, in the (α, β, σ) coordinate system.

The ASM equations are the folowing:

$$\frac{di_{\alpha M}}{d\tau} = \left[U_\alpha - R_{SM} i_{\alpha M} - L_1 (r_{rM} L_1 . L_{\alpha M} - T_1 \psi_{\alpha M} - w_{rM} \psi_{\beta M}\right] \cdot \frac{1}{L_S \Sigma}$$

$$\frac{di_{\beta M}}{d\tau} = \left[U_\beta - R_{SM} i_{\beta M} - L_1 (r_{rM} L_1 . L_{\beta M} - T_1 \psi_{\beta M} - w_{rM} \psi_{\alpha M}\right] \cdot \frac{1}{L_S \Sigma}$$

$$\frac{d\psi_{\alpha M}}{d\tau} = r_{rM} L_1 . i_{\alpha M} - T_1 \psi_{\alpha M} - w_{pM} \psi_{\beta M}$$

$$\frac{d\psi_{\beta M}}{d\tau} = r_{rM} L_1 . i_{\beta M} - T_1 \psi_{\beta M} - w_{rM} \psi_{\alpha m}$$

where :

$$R_{sM} = r_{rM} + R_n$$

$$L_{s\Sigma} = L_{sM} + L_n$$

$$L_1 = \frac{L}{L_{mM} + L_{rM}}$$

$$T_1 = \frac{r_{rM}}{L_{mM} + L_{rM}}$$

L_{rM} and L_{sM} :ASM's rotoric and statoric flux scattering inductances.

L_n **:** Inductance of the auxiliary resistance.

L_{mM} **:**Mutual inductance of the ASM's statoric and rotoric coils .

w_{rM} :The pulsation of the ASM's rotor rotation speed.

i_M : ASM statoric current .

ψ_M :Hooking flux of the ASM's rotor

The calculation of the transient regime in the ASM is performed in a relative units system, the nominal current amplitudes and the generator tension are taken as basis value, the basis time is the same for the processes calculation. The instantaneous values of the motor current in the generator relative units system are transformed using of the transfer coefficients

$$K_\sigma = \frac{i_{\sigma M}}{i_{\sigma G}}$$

$i_{\sigma M}$ and $i_{\sigma G}$: Basis values of the currents in the motor and the generator relative units system.

The electromagnetic couple developed by ASM is determined by the formula (2):

$$C_M = \psi_{\alpha M}.i_{\beta M} - \psi_{\beta M}.i_{\alpha M}$$

The equation of the movement of the mechanism axis that action the ASM is:

$$\frac{dw_{rM}}{d\tau} = \frac{1}{J\Sigma}\left(C_M - \frac{C_{cM}}{C_{\sigma M}}\right)$$

J_Σ: Sum of the inertias couples of the ASM mobile mass and of the mechanism translated to the motor rotor

C_{cM} : Couple of the mechanism resistance (N.m).

$C_{\sigma M}$: Basis value of the ASM couple (N.m).

To take into account the influences of the rotor current and the saturation of the machine iron on the variation of the rotation frequency at the starting time we include in the mathematical model the relations linking the rotor scattering inductance and the motor rotor active resistance with the motor sliding.

$$r_{rM} = (r_{nr} - r_{rM})g_M$$

$$L_{rM} = (L_{nr} - L_{rM})g_M$$

Where:

r_{nr} : Active resistance of the rotor.

L_{nr} :Rotor scattering inductance at the starting.

g_M : Motor sliding (g_M =1)

C - Mathematical model of the Tension Converter with Thyristors TCT For the development of the TCT mathematical model we take into account the following: The arm of each branch is composed of two thyristors connected head to foot when the command signal arrives to the thyristor trigger and become in the closed state regardless of the system tension where it is present at that given moment.

The thyristor remains closed so far the value of the current that crosses it is higher than the upholding current.

In its closed state, the thyristor is replaced by an active resistance; the drop of tension in this latter one corresponds to the drop of tension value in the thyristor in the closed state.

In its open state, the thyristor is replaced by an active resistance in which the current becomes equal to the inverse current of the chosen thyristor.

