M-TECH SERVICES

Test date. 21.02.01

Test Description

Mounted a TECO 18 kW 415 v AC 20 ams F.L.A. 1440 rpm Motor on a Dynometer cast-iron Test bed

Coupled a Dyno unit via a universalcoupling to the drive shaft of the motor

10mm Cable used to supply motor equipment. Rated @ 50 amps per phase.

Connected to a Sprecher & Schuh KTA3 Thermal overload unit to the 3 phase input cables. and set to trip to 33 amps.
IMC 22 Powersave Optimiser is rated at 45 amps Full Load Current.

Connected tails from contactor to input terminals on ES Unit.
Note: that the A phase leg was connected to current transformer post so as auto cut - off could be operated

Connected 3 phase tails to motor terminals and bridged terminals in Delta pattern for 415v. as per name plate.

Earthed Motor drive & Motor

Connected QUT Power Test Instruments to motor terminals to measure Voltage. current and power factor for power consumption measurements Cathode Ray Oscilloscopes to record wave form of volts and current.

Checked all settings in drive unit and bridged start control terminals for continuous run. Terminals 1 & 2.

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Report on Power Optimiser for Steve Rolls Electrical

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1. Introduction

The output torque, efficiency and general characteristic behaviour of a 3-phase induction motor can be changed by varying the amplitude of the 3-phase voltages supplied to it. A common method of varying the voltage is to utilise a conventional 3-phase soft starter under variable firing angle control. The Optimiser under test appears to use the same concepts but instead of the firing angle being under a fixed ramp control, as in a soft-starter, the firing angle is controlled by feed-forward of one of the motor electrical variables – possibly the input current.

This study considers a 3-phase induction motor operating under variable steady-state load conditions developed by a dynamometer with and without the Optimiser in circuit. Using measurements of input and output power and shaft speed, the efficiency of the motor can be determined. Additionally, the power factor of the motor can be found using measurements of input current and voltage.

2. Practical Arrangement

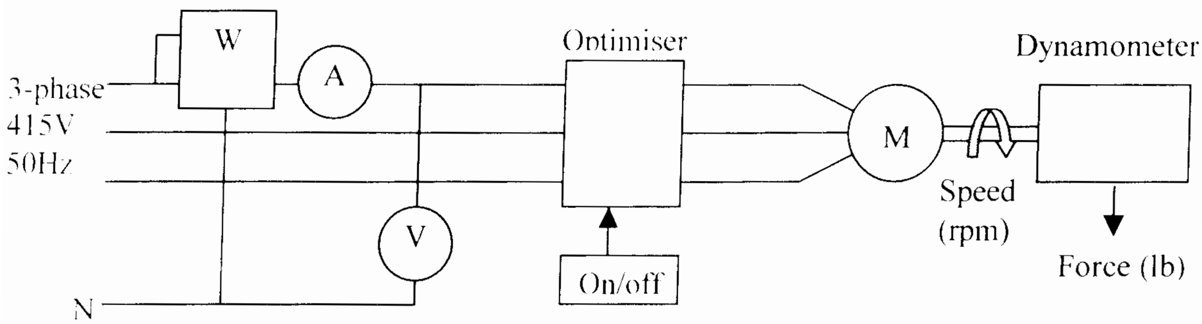


Figure 2.1: Basic measurement system.

Efficiency: $$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

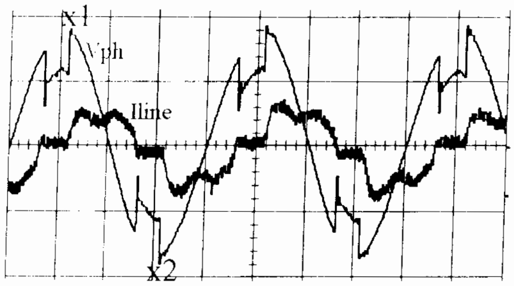
Power Factor: $$pf = \frac{P_{in} / phase}{V_{phase} \times I_{line}}$$

3. Results

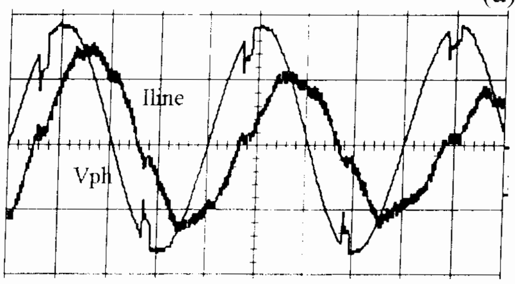
3.1 Optimiser switched on:

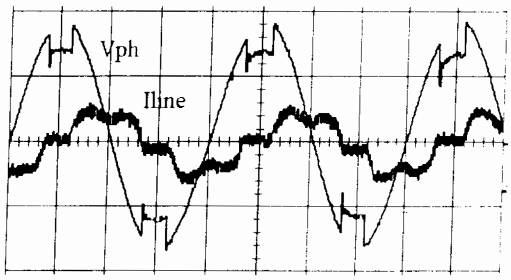
Table 3.1: Results for Optimiser switched on.

