THE STUDY OF TRANSIENT PROCESSES IN THE ASYNCHRONOUS STARTING OF THE SYNCHRONOUS MOTOR

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Abstract*:* *Starting synchronous motors can be achieved by several methods: starting with an auxiliary motor launch, starting in asynchronous regim, by feeding from a variable frequency source, auto-synchronization with the network.. In our case we study the transient processes in a asynchronous regim . In this case the synchronous motor is started like a squirrel cage induction motor . To start, the synchronous motor is equipped with a starting winding cage placed in the pole pieces of polar inducers; later , during the operation, this acts as a damping winding. Large synchronous motors have pole pieces made from massive polar inducers fulfilling the role of a cage winding*

1. INTRODUCTION

The synchronous motor develops an average synchronous torque only at synchronous angular speed operation $\Omega_1 = \omega_1 / p$. At a different speed as well as when starting, the synchronous motor connected to an AC mains and excited in DC develops a synchronous, alternating electromagnetic torque, its average value over a period of induced currents in the rotor being zero. At starting the induced currents' frequency is equal to the line frequency; the electromagnetic synchronous torque varies periodically with the same frequency. To turn the engine during a semiperiod requires that the moment of inertia and frequency should be low enough to permit the received energy from the stator to be sufficient to accelarate the rotor to its synchronous speed; in case of industrial frequency this is possible only in a microsynchronous motor.

2. THEORETICAL ASPECTS OF STARTING SYNCHRONOUS MOTORS

Starting synchronous motors can be achieved by several methods: starting with an auxiliary motor launch, starting in asynchronous regim, by feeding from a variable frequency source, auto-synchronization with the network.

In our case we study the transient processes in a asynchronous regim . In this case the synchronous motor is started like a squirrel cage induction motor . To start, the synchronous motor is equipped with a starting winding cage placed in the pole pieces of polar inducers; later , during the operation, this acts as a damping winding. Large synchronous motors have pole pieces made from massive polar inducers fulfilling the role of a cage winding.
Switching is done by connecting the motor directly to the network, or indirectly through a reactance of an autotransformer with two or more steps starting or star-delta method, based on admissible currents at startup and the load torque of the engine. During asynchronous starting the excitation winding is disconnected from the power supply of DC and the coil ends are connected across a rheostat with a resistance value of about 5 - 10 times higher than the excitation winding resistance . Excitation winding is not shorted at starting because a couple of uniaxial link can appear due to the single – phase induced in excitation winding, which would cause a saddle mechanical feature in starting a motor in asynchron.

Excitation winding is not left open because high voltage could be induced which could pierce its insulation.

Figure 1 shows the electromagnetic torque curve was plotted for the case where the excitation winding terminals are shorted (curve a) and connected to a resistance (curve b); in the latter case, mechanical characteristic saddle is lower and the danger of hanging the rotor at a speed approximately equal to (1/2) n1 is virtually eliminated.

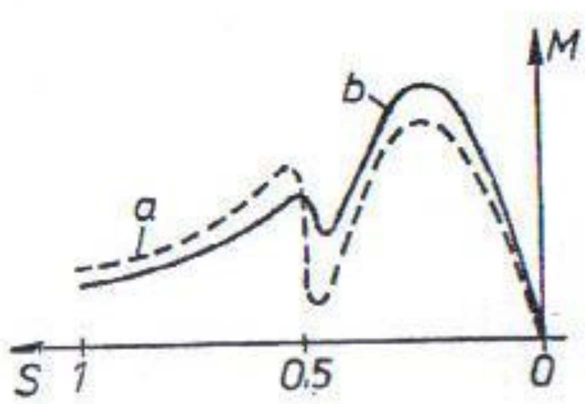


Fig. 1. Electromagnetic torque in synchronous operation
a - excitation winding connected in shorted method; b-excitation winding connected to a resistance

The unbalanced damping winding has a similar effect caused by the lack of the cross bars in the transverse axis and possibly, of the shorting ring segments from pole to pole. To partly dispose of these effects the damping winding bars are front short-circuited by complete rings.