Taking into account these simplifications, the control of the thyristors state is achieved by the analysis of every step of the command tension value calculation and the value of the current that crosses it at that given moment. To achieve this objective, the mathematical model takes into consideration the equations of the ASM phase current derived from the first two equations of the system (1)

$$\frac{di_a}{d\tau} = \left[(U_a - U_N) - R_{SM}i_a - L_1(r_{rM}L_1.i_a - w_r.\psi_{\beta M}\right]\frac{1}{L_{SM}}$$

$$\frac{di_b}{d\tau} = [(U_b - U_N) - R_{SM}i_b - L_1[\left(\frac{1}{2}(r_{rM}L_1.i_a - T_1\psi_{\alpha M} - w_r.\psi_{\beta M})\right) + \frac{\sqrt{3}}{2}\left(r_{rM}L_1\frac{i_b.i_c}{\sqrt{3}} - T_1\psi_{\beta M} + w_{rM}.\psi_{\alpha M}\right)]]\frac{1}{L_{s\Sigma}}$$

$$\frac{di_c}{d\tau} = [(U_c - U_N) - R_{SM}i_c - L_1[\left(-\frac{1}{2}(r_{rM}L_1.i_a - T_1\psi_{\alpha M} - w_{rM}.\psi_{\beta M})\right) - \frac{\sqrt{3}}{2}\left(r_{rM}L_1\frac{i_b.i_c}{\sqrt{3}} - T_1\psi_{\beta M} + w_{rM}.\psi_{\alpha M}\right)]]\frac{1}{L_{s\Sigma}}$$

Where:

$$U_a = U_\alpha$$

$$U_b = \frac{-U_\alpha}{2} + \frac{\sqrt{3}}{2}U_\beta$$

$$U_c = \frac{-U_\alpha}{2} - \frac{\sqrt{3}}{2}U_\beta$$

U_a, U_b and U_c :tensions of phases of AG

U_N : Tension between the neutral points of the AG and ASM statoric coils.

The functioning algorithm of TCT in the lack of a neutral link line in the naval network is limited by three possible conduction regimes that are:

- Three-phased conduction: closed arm for all phases.
- Two-phased conduction: closed arm for any phase.

- Neutral conduction: open state of the arms for the three phases.

For the TCT chosen types, taking into account the previous simplifications on the asynchronous machines symmetry,

U_N value can be determined for any time moment. At the time of the functioning of the symmetrical electric machines, U_N is different from zero only in the case of the two-phased conduction. For the thyristors that are used in the model and at the time of passing from TCT to any

conduction state that precedes the two-phased one, the initial values of the currents in the phases of open thyristor are equal in value but opposed in phase, on the other hand, U_N because in the AGD-ASM system, the symmetrical regime still exists at the following time moment. The same current will cross the two phases with open thyristor.

In these conditions, the instantaneous value of U_N can be calculated using the system of equations (7) that leads to the following values:

The phase (a) closed:

$$U_N = \left(U_b + U_c + L_1 . \frac{d\psi_{\alpha M}}{d\tau} \right) . \frac{1}{2.L_{sM}}$$

The phase (b) closed:

$$U_N = \left(U_b + U_c - L_1 . \left(\frac{1}{2} \frac{d\psi_{\alpha M}}{d\tau} - \frac{\sqrt{3}}{2} \frac{d\psi_{\beta M}}{d\tau} \right) \right) . \frac{1}{2.L_{sM}} \text{ T}$$

he phase (c) closed:

$$U_N = \left(U_a + U_b - L_1 . \left(\frac{1}{2} \frac{d\psi_{\alpha M}}{d\tau} - \frac{\sqrt{3}}{2} \frac{d\psi_{\beta M}}{d\tau} \right) \right) . \frac{1}{2.L_{sM}}$$

The opening of the thyristors command signal is formed using the command law taken for the TCT.

3. ALGORITHM OF CALCULATION OF THE STARTING REGIME

The simulation by MATLAB software of the system ((1) - (5)), using the Runge-Kutta method, has allowed us to get the following results of the ASM starting powered by AGD.