Volt(V)	Amps(A)	Speed(rpm)	Pin(W)	Pout(W)	Eff(%)	Tout(Nm)	PF
251	8	1497	2100.0	1396.0	66.5	8.9[1]	0.35
250	12.4	1495	3840.0	2788.2	72.6	17.8[2]	0.41
249.8	14.6	1492	5760.0	4173.9	72.5	26.7	0.53
249.8	16.2	1489	7200.0	5554.0	77.1	35.6	0.59
249.6	18	1486	8340.0	6928.5	83.1	44.5	0.62
250	18.8	1484	10380.0	8303.0	80.0	53.4	0.74
249.1	20.4	1481	11820.0	9667.2	81.8	62.3	0.78
249	22.6	1479	13380.0	11033.3	82.5	71.2	0.79
248.3	25.2	1476	15120.0	12387.3	81.9	80.1[3]	0.81
248	27	1472	16380.0	13726.4	83.8	89.0	0.82
249.6	31	1466	19200.0	16131.1	84.0	105.1	0.83

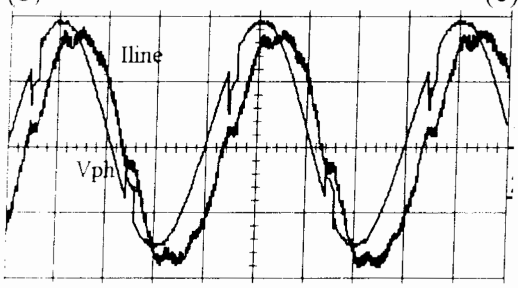


(a)





(b) (c)



(d)

Figure 3.1: Phase voltage and line current with the Optimiser switched on for output torque (a) T_{out} = 8.9Nm, (b) & (c) T_{out} = 17.8Nm, (d) T_{out} = 80.1Nm.
Scale: 200V/div, 20A/div.

[1] Figure 3.1(a)
[2] Figure 3.1(b)&(c)
[3] Figure 3.1(d)

3.2 Optimiser switched off:

Table 3.2: Results for Optimiser switched off.

Volt(V)	Amps(A)	Speed(rpm)	Pin(W)	Pout(W)	Eff(%)	Tout(Nm)	PF
250.2	12.2	1497	2820.0	1396.0	49.5	8.9[4]	0.31
250.2	12.8	1495	4200.0	2788.2	66.4	17.8[5]	0.44
250.3	14.4	1493	6000.0	4176.7	69.6	26.7	0.55
249.5	15.6	1491	7380.0	5561.4	75.4	35.6	0.63
250.2	16.6	1487	8580.0	6933.1	80.8	44.5	0.69
249.1	18.6	1484	10440.0	8303.0	79.5	53.4	0.75
248.6	20.6	1482	11700.0	9673.8	82.7	62.3	0.76
249	22.6	1480	13380.0	11040.8	82.5	71.2	0.79
248.6	25	1476	15120.0	12387.3	81.9	80.1[6]	0.81
248.5	27	1474	16380.0	13745.1	83.9	89.0	0.81
249.3	30.6	1468	19200.0	16153.1	84.1	105.1	0.84