After starting, the asynchronous motor speed is below synchronous speed, slip is less than 2 ... 3%, depending on the mechanical characteristic in asynchronous regim and the torque load. To synchronize the motor, disconnect the starting resistance of excitation winding terminals and connect the excitation source. The synchronous torque is produced by the interaction of the magnetic induction field produced by the rotor and the stator magnetic field, which is a rotating field to the rotor, with the rotor's sliding angular velocity in relation with the synchronous velocity; in the induction motor with poles growing out a synchronous torque reaction develops, which can produce, under certain conditions, the synchronization of the induction motor just before the rotor excitation.

In asynchronous regim, the steady, resistant torque is balanced by the asynchronous electromagnetic torque and the synchronous torque is zero; when operating in synchronism, the resistant torque is balanced by the synchronous torque and asynchronous torque is zero.

3. EXPERIMENTAL STUDY

For the experimental study of the synchronous motor starting asynchronously, the measurements were performed on a synchronous motor having the following characteristics: TYPE SCI 400, 1971, U = 400V, I = 7.2 A; 5KVA, cosφ 0.8; 3000rot/min; 50Hz IP23. For starting I used an automation made by contactors and timers, automation wiring diagram being shown in the figure below. Red dots indicate locations where we have made measurements with Fluke device 435.

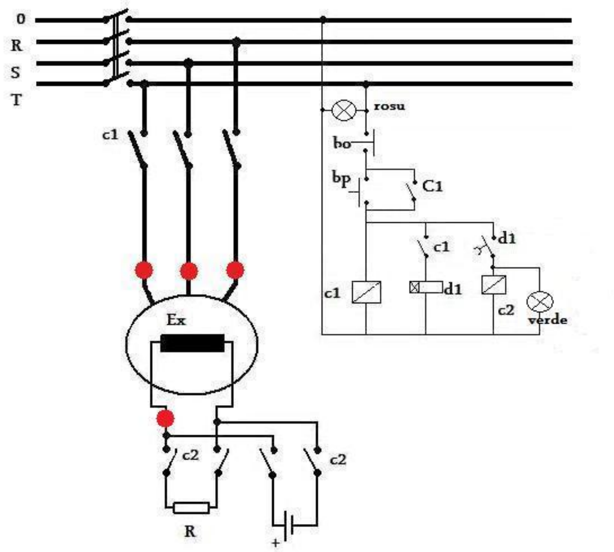


Fig 2 Automation scheme and points where measurements are taken.

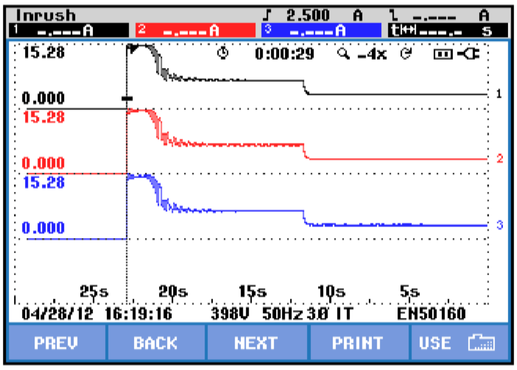
To be able to see transients that occur in the transition from asynchronous to synchronous induction motor, Fluke 435 is set on inrush mode. Inrush currents are transient currents that occur when a high load is connected or at low impedance. Normally the current will stabilize after a while, when the load reaches normal operating conditions. For example, the starting current for the induction motor can be 10 times higher than the nominal operating current. Inrush mode is a "single shot" to register the voltage and current trend after the occurrence of an event (trigger). An event occurs when the current waveform exceeds settable limits.