.

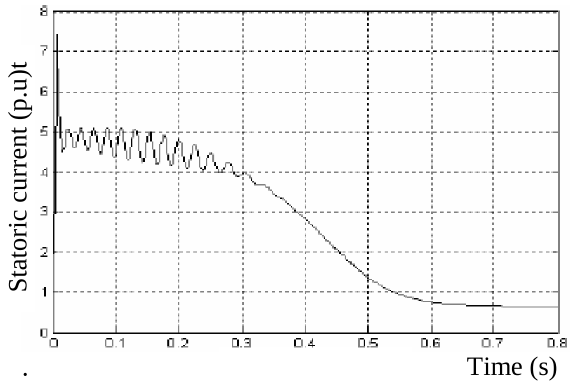

Figure 1: Variations of the Is current in terms of the time for a direct ASM starting powered by AGD

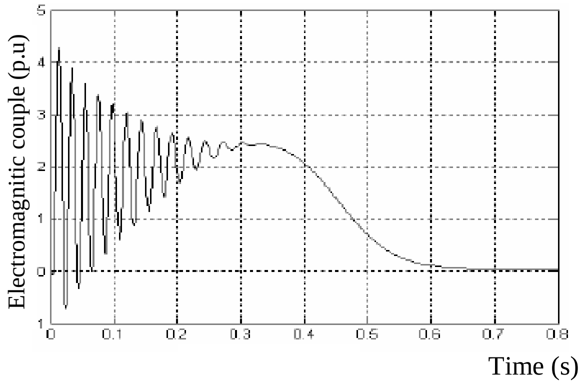

Fig. 2. Variations of the electromagnetic couple according to the time for a direct ASM starting powered by AGD

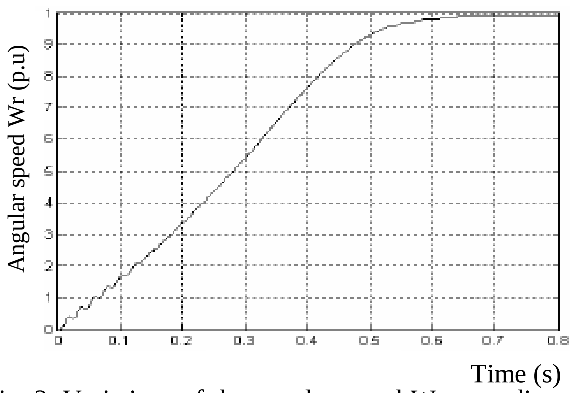

Fig. 3. Variations of the angular speed Wr according to the time for a direct ASM starting powered by AGD.

We notice on the three previous figures that at the time of the direct ASM starting powered by AGD, the existence of peaks of statoric currents and peaks of couple that can be the origin of the machine destruction by overheating, especially in the case of excessive repetitions

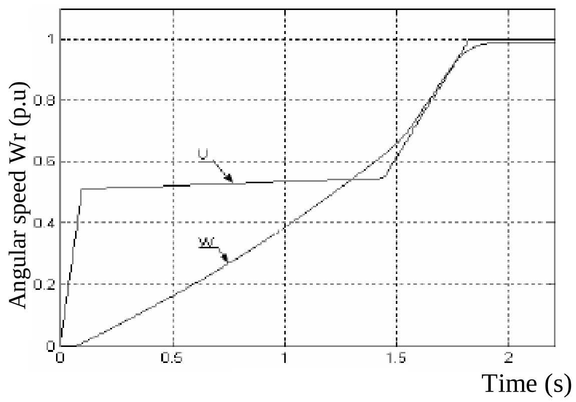

Fig. 4. Variations of the angular speed Wr and the U tension according to the time for an ASM starting with a TCT powered by AGD

We notice on this figure that for this type of starting the variation of tension that powers the ASM is progressive.

