

Reversing device for a two-pole single-phase synchronous motor.

The invention relates to a reversing device for a two-pole single-phase synchronous motor without starting auxiliary coil, which motor comprises a diametrically magnetized permanent-magnet rotor, whose shaft runs against
5 stops for reversing the direction of rotation, and a capacitor arranged in series with the stator exciter coil.

In various machines and appliances the direction of movement is or is to be reversed automatically at regular or irregular time intervals. For example, a small
10 citrus-juice extractor is known (AT-PS 355 752), in which the direction of rotation of the pressing cone is reversed after substantially every three quarters of a revolution. This improves the pressing result.

A single-phase synchronous motor with a permanent-
15 magnet rotor has the property that statistically it is capable of starting and running in either direction. Because of the high transmission ratio when used in a citrus-juice extractor the motor has to perform many reversals, i.e. every time assume and run in the stable
20 condition, in order to obtain said pressing-cone movement of substantially three quarters of a revolution. In order to reverse the direction of rotation of the pressing cone and of the motor there may be provided a number of more or less elastic stops against which the gear wheel
25 which drives the pressing cone runs alternately in the positive or negative direction of rotation, so that in order to reverse the direction of rotation, the motor is overloaded to such an extent that it stalls and then starts again in the opposite direction. Stalling and
30 starting in the other direction of rotation should be effected rapidly and the starting problems inherent in the single-phase synchronous motor, which problems may give rise to a number of undesired reversals under certain

circumstances, should be precluded. Otherwise, the operation of the pressing cone will be disturbed (so-called hesitation) with irregular, jerky movements (sputtering), and accompanied by noise.

5 In order to improve the operation of a.c. generators which are operated with a fluctuating speed in the generator mode, it is known from DE-C 974 260 to dimension a capacitor arranged in series with the armature inductance in such a way that its influence is large at
10 low speeds and very small at high speeds, in order to maintain the current in the load substantially constant down to low numbers of revolution.

From DE-C 589 319 it is known to provide a reversal of the direction of rotation by means of mechanical stops. On account of the multi-pole construction and
15 the consequently low operating speed the starting problem is insignificant. It is therefore obvious that the mechanical spring-reversing device is adequate for the purpose of reversal.

20 It is an object of the invention to provide a reversing device in which reversal is effected in a reliable manner without sputtering, i.e. in which the stable state is reached rapidly and without any problems.

According to the invention this object is achieved
25 in that the reactance of the capacitor at the mains frequency is higher than the reactance of the exciter coil, so that the capacitor values comply with the dimensioning rule:

30
$$\frac{\omega L - \frac{1}{\omega C}}{R} < 0,$$

in such a way that the operating current for the exciter coil with capacitor has substantially the same effective value as the operating current without series capacitor,
35 because the motor is then warmed up to the same extent.

This means that the capacitor is dimensioned so that the series resonant circuit comprising the capacitor,

coil inductance and coil resistance becomes highly capacitive.

The pressing-cone movement of a citrus-juice extractor will now be reversed without any problems.

5 The stability problems associated with single-phase synchronous motors (DE-PS 26 12 851) do not occur. The stable state is reached rapidly and without any problems.

10 It is known that the starting behaviour and the stable operation of single-phase synchronous motors can be improved by increasing the ohmic resistance (Philips Research Reports Supp. 1971, No. 5, page 98), sometimes by the use of a series resistor (DE-PS 26 12 851).

15 In DE-PS 26 12 851 (column 3, lines 12 to 18) a series resistor is included during the starting phase in order to suppress the 33 1/3 Hz interference (and thus the adjacent range in which starting problems occur, accompanied by reversal of the direction of rotation), and in general to shift sub-harmonic resonances beyond the
20 operating range, or as in the case of the 25 Hz resonance and the corresponding unstable swinging ranges, to eliminate these completely by further increasing the value of the series resistor. The actual starting movement with the associated stalling is not considered in said Patent
25 Specification. The series resistor in the starting phase generally leads to a substantial reduction of the stalling power. Therefore, the series resistor is generally bypassed after starting. This may be omitted only if the residual power is adequate. The steps described in said
30 Patent Specification have a positive effect also in the case that the synchronous motor drives a reversing mechanism of the type described. However, this solution remains problematic and unreliable if a correct direction reversal is required over a wide range of voltages and
35 load-parameter tolerances.

