UNIVERSIYT OF GAZİANTEP
ELECTIRICAL AND ELECTRONIC ENGINEERING DEPARTMENT
EEE 322
EXPERIMENT 3
SYNCHRONISATION OF SYNCHRONOUS MACHINES

A. Object of the Experiment:

The object of the experiment is to synchronize a synchronous machine on to a three-phase bus-bar using three types of synchroscope, two employing bulbs and the other one is an oscilloscope.

B. Theory:

Synchronization of Synchronous Machines

Synchronous m/c 's are usually operated being connected to infinite bus-bars. They are either driven by a prime mover (then they act as an alternator) or coupled to a load when they act as a synchronous motor. An infinite bus-bar is a supply system which can either absorb or supply electrical power and is not affected by the changes in any individual m/c 's connected to it synchronous speed by some auxiliary mean before they are connected to the infinite bus-bars.

In small m/c 's (some of the m/c 's having R12, R13, R16 and R17 type of rotors in our laboratory) "run-up" mat be achieved by an auxiliary set of winding, at reduced voltage. While synchronous machine is operating at a speed close to the synchronous speed 4 conditions must be satisfied before the synchronizing switch is closed.

a) The armature voltage of the m/c and bus-bar voltage should have the same magnitude. Otherwise, a large transient current would momentarily flow. Since the impedance of the transient current path is small, even relatively small resultant voltage may induce a very large current. Therefore, excitation of the synchronous generator to be connected to should be adjusted until both voltage are the same. The condition is verified using two-voltmeters.

b) Phase sequence of three-phase armature voltages should be the same as that of the bus-bars, otherwise during synchronization large resultant voltage may be produced in the m/c winding and heavy currents would flow. This condition is achieved by using phase sequence indicator.

c) The frequency of two sets of voltages should be the same. Otherwise, heavy current would flow during synchronization, since the m/c would tend to run synchronously this means that the alternator must be driven at synchronous speed. This condition is achieved by using double frequency meters.

d) Corresponding phase voltages of the alternator and bus-bar must be coincident on synchronization. Otherwise, resultant voltage may exist as shown in the figure below causing a large transient current to flow.

C. Procedure

R12, r13, R10 and R17 types of rotors will be used in this experiment.

1.Connect circuit as shown in Fig.3. With the straight connected bulb-type synchroscope connected across the synchronizing switch S2 as shown in Fig.4(a) start the d.c driving machine and adjust its speed to a value close to that of the synchronous machine. Switch on the three-phase supply and adjust the three-phase variac until the line-to-line voltage across the supply terminals of synchronizing switch is equal to the rated value. Slowly increase the field current of synchronous m/c until the line-to line voltage across m/c terminals of the synchronizing switch is equal to that across the supply terminals. Check the phase sequence of the voltages at the machine and supply terminals of the synchronizing switch, using the phase sequence indicator. If the phase sequence of the each system is not the same, switch-off and three-phase supply and interchange the two phases of the supply.

It will be observed that the bulb of the synchroscope now flash on and off simultaneously. Adjust the speed of d.c driving machine until the bulb flash on about once every two second. Close the synchronizing switch when the bulbs are off. Observe with the aid of the strobe-flash that the m/c is now synchronized onto the three-phase bus-bar. Stop the d.c driving machine using the starter and observe that.

2. Repeat procedure (1) with the cross-connected synchroscope as shown in Fig.4(b) and observe that in this case bulbs flash on sequentially. Note the change in sequence of the flashing bulbs as the speed of d.c driving machine is varied below and above the synchronous speed of the synchronous m/c. close the synchronizing switch when the bulb which is straight-connected is off.

3. repeat procedure (1) above with the synchronizing switch connected to an oscilloscope as shown in Fig.4(c). Note that in fact an attenuator (probe) must be connected to the X and Y plates in order to obtain a Lissajous figure which is displayed on the CRO screen. Observe that before synchronization, a rotating Lissajous figure is obtained on the screen. Initially connecting both X and Y plates to the same phase, say phase B, check the shape of Lissajous figure. Once a straight line with a slope less than 90º is observed on the CRO screen, close the synchronizing switch.

Condition (a) may be ensured by simple measurement: Condition (b) using a phase sequence meter and the following two conditions especially the fourth one is the most difficult to achieved and requires a synchroscope.