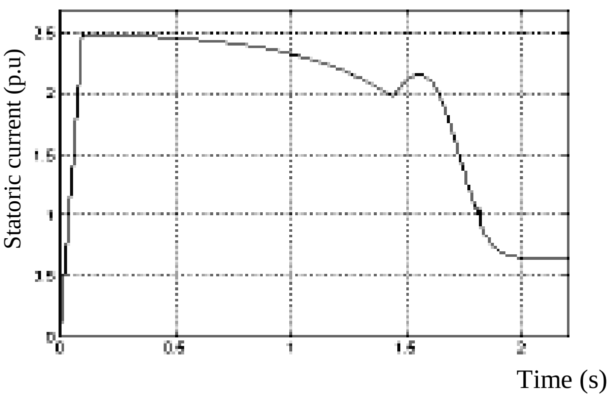

Fig. 5. Variations of the I_s current in terms of time for an ASM starting with a TCT powered by AGD

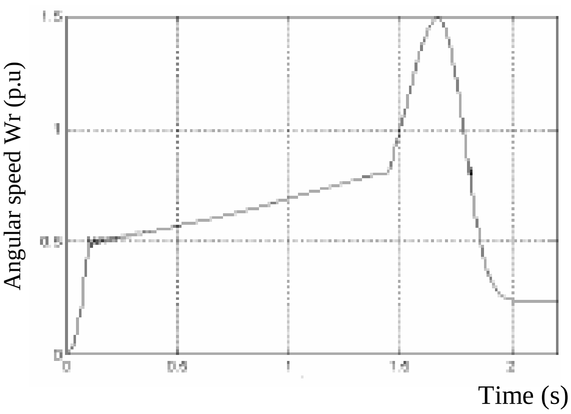

Fig. 6 . Variations of the electromagnetic couple Cem in terms of time for an ASM starting with a TCT powered by AGD

We notice on the two previous figures, the absence of any current or couple abrupt peaks. The resulting drop of tension that and mechanical shocks due to the brutal apparition of the couple. The starting time in this case can exceed the direct starting time by several times.

4. COMMAND OF THE STARTING REGIME BY A TENSION CONVERTER WITH THYRISTORS

For an ASM starting, the limitation of the current peaks can be obtained not only by the reduction of the tension amplitude via the introduction of the auxiliary resistances in its statoric circuit, but also using other regulation methods of this tension value in the devices that allow the command of this starting regime, by means of varying the commutation of the allowed or blocked state of the semiconductor components (thyristor, power transistor, triac).

The most efficient activators of asynchronous mechanisms are the starting devices constructed on the basis of Tension Converters with Thyristor (TCT) commanded by a phase angle. For an automatic command of the starting regimes of the asynchronous activators mechanisms, several solutions exist currently. Amongst them we can mention the solution that uses gradators, where the power circuit includes in every phase two thyristors assembled head to foot; the variation of tension that powers the ASM is progressive and is obtained via varying the conduction time by phase angle of these thyristors during every half period (fig.7).

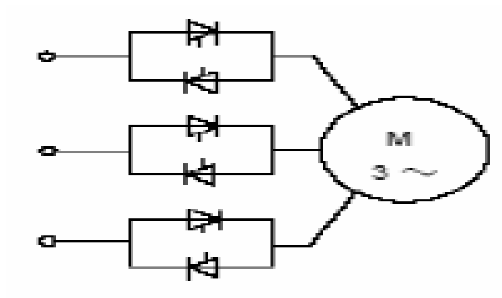

Fig. 7. Block diagram of the ASM starting through a gradator

This type of starting limits the call of current, the ensuing drop of tension and the mechanical shocks resulting from the brutal apparition of the couple. For the ADG energizing systems linked to an excitation device (DRY) whose action rapidity can be compared to the action rapidity of the command system by phase angle of the TCT key elements and which can have a positive effect if we introduce in the TCT automatic system a negative return loop between the starting angle of the thyristors' triggers and the drop of tension between the AGD limits. The possibility to use a system with TCT for the ASM starting command from an AGD is represented on the figure (8). For the elements of commutation we use some photothyristors that can be commanded by a luminous impulse. To assure a galvanic insulation between the power circuit and the command circuit at the time of the of the installation functioning, the primaries of the impulsion transformers T1-T3 are joined with the AGD statoric coils , the secondary of these transformers are plugged with the Zener diodes DZ7-DZ12 stabilizing the phases tensions.