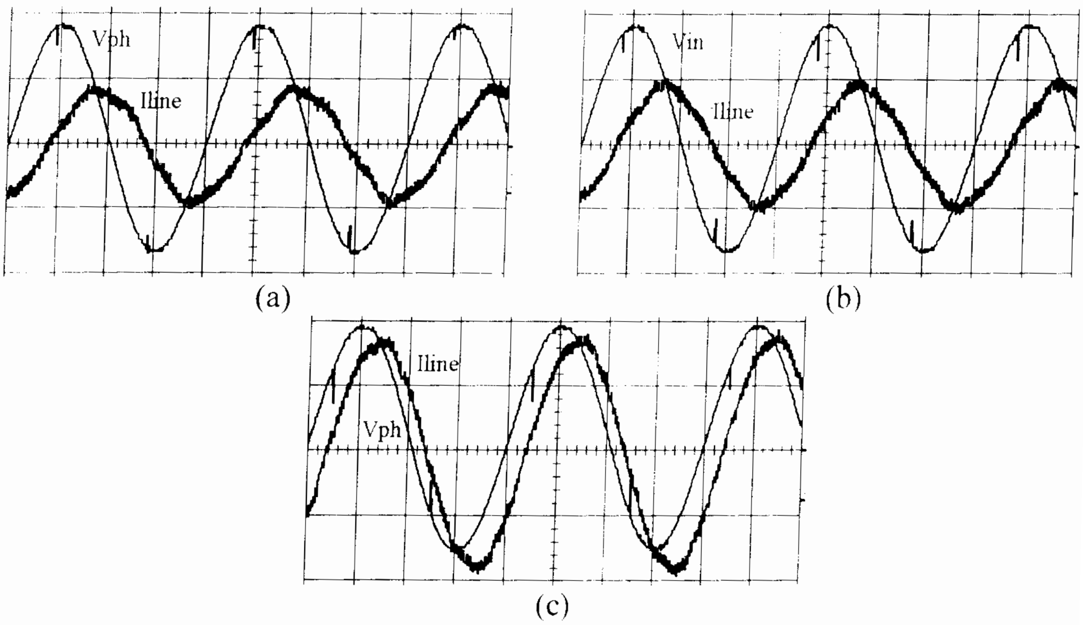


Figure 3.2: Phase voltage and line current with the Optimiser switched off for output torque (a) T_{out} = 8.9Nm, (b) & (c) T_{out} = 17.8Nm, (d) T_{out} = 80.1Nm.
Scale: 200V/div, 20A/div.

[4] Figure 3.2(a)
[5] Figure 3.2(b)
[6] Figure 3.2(c)

3.3 Torque, Input Power, Efficiency & Power Factor Comparisons

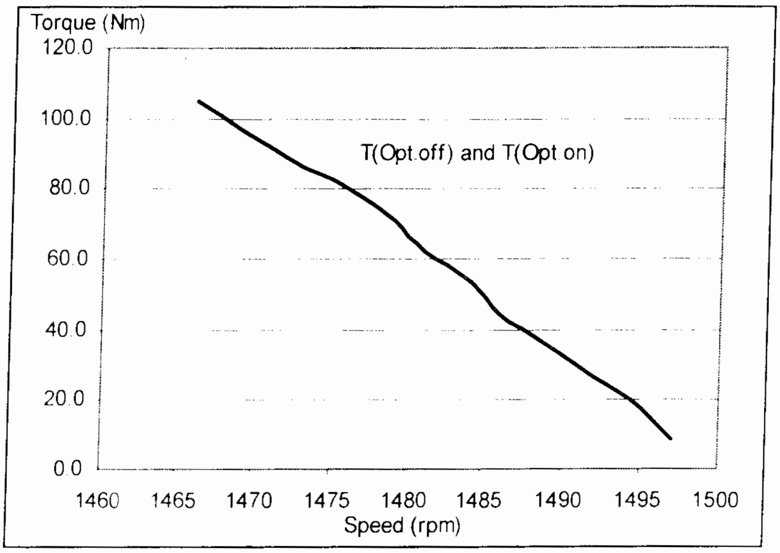


Figure 3.3: Torque-speed curves for induction motor operating with and without the Optimiser.

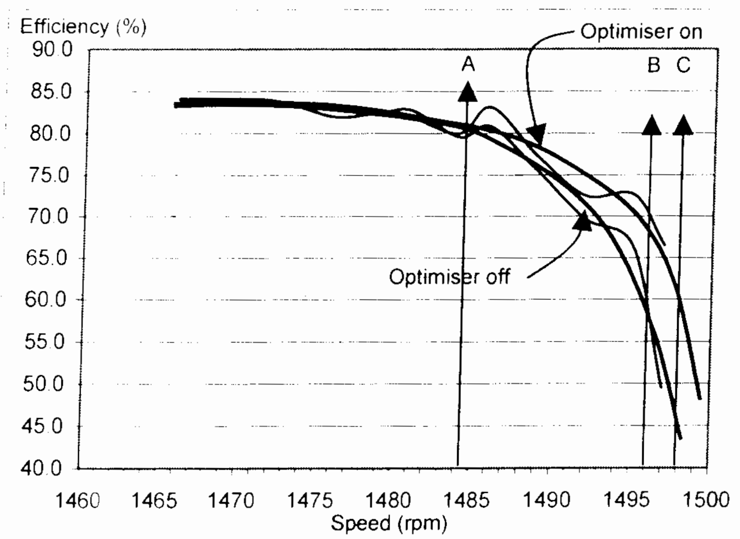


Figure 3.4: Efficiency-speed curves for induction motor operating with and without the Optimiser.