The principle underlying the operation of a straight-connected lamp type synchroscope can be illustrated by the simple arrangement shown in fig.1(a). Assume that phase sequence of the incoming m/c is Al, B1, Cl and that of the three phase bus bar is A2, B2, C2. Also assume that conditions (a) and (b) are already satisfied. Now the phasor diagram representing the to sets of the voltages can be drawn as in fig.1(h) The instantaneous voltage across any of the lamps is therefore equal to the difference of the corresponding phasor voltages. The voltage across lamp L1 can be represented by: $\overline{V}_{L1}=\overline{V}_{A1}-\overline{V}_{A2}$. If $\overline{V}_{A1}$ and $\overline{V}_{A2}$ rotate at the same frequency f (angular speeds w), then ($\overline{V}_{A1}-\overline{V}_{A2}$) will be a constant phasor rotating at the same frequency. Assume that two sets of voltages have slightly different frequencies, f_1 and f_2 (hence speeds of the w_1 and w_2) then the phasor difference ($\overline{V}_{A1}-\overline{V}_{A2}$) is no more constant, but its magnitude varies in time in accordance with the difference in frequency. Therefore the brightness of lamp L1 changes in time. The two phasors $\overline{V}_{A1}-\overline{V}_{A2}$ overlap $(w_1-w_2)/2\pi$ times each second and hence the voltage across L1 passes through zero and L1 becomes off at this instant. The corresponding phase voltages coincide at this instant and synchronization can be achieved by closing the switch.

Consider the “cross connected" synchroscope shown in Fig.2(a). Lamps L1 and L2 are cross-connected. L3 is straight connected. The corresponding phasor diagram is as shown in Fig2(b). An analysis of this diagram will show that the voltages across the lamps will vary in a cyclic manner. Consequently, the lamps will now light up sequentially. This sequence will be determined by the relative speed between two systems, and hence this, method has the advantage of showing whether the incoming m/c is running above or below the synchronous speed.

Cross-connected Lamp synchroscope

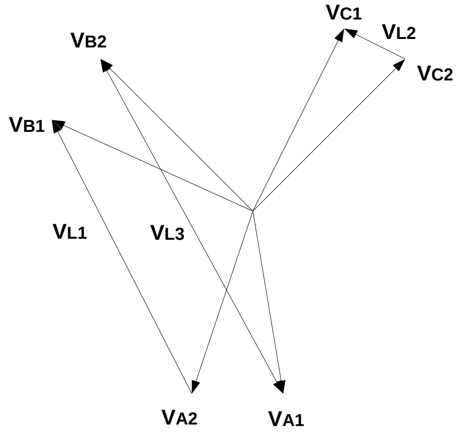
This connection with a certain difference in frequencies results in successive lighting and extinction of the lamps and produces the impression of light rotation when the lamps are arranged in cyclic manner. The lamp lighting frequency and consequently the apparent speed of light rotation will correspond to the difference between the line frequency and that of the generator being connected. When the generator being connected runs at a speed below the synchronous speed the light will rotate in one direction and at a speed above synchronous, the rotation of light will be reversed. Thus the direction of light rotation indicates whether the speed of the incoming m/c is to be increased or decreased to bring it into synchronism. This cannot be attained when the lamps are straight connected. The proper moment for switch closure is indicated more precisely by the phasing lamp connected to phase C (Lamp L3) in our case fig.2(a).

The lamps used for synchronization must be connected through voltage transformers if the synchronous m/c’s have voltage higher than that permissible for lamps. But care must be taken in choosing voltage transformers having the same vector group.

In modern power stations developed synchronous devices are used. For example lamp light rotation is replaced by the rotation of the pointer of a special synchroscope operation on the difference frequency allowing to find the point of synchronism. In conjunction, a null voltmeter and a double frequency meter are used.

