

# P151664 PED Assign 1

*by* Derek Lockhart

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11<sup>th</sup> December 2018

Synchronous Motors

and

Power Factor Correction

P151664 Derek Lockhart  
M6X00375 Power Electronics and Drives  
Dr Steve Mosey

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## 1. Abstract

Lab exercise to examine power factor correction in a three-phase motor with a single-phase supply and the effects various correction capacitor sizes have on phase angle and current magnitude. Further investigating a fault scenario and the effects this will have on power factor.

## 2. Literature Review

This paper shall examine the operation of synchronous motors and the effects of power factor correction. Rashid et al [1], define synchronous motors as those motors using a polyphase winding on the stator and a DC carrying winding on the rotor. Wildi [2], explains that synchronous motors once started are locked into synchronisation with the rotating magnetic field produced by the stator windings. Wildi further explains that synchronous motors are designed to operate at unity power factor. This is advantageous as it reduces the reactive load on the supply, further, DC overexcitation of the rotor will give a capacitive like leading power factor. Hughes [3], explains that synchronous motors are not inherently self-starting, this is due to the rotating magnetic field having insufficient force to overcome the rotor inertia in a single pass, therefore as the rotating field passes the rotor an opposite force is applied, this results in the rotor effectively juddering and an average torque of zero. To overcome this a rotor cage is used, in effect starting the synchronous motor as an induction motor, this will continue until almost at synchronous speed whence the dc excitation is applied to the rotor and the rotational speed is locked. Chapman [4], seems to agree and refers to the rotor cage as amortisseur windings, literally damper windings[5], as they will have a damping effect on changes to system stability, e.g. load. Chapman further describes other methods of starting synchronous motors, from using smaller

starting motors, generally induction motors, or alternatively by reducing the stator input frequency before increasing it as the rotor speed builds. However, in this case the equipment is a three phase motor and a single-phase supply, therefore a different starting system shall be used. Lemau [6] explains the limitations of a single phase supply on a three phase motor such that the motor direction is dependent on the choice of star or delta configuration.

1

**Lemau and reduced starting torque.** Malyar and Malyar[7], further explain that the use of a shunt capacitor creates a shift in the phase current sufficient to create a rotating magnetic field and start the motor in effectively the same way as an inductive motor.

### 3. Power Factor Correction Exercise

Power factor is a dimensionless measure, that is less than or equal to 1, and defines how well a load draws real power as opposed to apparent power[8]. A power factor of 1 will show as the voltage and current being in phase, as such then all reactive currents will be equal and in antiphase and therefore cancel each other out. This is shown in Figure 1.

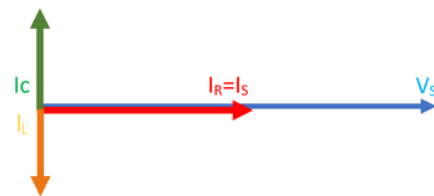


Figure 2 Power factor 1 phasor diagram

To calculate the Power Factor if the supply (load) current lags the applied voltage by  $25^\circ$ .