It is known to employ a capacitor in conjunction with a single-phase synchronous motor. For example, a

capacitor is used in the operating circuit of a single-phase synchronous motor described in DE-PS 14 38 569.

However, in this case the capacitor only serves to dimension the motor for maximum power output. According to the inventors's statements in ETZ-A, 87, March 1966, pages 171 to 175, Eq. 11, it is then required that

$$\frac{E}{U} = \frac{1}{2 \cos \alpha}, \text{ where}$$

E = the induced voltage

U = the applied voltage

10

$$\omega L - \frac{1}{\omega C}$$

$\alpha = \arctan \frac{\omega L - \frac{1}{\omega C}}{R} = \text{phase angle of the circuit}$

ω = the mains-frequency

C = the series capacitor

15

R = the non-reactive motor resistance

L = the coil inductance.

DE-PS 14 38 569 specifically mentions values for $\tan \alpha$ between 0 and 5, i.e. inductive circuits, which also remain inductive when a capacitor is arranged in series. In the case of motor load systems which should not be loaded dynamically up to the actual maximum power, this capacitor serves to increase the maximum dynamic power. The use of a capacitor is only in conformity with this inventive concept if the total phase angle is not reduced too far below the value which corresponds to the dynamically permissible angular area $F_{Cu, dyn}$. Otherwise the power output rapidly decreases below the value $P_{ab, dyn}$ possible for the given permissible power dissipation. Here, negative phase angles were not considered either.

In addition to the series resistor, DE-PS 26 12 851 inter alia also mentions a capacitor or a combination of a capacitor and a resistor for starting purposes. The object of these additional elements is again to shift the subharmonic resonances or to damp the 25-Hz interference and adjacent unstable ranges. The actual starting movement with associated stalling is not considered in the Patent

Specification. As can be seen, this starting movement is not improved by including a capacitor which serves for shifting the unstable ranges. In addition, it is apparent from the entire context that only comparatively small changes of the impedances are envisaged, as necessary in order to shift the unstable and stable ranges beyond the operating region. Changing the inductive properties of the circuit has neither been intended nor implied.

By the use of the capacitor dimensioned in accordance with the invention, the attainable stalling power can be reduced. In a further embodiment of the invention the capacitor is disconnectable during motor operation between the points of reversal. For this purpose, there is provided a switch, which may be a mechanical or an electronic switch, but which may alternatively comprise a non-linear temperature-dependent resistor.

For the purpose of current limiting, in accordance with a further embodiment of the invention, an additional resistor is arranged in series with the capacitor.

It is found that a further optimization of the drive mechanism is possible by changing the mass moment of inertia. It may then be favourable if inertial elements in the form of discs or weights are arranged in the drive mechanism, for example on the motor shaft.

Embodiments of the invention will now be described in more detail, by way of example, with reference to the drawing. In the drawing:

Fig. 1 represents the principle of a drive mechanism for the pressing cone of a citrus-juice extractor, driven by a single-phase synchronous motor with permanent-magnet rotor and without auxiliary coil, the direction of rotation of the pressing cone being reversed continually,

Fig. 2 is a plan view of the mechanical reversing device of the pressing-cone drive mechanism,

Fig. 3 shows a reversing circuit for the single-phase synchronous motor, and

Fig. 4 is a modification to the circuit shown in Fig. 3.

A single-phase synchronous motor 3 with a permanent-magnet rotor and without auxiliary coil is constructed for connection to a single-phase a.c. mains 5. A capacitor 9 is arranged in the supply line 7 of the single-phase synchronous motor to obtain a reliable and intentional reversal of the direction of rotation of the single-phase synchronous motor.

The drive shaft 11 of the single-phase synchronous motor 3 drives the shaft 15 of the pressing cone 17 of a citrus-juice extractor via a bevel gear mechanism 13. The shaft 15 carries a reversing disc 19, Fig. 2 showing the disc in a plan view at the location of the line II-II in Fig. 1.

The reversing disc 19 is provided with stop cams which co-operate with stops 23. The stops 23 are resilient and, in order to obtain this resilient action, they act on the housing 25 via pressure springs 27.

A single-phase synchronous motor with a permanent-magnet rotor and without auxiliary coil does not have a fixed starting direction. If it encounters a braking moment which causes it to stall, it changes over and can start again in the opposite direction of rotation. In the claimed device this property is utilized for driving the pressing cone of a citrus-juice extractor, whose direction of rotation should change continually in a constant rhythm. Because of the starting properties of the single-phase synchronous motor the pressing cone rotation should merely be stopped in order to bring about a reversal of the direction of rotation of the single-phase synchronous motor.