D. Conclusion

1. Discuss the advantages and disadvantages of each type of synchroscope.



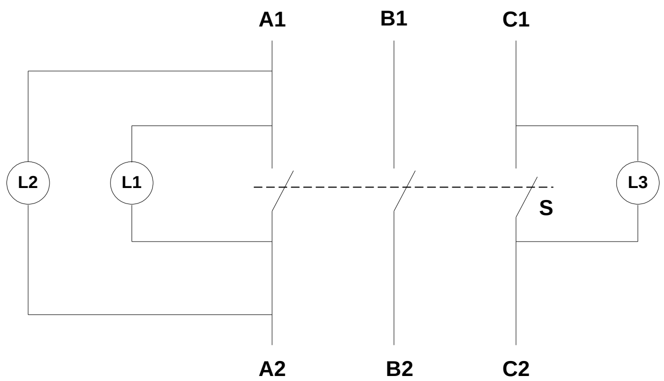


Fig.1(a) straight-connected lamp synchroscope

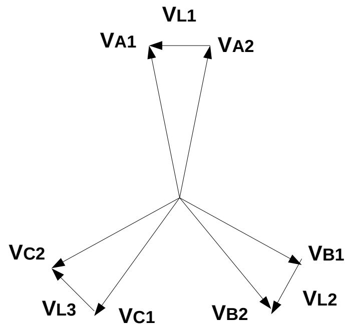


Fig.1(b) phasor diagram corresponding to Fig.1(a)