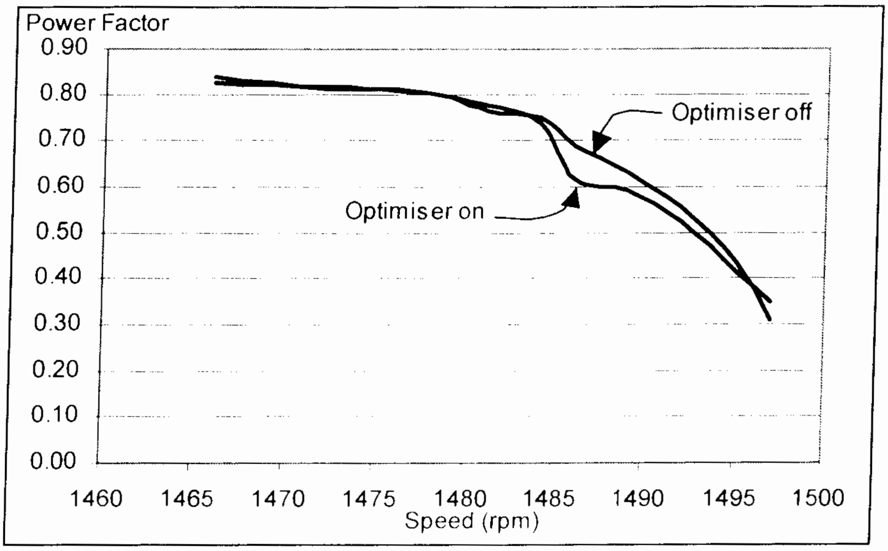
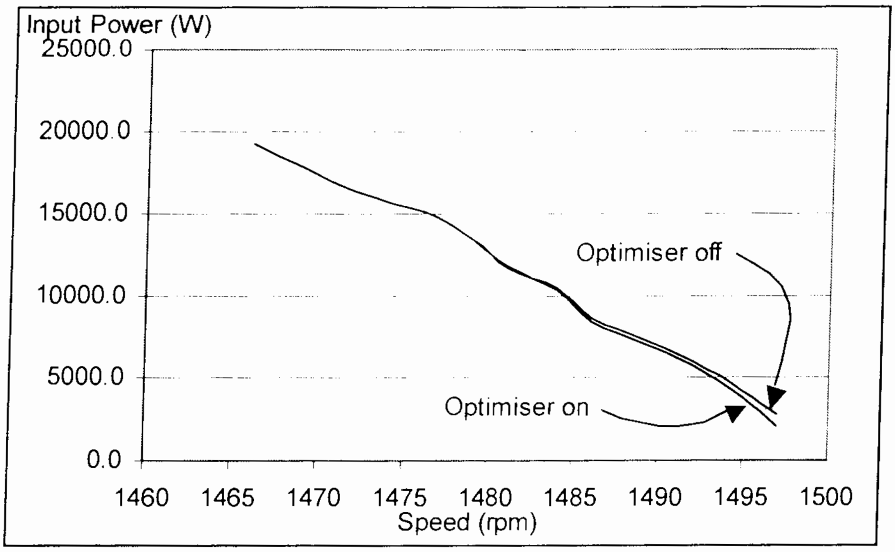
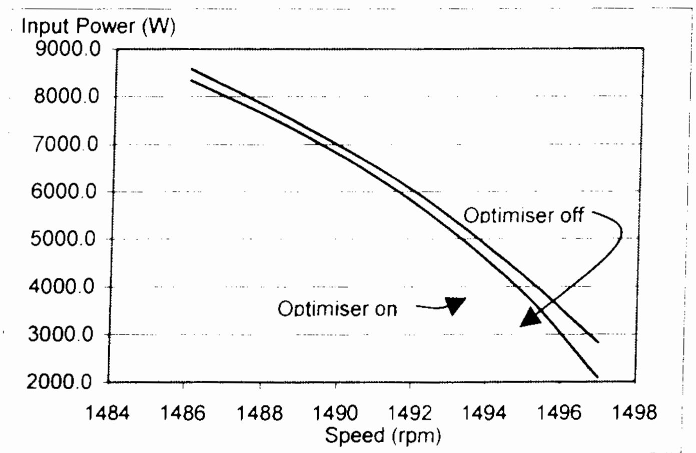


Figure 3.5: Power factor-speed curves for induction motor operating with and without the Optimiser.