Fig. 3 Fluke device for analyzing power

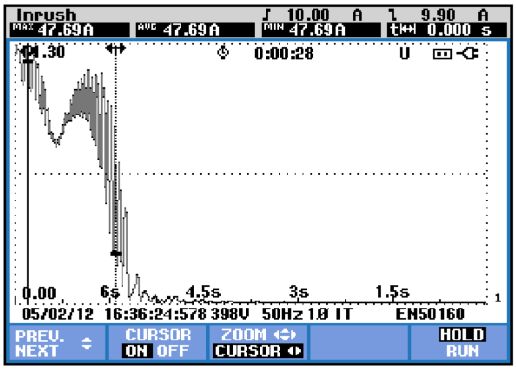
Several measurements have been made without mechanical loading of the synchronous motor, but we have varied the excitation voltage applied and the value of the resistance that has been connected to the ending wiring of the excitation coil.

Nr. Crt.	**Excitation voltage applied**	**Resistance value related to the excitation winding**	**Case**
1	10Vc.c.	90Ω	1
2	15Vc.c.	90Ω	2
3	20Vc.c.	90Ω	3
4	24Vc.c.	90Ω	4
5	30Vc.c.	90Ω	5
6	40Vc.c.	90Ω	6
7	10Vc.c.	190Ω	7
8	24Vc.c.	190Ω	8
9	40Vc.c.	190Ω	9

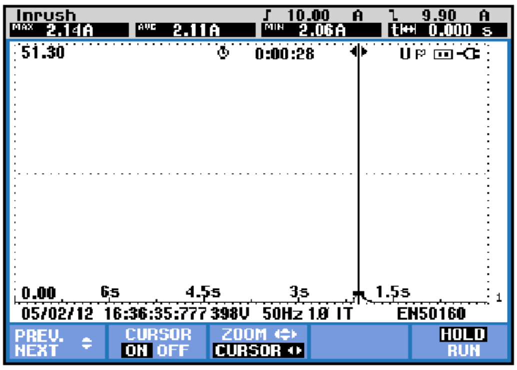
***Case 1* (10Vc.c., 90Ω):**



1.1



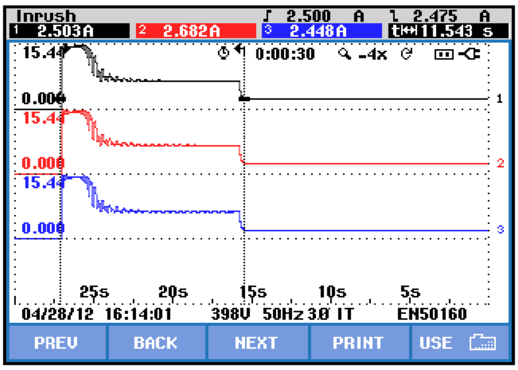
1.2



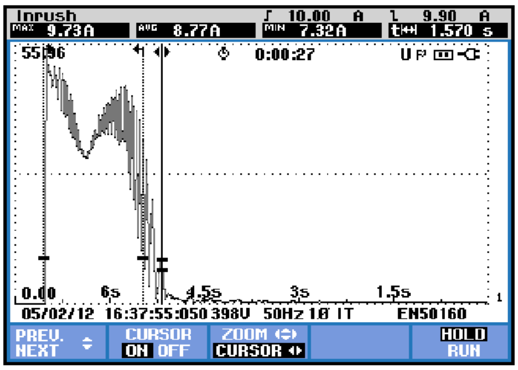
1.3

At 10Vc.c., applied voltage excitation, the synchronism entry is easy, without any current fluctuations, even with a decrease from the current asynchronous regim. Diagram 1.2 presents the the current variations and value (about 50A) when the synchronous motor is functioning in asynchronous regim. And in diagram 1.3, the entry into synchronicity is pointed out by a small leap of current (2 A).