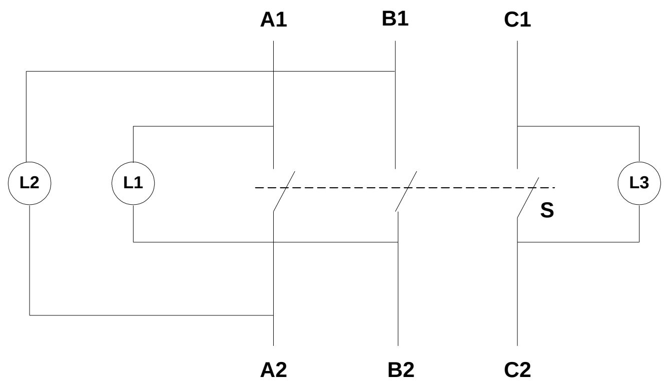


Fig.2(a) Cross-connected lamp synchroscope

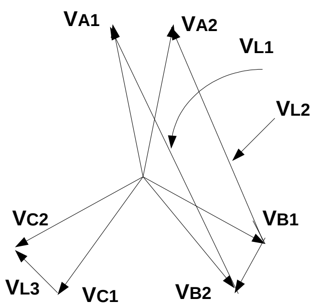
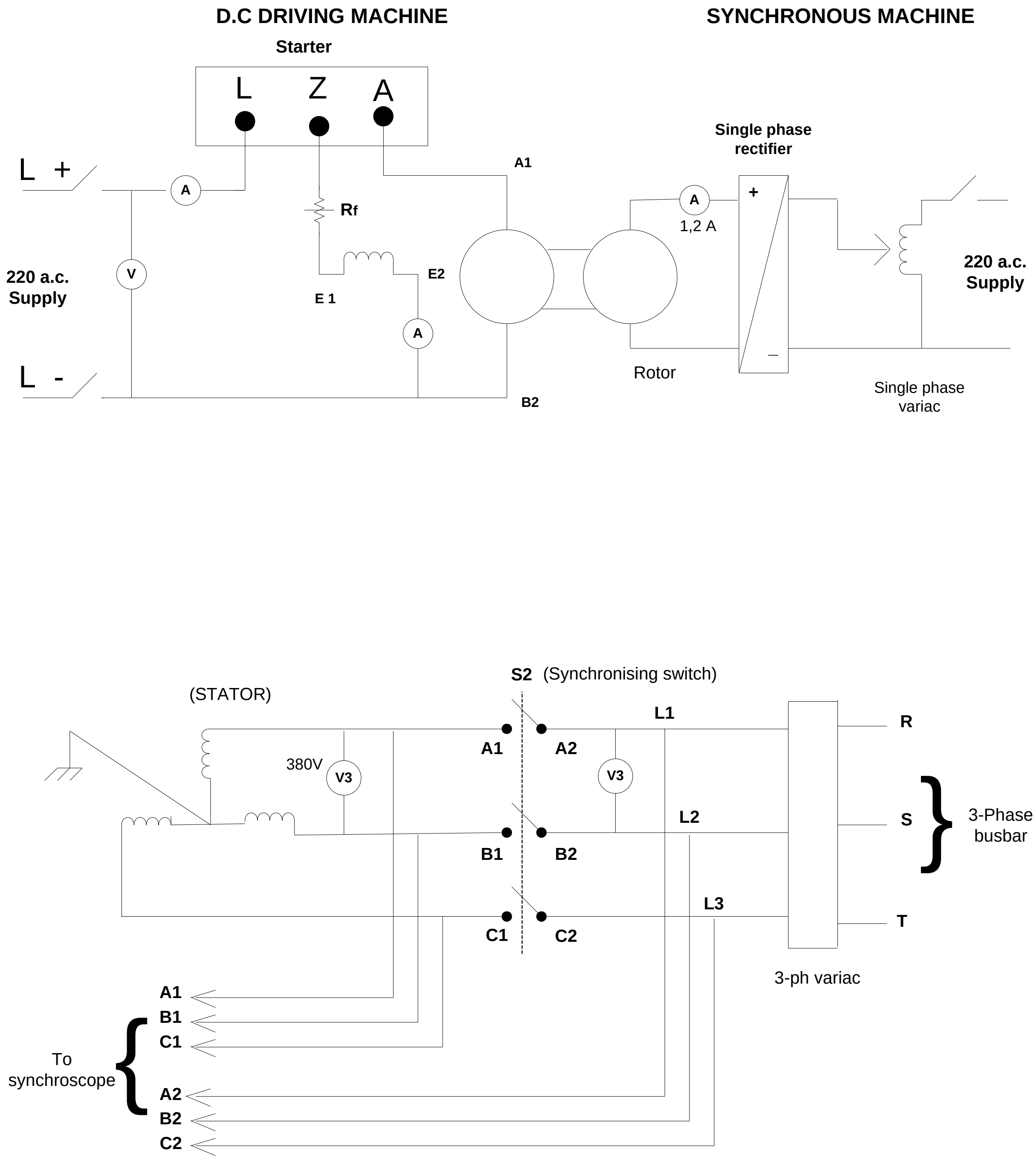
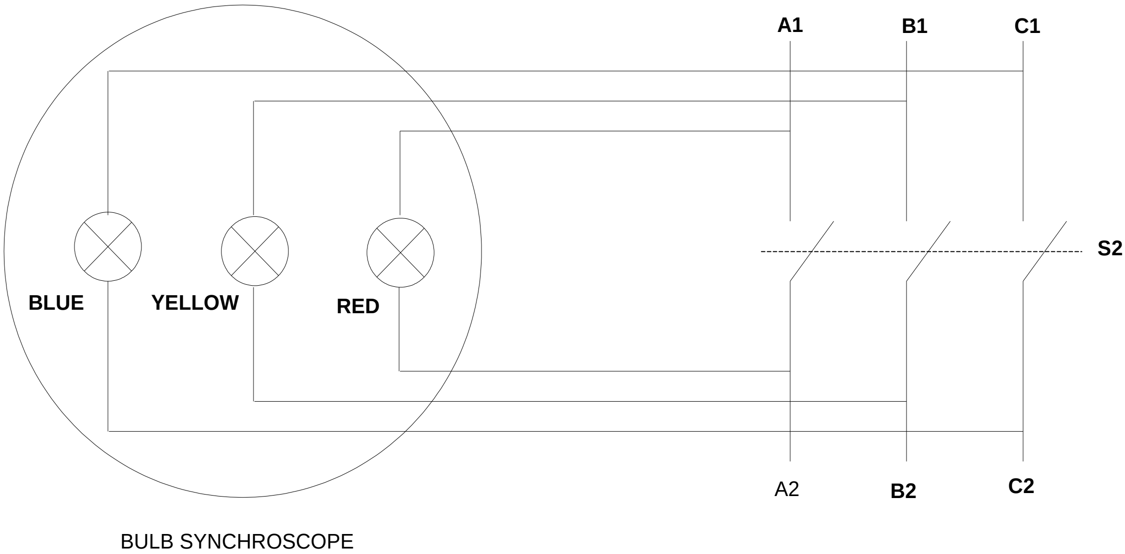


Fig.2(b) phasor diagram corresponding to Fig.2(a)