In order to ensure that the single-phase synchronous motor starts smoothly and immediately upon the reversal of the direction of rotation at the points of reversal at the stops 23, the capacitor 9 is arranged in the power-supply line 7. Fig. 3 shows the power-supply

circuit for the synchronous motor 3. The capacitor 9 is arranged in the power-supply line. The single-phase synchronous motor 3, whose equivalent diagram comprises the ohmic coil resistance 31, the coil inductance 29 and the EMF 4, is arranged in series with the capacitor 9. The capacitor 9 is dimensioned so that the reactance of the capacitor at the mains frequency is higher than the reactance of the exciter coil. This means that the capacitor 9 is dimensioned so that the series resonant circuit comprising the capacitor 9, the coil inductance 29 and the coil resistance 31 becomes highly capacitive. This precludes so-called sputtering upon the reversal and thus a hesitation or fluttering of the pressing cone upon starting.

The circuit is dimensioned so that

$$\tan \frac{\omega L - \frac{1}{\omega C}}{R} < 0.$$

The operating current for the exciter coil with capacitor then suitably has an effective value corresponding to the effective value of the operating current without series capacitor, because the motor is then warmed up to the same extent.

If the direction of rotation in which the rotor can be pulled out of the parallel position by the magnetic detent torque is assumed to be the positive direction of rotation, the stop springs 27, in particular their resilience, should be dimensioned in such a way that for starting from the end and reversal position in the positive direction of rotation near the parallel position the sum of the spring torque and the detent torque is larger than the friction torque. For starting from the positive end or reversal position in the negative direction of rotation it follows that near the parallel position the difference between the spring torque and the detent torque should be larger than the friction torque.

The elasticity of the stops 23 is also of advantage for the dynamic operation, because during normal reversing operation the kinetic energy of the system is stored in the springs and the springs consequently
5 accelerate the rotor in the opposite direction.

In order to improve the properties of the drive mechanism, a disc 33 is arranged on the shaft 11. This disc 33 changes the mass moment of inertia of the drive mechanism.

10 In Fig. 4 the capacitor 9 is shunted by a parallel line 35 in which the switch 37 is arranged. This switch 37 is always closed when the synchronous motor 3 runs between the points of reversal defined by the stops 23. In this way the capacitor 9, which only
15 serves for reversal, does not present a load to the drive mechanism during the rotation of the pressing cone. The switch 37 may be a mechanical or an electronic switch, but may alternatively comprise an additional non-linear temperature-dependent resistor.

20 In Fig. 4 a further resistor 39 is represented by a broken line, which resistor may be arranged in the supply line 7. Such an additional resistor provides a more stable starting behaviour.

25

30

35

CLAIMS:

1. A reversing device for a two-pole single-phase synchronous motor (3) without starting auxiliary coil, which motor comprises a diametrically magnetized permanent-magnet rotor, whose shaft runs against stops for reversing the direction of rotation, and a capacitor arranged in series with the stator exciter coil, characterized in that the reactance of the capacitor (9) at the mains frequency is higher than the reactance (5) of the exciter coil, so that the capacitor values comply with the dimensioning rule:

$$\frac{\omega L - \frac{1}{\omega C}}{R} < 0$$

- in such a way that the operating current for the exciter coil with capacitor (9) has substantially the same effective value as the operating current without series capacitor.

2. A reversing device as claimed in Claim 1, characterized in that the capacitor (9) is disconnectable during motor operation between the points of reversal.

3. A reversing device as claimed in Claim 1, characterized in that an additional resistor (39) is arranged in series with the capacitor.

4. A reversing device as claimed in any one or several of the Claims 1 to 3, characterized in that an additional inertial element (33) is arranged on the motor shaft.

5. A reversing device as claimed in any one or several of the Claims 1 to 4, characterized in that the drive mechanism comprises a reversing disc (19) equipped with stop cams (21).



6. A reversing device as claimed in Claim 5, characterized in that the reversing disc (19) is arranged directly on the pressing-cone shaft (15).

7. A reversing device as claimed in Claim 1, characterized in that the reversing stops (23) are elastic.

10

15

20

25

30

35