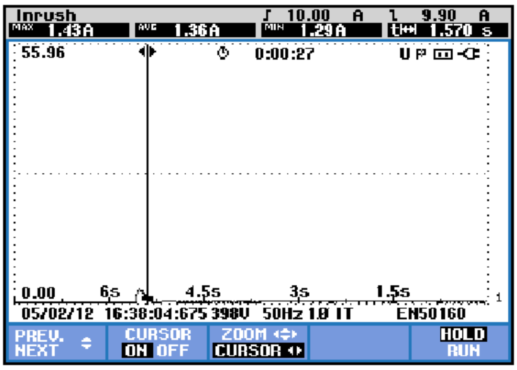
***Case 2* (15Vc.c., 90Ω):**



2.1



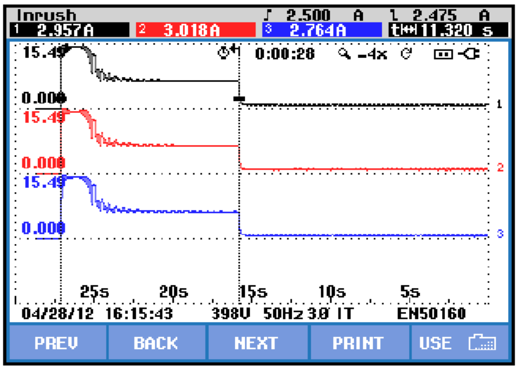
2.2



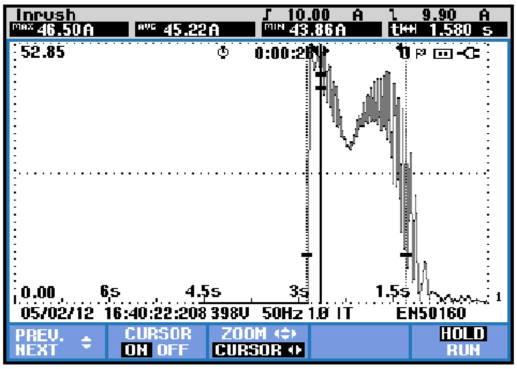
2.3

Figure 2.1 shows values and changes in the starting current wave absorbed by the motor, similar to the previous case, and Figure 2.2 presents the variation of current wave which is the same as in the previous case, only when entering in the synchronization, the current fluctuation has slightly increased.

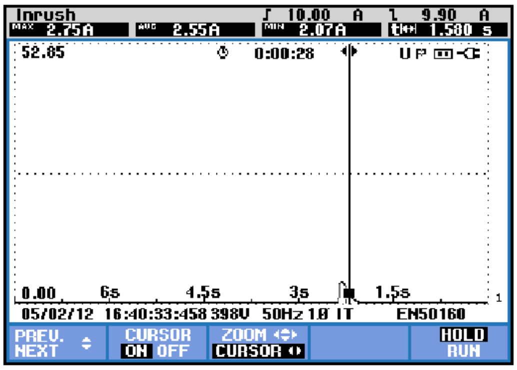
***Case 3* (20Vc.c., 90Ω):**



3.1



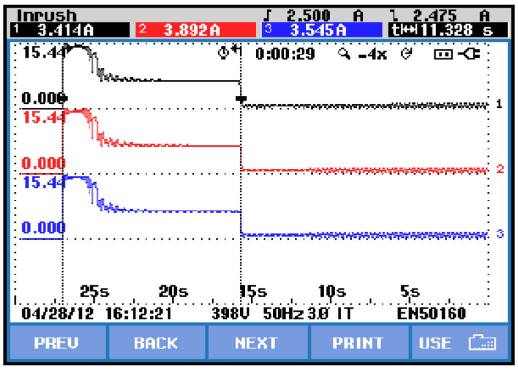
3.2



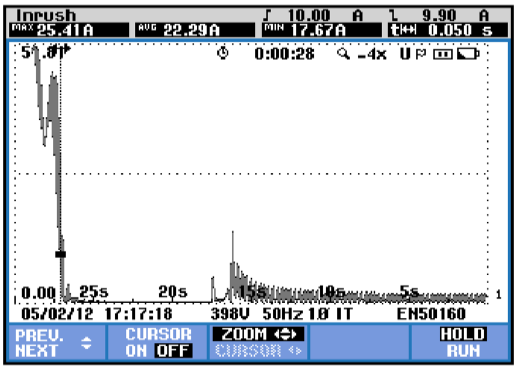
3.3

At 20V d.c. voltage applied to the excitation winding, the currents are similar to previous cases in both points of measurement.

