Introduction of Products

COMPOUND INDUCTION SYNCHRONOUS MOTOR FOR BALL MILL DRIVE

We have paid attention to excellent characteristics of the induction synchronous motor and made much studies and researches of applying the motor for cement ball mill. Recently we have got a chance to manufacture the compound induction synchronous motor and gained the successful result. The following is the outline of the motor and its test result.

The compound induction synchronous motor is an induction synchronous motor, provided with the compound excitation system. The compound excitation system consists of a current transformer, potential transformer, reactor and metal rectifiers, and is based on the same principle as the compound self-excitation system which has been widely adopted to the marine use generators. This excitation system supplies DC current, corresponding to load current, to the exciting circuit by means of the current transformer and metal rectifiers. This system, therefore, possesses superior quick response ability, and makes the motor possible to withstand the large overload without increasing its size. One of the reasons, why the induction synchronous motor was not used very much in the past despite its superior starting efficiency, is the fact that it was not suitable for peak load service due to its low pull-out torque. Employing the compound excitation system, however, the compound induction synchronous motor overcomes this defect and can be applied for fluctuating loads with its inherently excellent characteristics. It is considered that the motor of this type is most suitable for the service, having severe starting and operating conditions as in the case of the ball mill drive.

Two sets of 900 HP compound induction synchronous motor recently completed, are destined for the Cebu Portland Cement Company (Philippines) via Kobe Steel Works and used for driving a raw materials pulverizing mill and a finishing mill.

The specification of the motor is as follows.

Output	900 HP
Voltage	2,300 V
No. of poles	36
Rating	continuous
Frequency	60 c/s
Speed	200 rpm
Power factor	0.9 (leading)
Insulation	B class

Guaranteed characteristics are as follows.

Starting torque	more than 150%
Starting current	less than 180%
Pull-in torque	110%
Pull-out torque	200%
Temperature-rise	less than 50°C (by Thermometer)

Though output of the motor is 900 HP, it is requested that the motor can be operated continuously at 1,000 HP (power factor 100%) on account of ball mill service conditions. Thus, considaration has been taken so that even in such cases, it can be operated without difficulty.

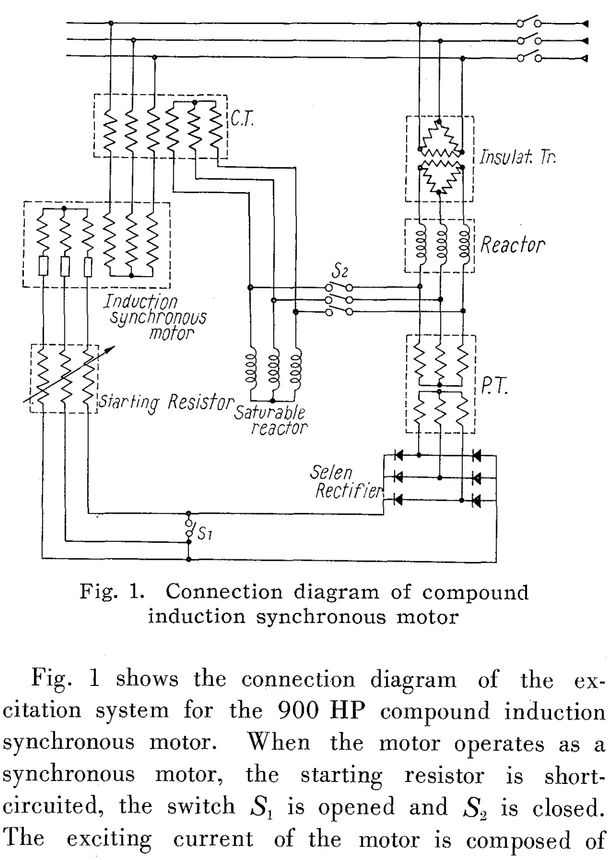
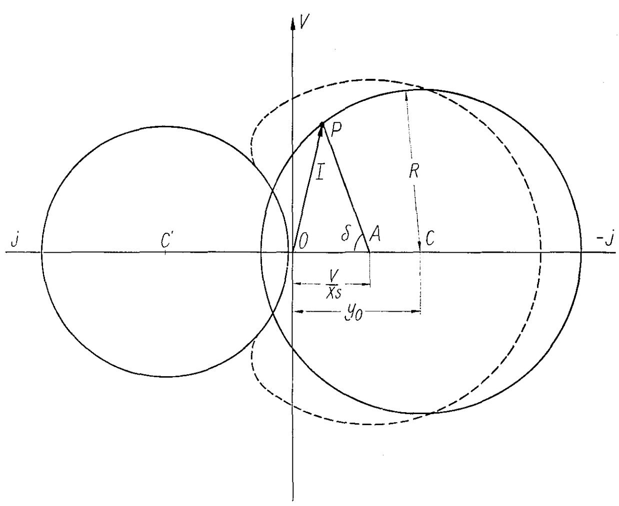