If a drop of tension appears the phase changes and the length of the command luminous impulse that determines the value of the starting angle of the photothyristor also changes. The choice of the command tensions phase angle and the parameters of the photothyristors allow the creation of a negative return loop by a drop of tension. We can have a large regulation interval of the photothyristors starting angle by means of the formation of the phase command signal that has a tension which exceed the anode-cathode tension of these photothyristors in a varying interval between 30° and 120°. The relation of the photothyristors starting angle with the tension phase amplitude is determined by the equation (8)

$$\alpha = \frac{\pi}{3} + \arcsin.\frac{U_{sT}.k_T}{U_m}$$

Where:

α : Pothothyristors starting angle

U_{sT} : Stabilizer tension

k_T : Transformers transformation coefficient

U_m : Amplitude of the tension phase instantaneous value

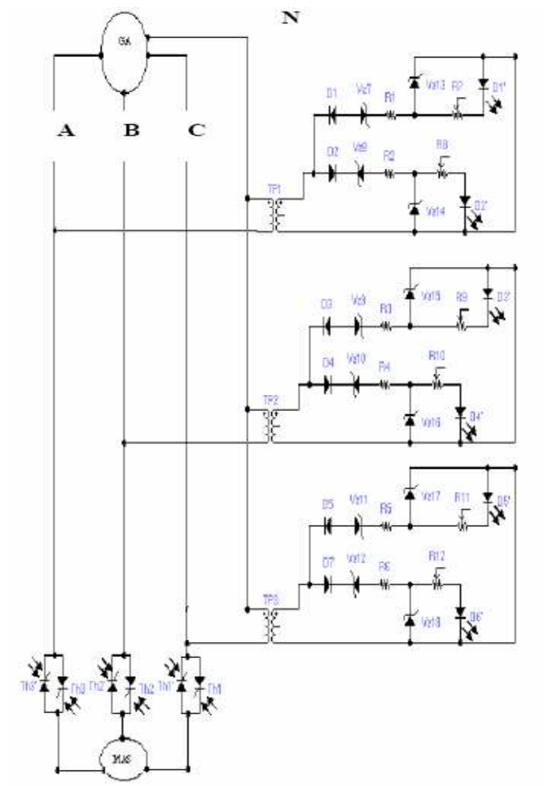

Fig. 8. Electric diagram of the ASM starting powered by AGD through a TCT

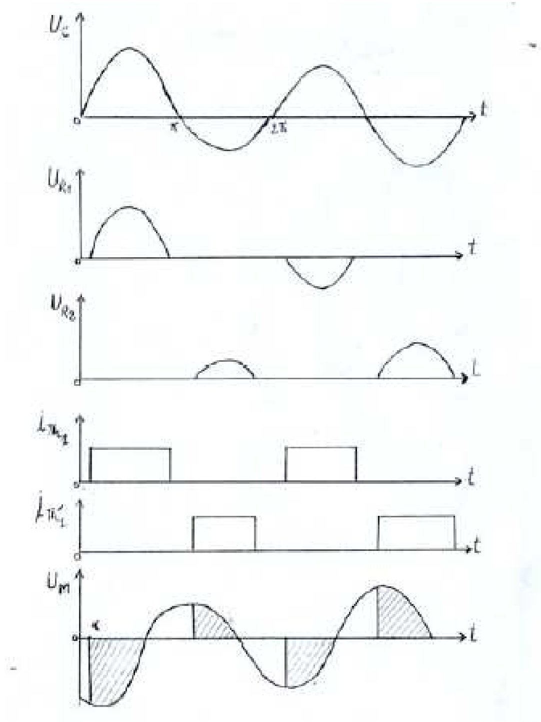

Fig . 9 . Functioning chronogram of the photothyristors

We take into consideration the variation character of the ASM power coefficient at the time of its starting. The chosen regulation interval of the starting angle is sufficient to command this starting because it ensures the conditions of TCT functioning in the case of three or two conductor arms.