***Case 4* (24Vc.c., 90Ω):**



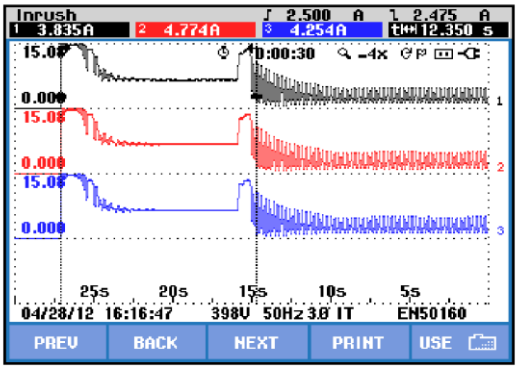
4.1



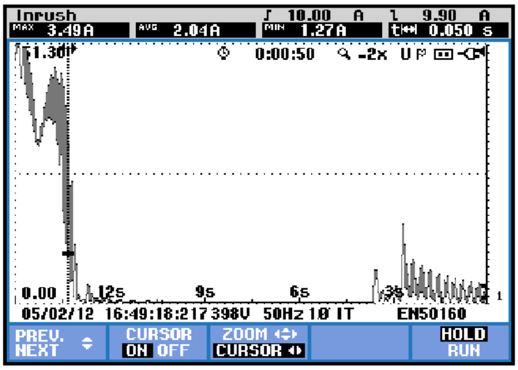
4.2

In this case the starting is the same as in the previous cases, except that after a while of running in synchronous regim, some fluctuations of curent occur which produce mechanical vibration. In figure 4.2. an aperiodic component appears at the entry into synchronicity which is amortized in time to a certain value.

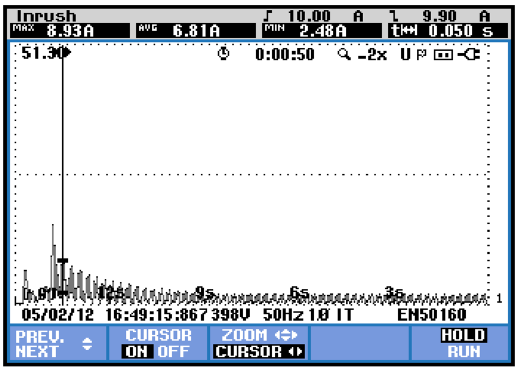
***Case 5* (30Vc.c., 90Ω):**



5.1



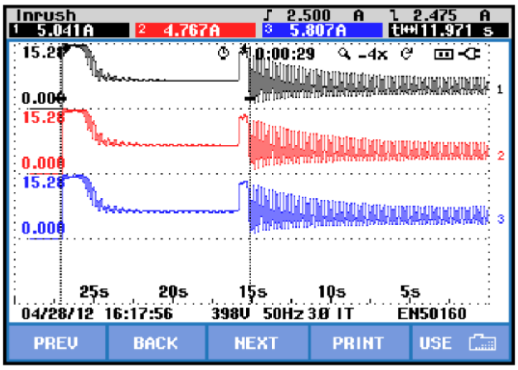
5.2



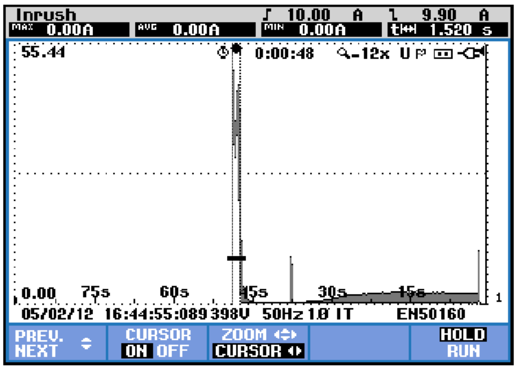
5.3

In this case, a current close to the starting current appears at synchronous entry, and continues with some intereferences and mechanical vibrations that no longer attenuate during running. On the excitation winding there is a jump of current at syncronicity entry followed by some current fluctuation that are no longer depreciated.