Fig. 1. Connection diagram of compound induction synchronous motor

Fig. 1 shows the connection diagram of the excitation system for the 900 HP compound induction synchronous motor. When the motor operates as a synchronous motor, the starting resistor is short-circuited, the switch S_1 is opened and S_2 is closed. The exciting current of the motor is composed of a reactor component and a current transformer component. The former is supplied through the reactor and kept nearly constant corresponding to the line voltage. The latter is a variable component and dependent linearly on the primary current of the motor. These two components are mixed at the potential transformer, rectified by metal rectifiers (selenium rectifiers), and then supplied to the field winding. The phase relation between the reactor and the current transformer-component is so arranged that these are added algebrarically when the current of the motor is leading. This arrangement is necessary to secure the stability of the motor.

The running characteristics of the induction synchronous motor, provided with the above-mentioned exciting system, are represented by such a circle diagram as shown in Fig. 2. The description of the symbols used in Fig. 2 is as follows.

E_0 : Internal voltage
V : Terminal voltage
I : Primary current
δ : Internal angle
X_s : Synchronous reactance
α : Turn-ratio of the current transformer
k : Constant depending on the design of the motor, the potential transformer, and so on.
i_0 : Reactor component



$$Y_0 = -\frac{V + \dfrac{k^2\alpha i_0}{X_S}}{X_S - \dfrac{k^2\alpha^2}{X_S}} \qquad R = \left| \frac{k\left(i_0 + \dfrac{\alpha V}{X_S}\right)}{X_S - \dfrac{k^2\alpha^2}{X_S}} \right|$$

$$C;\ X_S^2 - k^2\alpha^2 > 0 \qquad C;\ X_S^2 - k^2\alpha^2 < 0$$

Fig. 2. Circle diagram of compound induction synchronous motor

From the equation for the circle of Fig. 2, it is induced that the radius of the circle or pull-out torque of the motor can be much increased by selecting properly the exciting apparatus and making the value of $k \cdot \alpha$ near the value of X_S.

In the case of the 900 HP motor, the exciting apparatus is designed considering the following two running circles. In one running circle, power factor of the motor is kept about 90% (leading) within the range from full load to 50% load, and in the other that of the motor is almost unity in that range. In the both running circles, the exciting apparatus is so arranged that pull-out torque becomes more than 200%.

Starting and synchronizing of the 900 HP motor are smoothly carried out without any disturbance to the power source. It is proved that starting efficiency of the motor is as good as that of wound rotor type induction motor, and large synchronizing torque is generated by means of the compound excitation. At starting, the switch S_1 of Fig. 1 is closed, S_2 is opened, and the starting resistor is inserted. Isolating the rotor circuit from the exciting circuit, the motor operates as a wound rotor type induction motor. Opening the switch S_2, selenium rectifiers are protected from damage due to over current which is boosted by starting current through the current transformer. Synchronizing is carried out by opening S_1 and closing S_2. These switches are operated by the so called angle switching at the instant when the phase of the supply line and that of the motor are coincided. By means of the angle switching, the motor is able to bring a heavy inertia load into synchronism and rush current is adequately reduced.