$$\text{Power factor} = \cos \phi = \cos 25^\circ = 0.906$$

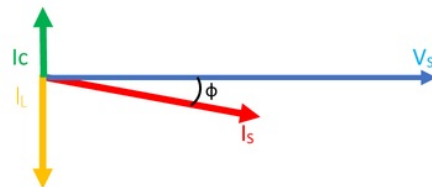


Figure 3 Power factor in inductive circuit

The circuit was configured in accordance with Figure 3

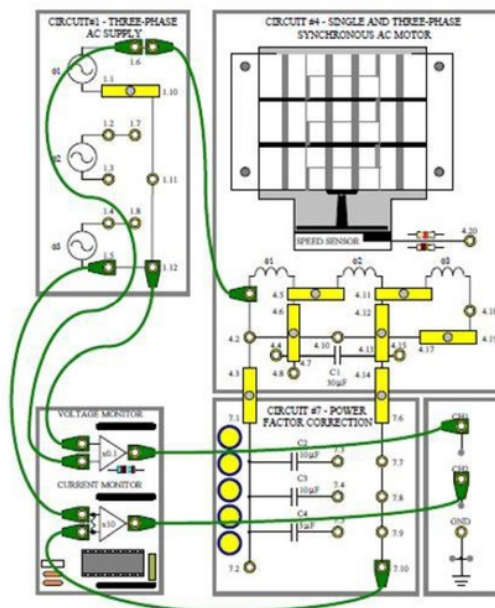


Figure 4 Exercise Power Factor Configuration

Redrawn this gives a circuit layout as shown in Figure 4

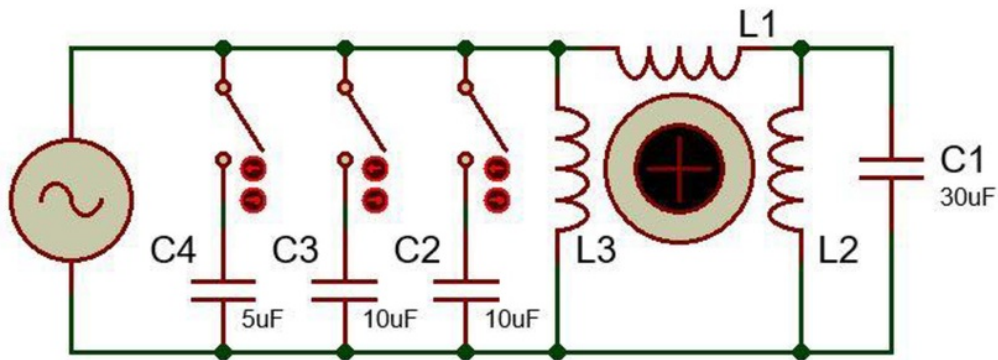


Figure 5 Redrawn circuit diagram

As motor inductive reactance increases with frequency this exercise shall show the effects off capacitive correction of the power factor. Therefore, the supply frequency was increased to maximum, this was measured to be 70Hz.

The phase angle and current amplitude was measured with different combinations of the corrective capacitors C2, C3 & C4.

| Correction Capacitor   | None               | C2 – 10uF            | C2 + C3 -20uF     | C2 + C4 – 15uF      |
|------------------------|--------------------|----------------------|-------------------|---------------------|
| Phase Angle (Lead/Lag) | <b>I Lag 30.5°</b> | <b>I Lag 11.025°</b> | <b>I Lead 20°</b> | <b>I Lead 4.23°</b> |
| Current Amplitude      | <b>480mA p-p</b>   | <b>411mA p-p</b>     | <b>457mA p-p</b>  | <b>368mA p-p</b>    |

Table 1 Phase and Current for various corrective capacitor values

Therefore, the shunt capacitance value that gives the nearest to complete correction of phase angle is 15uF.

It can be seen that with the best available value of power factor correction, the phase angle and current are both minimum. The power factor of this circuit with no correction capacitor in circuit is calculated thus

$$\text{pf} = \cos 0 = \cos 30.5^\circ = 0.86.$$

Similarly, the power factor of this circuit with the best correction capacitor available is

$$pf = \cos 0 = \cos 4.23^\circ = 0.997.$$

The supply voltage was measured at **52.3V p-p**.

With no correction capacitor in circuit the power supplied was

$$\frac{52.3V \times 480mA}{8} \times \cos 30.5^\circ = 2.688W$$

With the best available correction capacitor in circuit the power supplied was

$$\frac{52.3V \times 368mA}{8} \times \cos 4.23^\circ = 2.399W$$

It can be seen that the decreased phase angle and circuit current has produced a corresponding decrease in the power consumed. This can further be seen in Figure 5. Although only four data points have been recorded Figure 5 does show the dip synonymous with this graph, such that in a perfectly corrected system the current shall tend towards zero plus losses within the system[4] [9].

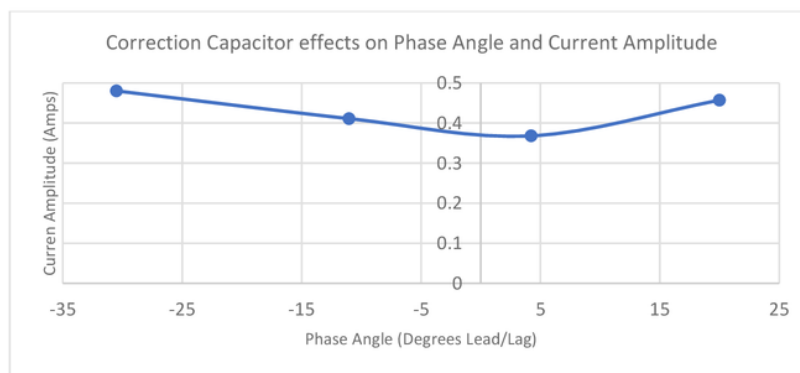


Figure 6 Phase angle and current amplitude

#### 4 Fault Finding Exercise

With a fault switched into the circuit the phase angle and current amplitude measurements were repeated, the results are shown in Table 2.

| Correction Capacitor   | None        | C2 – 10uF   | C2 + C3 -20uF | C2 + C4 – 15uF |
|------------------------|-------------|-------------|---------------|----------------|
| Phase Angle (Lead/Lag) | I Lag 31.2° | I Lag 20.1° | I Lead 2.1°   | I Lag 12.23°   |
| Current Amplitude      | 501mA p-p   | 432mA p-p   | 354mA p-p     | 416mA p-p      |

Table 2 Phase and Current for various corrective capacitor values in fault conditions

The data from this fault series of readings has been plotted for comparison with the original data in Figure 6.