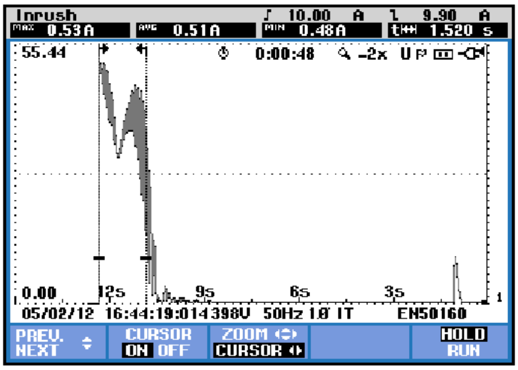
***Case 6* (40Vc.c., 90Ω):**



6.1



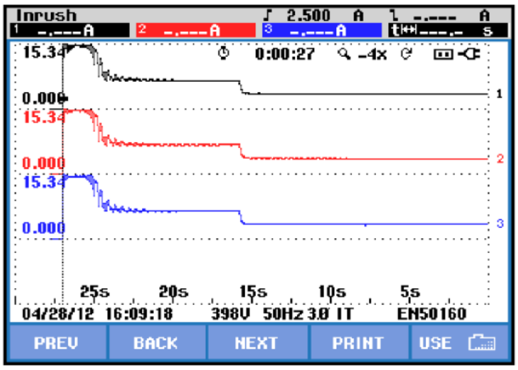
6.2



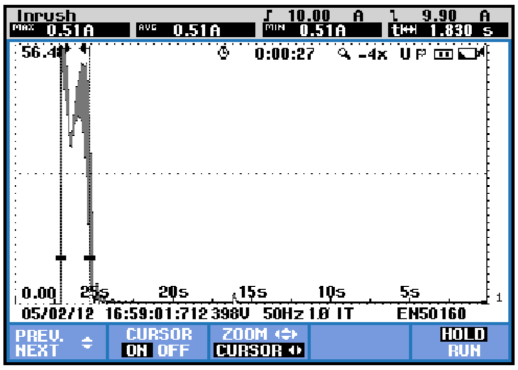
6.3

As in the previous case at synchronism entry the same current jump appears almost to the starting current, the running is continued with disturbances and mechanical vibrations that are no longer depreciated . Current fluctuations occur in the stator circuit (6.1) and the excitation winding (6.3).

***Case 7* (10Vc.c., 190Ω) :**



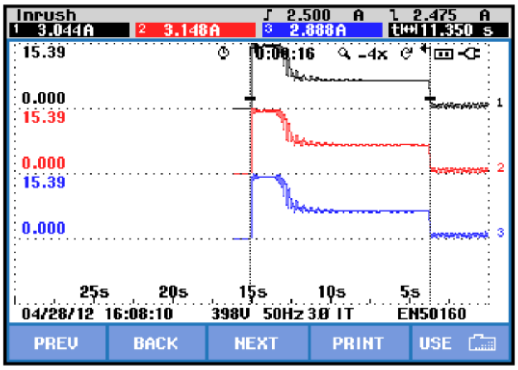
7.1



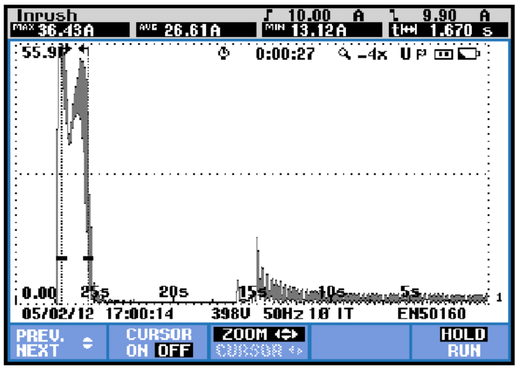
7.2

Current fluctuations and the waveform are the same as in case 1 where the resistance is half.