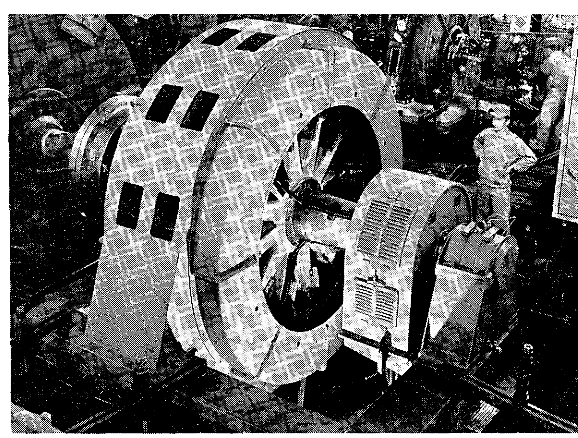


Fig. 3. 900 HP compound induction synchronous motor

Fig. 3 shows the outerview of the 900 HP motor at our test house. The motor is of open type and provided with stator displacement device, so that maintenance of the motor, used at such a place as cement plant where a great amount of dust is present, becomes very easy. The construction of the stator does not differ from the ordinary large capacity induction motor in any point. The rotor winding is star-connected at starting and the excitation is applied between the U phase terminal and the connected terminal of V and W phase. This type of the rotor winding connection gives large damping torque. The sectional area of U phase conductor is double that of V and W phase to get rid of over-heating. The insulation of the stator and the rotor winding is so carefully treated as to withstand heavy moisture of tropical climate expect during shipment and at the site of installation.

The exciting apparatus and a set of controlling equipments are mounted in the enclosed dust-proof type cubicle shown in Fig. 4. The current trans-

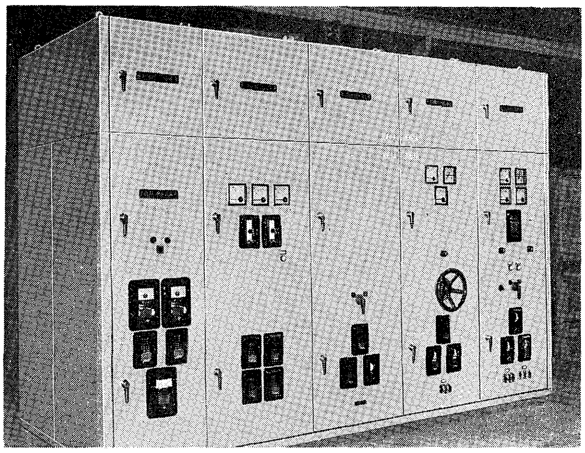


Fig. 4. Switch cubicle for 900 HP compound induction synchronous motor

former, the potential transformer, the reactor, and the saturable reactor are of dry type and insulated with H class insulators. The selenium rectifiers are ventilated by the cooling fan mounted in the cubicle, and cooling air is taken from an air intake which is arranged at the back of the cubicle and equiped with an air filter. From over-voltage expected at starting and synchronizing process, the selenium rectifier is protected by an over-voltage relay which is connected at the DC side of the rectifier. The installation area of the above stationary exciting system may be much reduced and less troubles occur than rotating exciter.

In order to select the running characteristics of motor, two taps are provided on the exciting current transformer and the tap-changing is possible during operation by a hand operated change-over switch.

In such a service as ball mill, inching start of the motor is sometimes required. Consideration has taken so that inching can be carried out by operating the change-over switch for inching on the switch board and by switching O.C.B. At that time, the operating motor of the starter is locked and resistance of the starting rheostat is set at its maximum value. Moving contacts of the O.C.B. are made from arc-resisting metal and much resistible against damage due to inching.

The equivalent tests of starting and synchronizing characteristics are carried out at our test house using a DC generator as a load and supplying 50 c/s power. According to the test, starting current be-

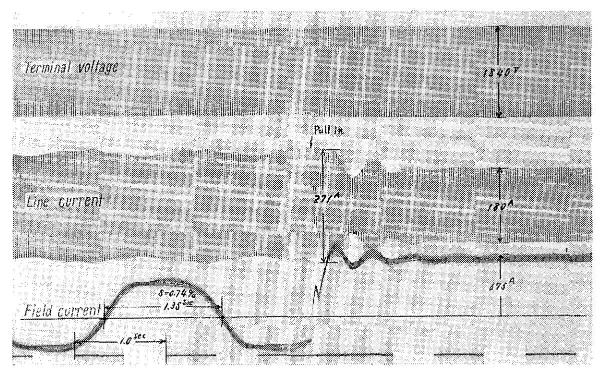


Fig. 5. Oscillogram of synchronizing phenomena

came 173% and starting torque 143%. Fig. 5 is an oscillogram of the synchronizing phenomena of this motor, and shows that synchronizing is carried out without any disturbance by means of the angle switching.

Besides the 900 HP motor described above, two 1,000 HP compound induction synchronous motors have been manufactured and delivered via Kobe Steel Works to Philippines also.

From the foregoing, we convince that the compound induction synchronous motor possesses the characteristics conductive to develop new fields and will be widely accepted by all quarters.

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