There appears to be a general decrease in the current demand through this series of readings, due to its consistency, this discrepancy could be assumed to be a consequence of the training rig implementation and shall be disregarded. It can also be seen that the readings for zero added capacitance are roughly comparable and show no significant change.

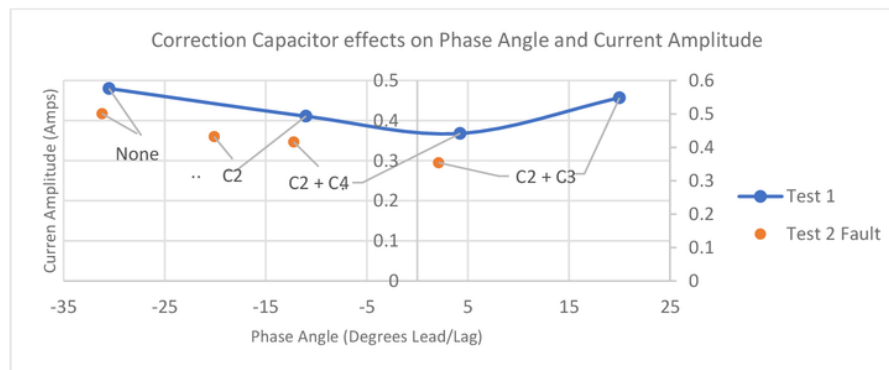


Figure 7 Phase and current comparisons

It is noted that the first series data point for C2 (10uF) and the fault series data point for C2 + C4 (15uF) are directly comparable. It is also be noted

that the data points for series one C2 + C4 (15uF) and fault series C2 + C3 (20uF) are similarly comparable.

It would seem reasonable to surmise from this trend that the common denominator for this skewed series of data points would be C2, this would seem to be confirmed by the lone C2 data point in the second series.

From this observation it is proposed that the fault is the C2 capacitor that is not performing to specification. By these readings it would appear to be providing approximately half its rated 10uF.

## 5. Conclusion

Synchronous motors are devices that may be used for high accuracy devices, they may also be reconfigured to act to correct power factor. Synchronous motors are not self-starting, and various methods are available to achieve rotation at which point the dc excitation would lock the rotor into speed with the rotating magnetic field on the stator. Correct power factor correction can reduce the power consumption of the motor and can be used to correct the power factor on the supply voltage line.

## 6. References

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- [6] Lemau, "How to use three phase motor in single phase power supply," *Electric Neutron*, 2014. [Online]. Available: <https://www.electricneutron.com/electric-motor/use-three-phase-motor-single-phase-power-supply/>. [Accessed: 10-Dec-2018].
- [7] V. S. Malyar and A. V Malyar, *Electrical engineering & electromechanics.*, no. 3. Kharkiv Polytechnic Institute, 2016.
- [8] N. Mohan, T. M. Undeland, and W. P. Robbins, *Power electronics : converters, applications, and design*. Wiley, 1995.
- [9] S. N. Vukosavi  , *Electrical machines*. Springer, 2013.

# P151664 PED Assign 1

## GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

76/100

**Instructor**

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### Comment 1

Not sure what you mean in this sentence. I think you may have started editing it and forgotten to finish.

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GRADING FORM: SMU GENERIC\_SMOSEY

DEREK LOCKHART

75.85

## ENGAGEMENT WITH LITERATURE

*including reading, referencing, academic conventions and academic honesty*

 A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied

**3.75**

## KNOWLEDGE & UNDERSTANDING

*Knowledge of the basic underlying concepts and principles of a subject.*

 Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.

**22.2**

## COGNITIVE & INTELLECTUAL

*Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.*

 Thoroughly logical work, supported by evaluated evidence. High quality analysis. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.

**23.4**

## PRACTICAL APPLICATION SKILLS



An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, with use of relevant examples. Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.

**22.5**

## **TRANSFERABLE SKILLS**

*Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.*



Can communicate with an exceptionally high level of professionalism. Work is exceptionally coherent, very fluent and is presented professionally.

**4**