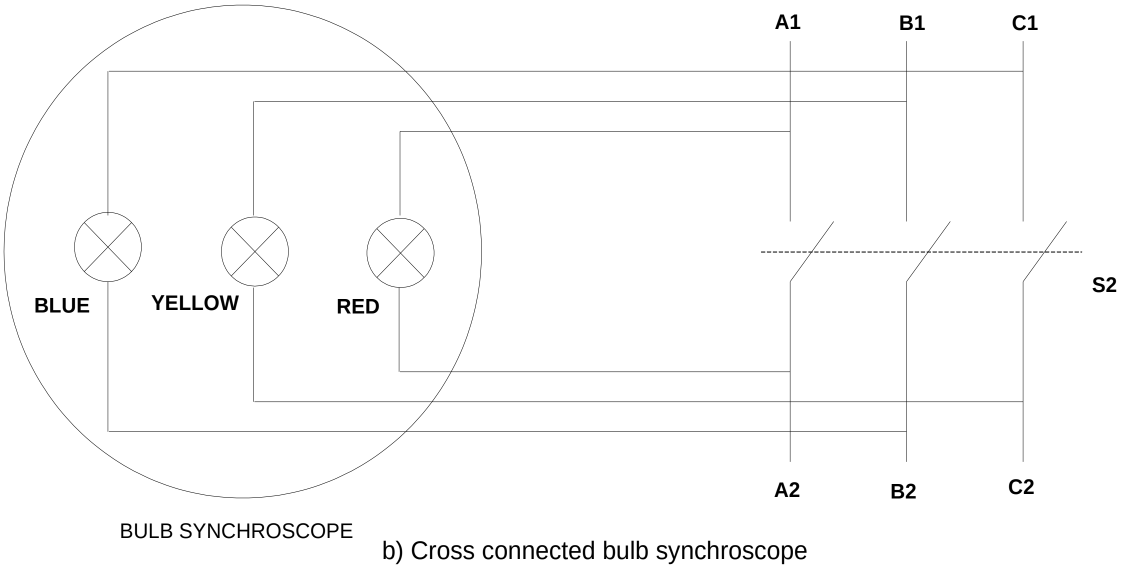


D.C DRIVING MACHINE
SYNCHRONOUS MACHINE
Starter
L
Z
A
L +
L -
A
V
220 a.c.
Supply
Rf
E 1
E2
A
A1
B2
A
1,2 A
Single phase
rectifier
+
–
Rotor
Single phase
variac
220 a.c.
Supply
S2 (Synchronising switch)
(STATOR)
380V
V3
A1
A2
B1
B2
C1
C2
V3
L1
L2
L3
R
S
T
3-Phase
busbar
3-ph variac
To
synchroscope
A1
B1
C1
A2
B2
C2

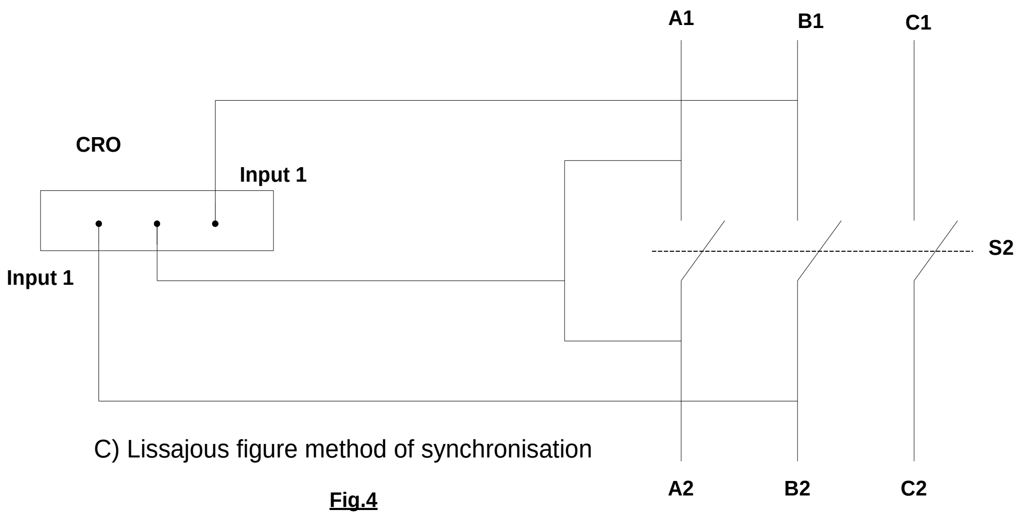
Fig.3



a) straight connected bulb synchroscope



b) Cross connected bulb synchroscope



C) Lissajous figure method of synchronisation

Fig.4

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