On the figure (10) we represented the oscillogramms of the regime in the case of an ASM starting through a TCT. The curves represent the effective tension value, the frequency of the diesel generator activator and the starting duration of ASM for different powers. The comparison between these features and the parameters of the ASM's direct starting regimes (fig(1)-(2)) permits to point out that the use of the TCT lead to the decrease the drop of tension in the load, the starting time in this case can exceed the time of direct starting by several multiples.

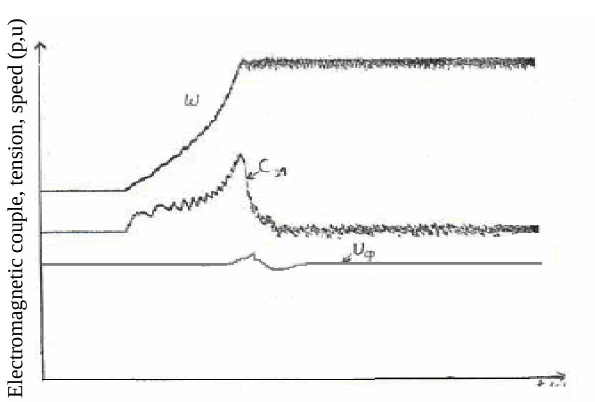

Fig . 10. Oscillogramme of the ASM starting powered by AGD through a TCT

5. CONCLUSION

We have developed a mathematical model of the common functioning regime dynamics of the AGD and of the mechanisms with asynchronous actionneur. This model takes into consideration the elements of the following system:

1- Diesel, asynchronous generating, asynchronous motor with auxiliary resistances in the statoric circuit with a resistance couple on the corresponding axis of the different mechanisms, tension regulator with thyristors, the calculation parameters of the transient regimes are closer of the experimental data with a precision around 13%.

2- The calculations of the parameters of the asynchronous machines starting regimes of 4A, AM and AO series, for a capacity of DRY equal to 1.45 pu and for a limitation of tension drop on the borders of AGD of 20% of U_n , give a steady direct starting of the asynchronous machines of a power of 20 to 25% of the nominal power of AG, without limitation of the tension drop value and for the same value of DRY capacity the AGD can assure a direct ASM starting with a power of 30 to 40% of the nominal power of AG.

3- The analysis of the possibilities of the starting regime command of the mechanisms with asynchronous actionner by a AGD with the use of a TCT with negative return loop between the angle of the thyristors triggers opened state and the drop of tension on the borders of AGD, shows that by this method we can limit the drop of tension on the borders of the load and can increase the unit of motors power started for a limited value of the DRY capacity. We noticed that the couple developed by ASM in the time of starting through a TCT has a smaller value compared to the starting through auxiliary resistances for the same value of tension drop that appeared on the AGD borders.

REFERENCES

Glasinko T.A,.Khrisanov V.I, 1981 Semiconductor systems electric actuators, low-power asynchronous impulsive, Liningrad, *Inergoatomisdat*, 144 p.

Abudura S., Konacof G.A. 2000 The determination of the power of Diesel in naval operations *Installation énergétique navale*, N°2, Odessa, p 43-49.

Caron. J.P . J-P.Hautier, 1995 Modelling and control of the asynchronous machine, éditions TECHNIP, 324p

Kobilov, I.B. 1986 Electrical machinery, Moscou, Inergoatomisdat, 360p

Kobilov, I.B. 1987, Mathematical modeling of electrical machines , Moscou, The upper school, 247p.

Abudura, S. 2002 The regimes of operation of naval diesel engines and diesel generators, Odessa, Konsalting, 236 p.

AUTHORS PROFILE

Dr. H. Meglouli is currently working as Assistant Professor at the Department of Automatisation and electrification of process, in university of Boumerdes-Algeria. He obtained his Ph. D degree in technical sciences at petroleum institute of Moscow.

B. IKHLEF is currently a doctoral student at the University of Boumerdes, he received his engineering degree in automatic control at the University of Tizi Ouzou, Algeria, and master degree in applied automation and signal processing at the University of Boumerdes.