***Case 8* (24Vc.c., 190Ω):**



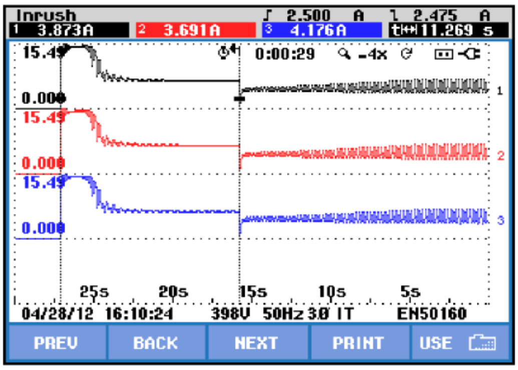
8.1



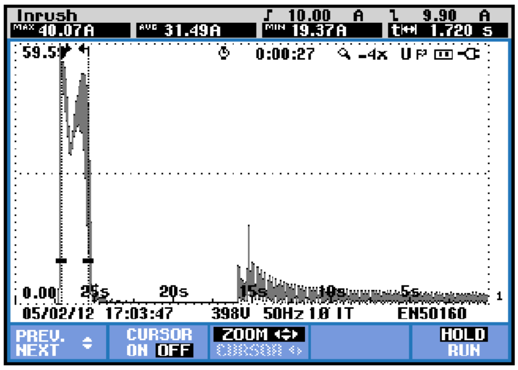
8.2

As in the previous case, when the resistance connected to the excitation winding has 90 Ω value, the starting current has the same value as the starting currents, even the disturbance and mechanical vibration are still present .

***Case 9* (40Vc.c., 190Ω):**



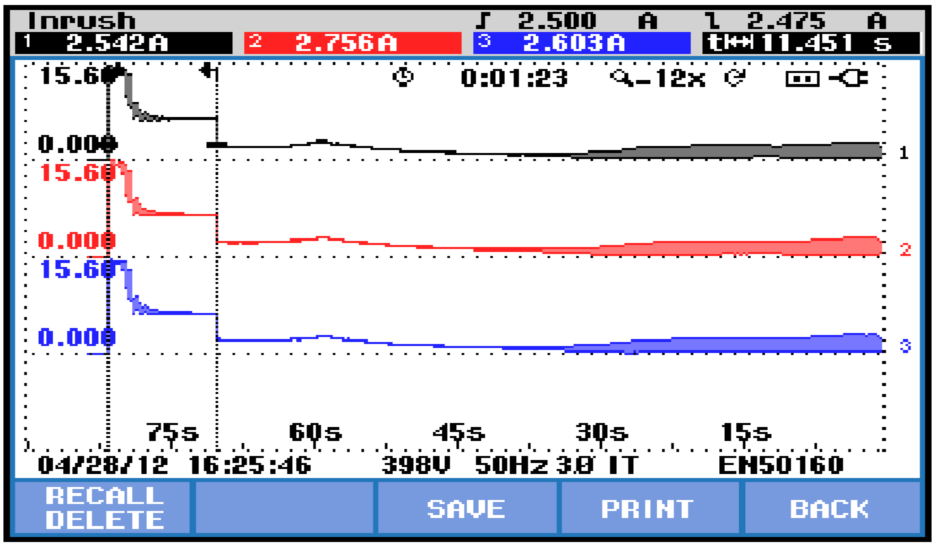
9.1



9.2

In this case, fig. 9.1. shows that at the entry into syncronicity there is a decrease of current value followed by some fluctuation in current that is amplified and remains present throught the whole period of engine operation, producing large mechanical vibration. In the rotor the *aperiodic* component is amortized up to a certain value.

Observation



Without a mechanical loading at 20Vc.c., on the excitation winding of the synchronous motor terminals there can be found the lowest current of 0.8 A.

4. CONCLUSIONS

When starting a synchornous motor in asynchronous regim the current surge relies heavily on the starting cage, not on the resistance connected to the excitation winding . This only has an influence on the maximum current in the excitation winding. For a better synchonization, is appropriate to use such a voltage on the excitation winding, as to make sure the synchronization regim is an inductive one. In the studied case at a voltage of 10Vc.c. synchronization is very smooth. The excitation voltage at which the full load power factor is unit is worth about 24Vc.c.

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