(a)



(b)

Figure 3.6: Input Power-speed curves for induction motor operating with and without the Optimiser (a) full slip window, (b) magnified section close to synchronous speed.

4. Discussion of Results

The most important results are presented in figure 3.4 and show efficiency versus speed curves for the motor operating with and without the Optimiser. It can be seen that the original results reflect a degree of experimental error and trend-lines have been inserted to assist with the analysis. The effective operation of the optimiser can be seen to occur at speeds above 1485rpm (A on graph) or, using tables 3.1 and 3.2, at line currents below approximately 18A(rms).

Further, the effectiveness of the Optimiser increases the efficiency of the motor by approximately 10% at 1496rpm (B on graph) rising to a predicted 15% at 1498rpm (C on graph). At higher speeds the efficiency difference will decrease as the efficiency curves both fall to close to zero efficiency at the synchronous speed of 1500rpm.

The oscilloscope curves shown in figure 3.1 for the Optimiser turned on illustrate the degree of current waveform deformation and harmonic current injection when the unit is operating at low line currents (figures 3.1(a)).

Figures 3.1(b) and (c) show the Optimiser in operation at slightly higher input currents but oscillating between two different switch firing angles. It is not known whether this is a normal operating mode – the induction motor failed to respond to these oscillations – or whether a small instability existed within the control and feedback loops. Note – the switch firing angles are shown as x1 and x2 in figure 3.1(a).

When the load torque is increased (figure 3.1(d)), the Optimiser switch firing angle decreases further (a higher average voltage is applied) and the current becomes almost sinusoidal to the extent that the motor performance will be the same as if the Optimiser were switched off.

Figure 3.2 demonstrate the motor line currents when the Optimiser is turned off. These currents can be seen to have a higher peak value compared to the results of figure 3.1 and the same peak value as the result shown in figure 3.1(d). This illustrates that the Optimiser is causing the line current to be reduced at speeds close to synchronous speed (1500rpm).

The torque-speed curves of figure 3.3 are the same for motor with and without the Optimiser working.

Figure 3.5 shows that the power factor is decreased by a maximum of around 0.5 when the Optimiser is turned on (the perturbation at 1486rpm has been ignored). However, this occurs only at about 1489rpm and the effect appears to reduce to zero within 6 or 7 rpm on either side of that.

From figure 3.6(a) and (b) it can be seen that the power drawn from the supply is up to1kW less when the Optimiser is switched on. Higher differences would be achieved if the motor were operated closer to synchronous speed, that is, with lower loads.

5. Conclusion

- The efficiency of the motor is improved by a maximum of about 15%, but this improvement is over a limited range of operation ie. when there is low torque being produced by the motor.
- Either the Optimiser must be tuned to give the improvement in efficiency at a more reasonable and higher torque, closer to where the motor would normally operate, or a different Optimiser should be used to suit the power rating of the motor.
- However, it may not be possible to change these characteristics – it does depend on the load and the motor torque-speed characteristics and the interaction between the two.
- The Optimiser ceases to have any effect below 1485rpm for the motor used in this test.
- The torque-speed curve of the motor is not affected by the presence of the Optimiser in circuit.
- There is a small reduction in power factor of up to 0.5 when the Optimiser is operating in its effective range.
- When switched on, the Optimiser causes a certain amount of current harmonics to be injected into the supply (ie. The current waveforms are not purely sinusoidal). As this occurs at low current levels the effects on the supply should be minimal.
- The Optimiser causes the input power to decrease by a maximum of about 1kW for the same output power but only when the mechanical load is small and the motor is operating close to synchronous speed.

Dr Keith Hoffman

Test of Control Unit	Results
Each test was carried out with optimisation on and then with optimisation taken off so that load settings were not varied for each test.	
TEST 1	
Started unit under **no load** conditions	Motor ran up to speed correctly, with indication of normal running, and power save mode initiated after factory set time out period. All OK Checked all instrument settings and measured shaft speed with Photo Tacho.
TEST 2 Increased load on Motor to 30% while motor was running	Motor continued run as required.
TEST 3 Increased load on Motor to 50% while motor was running	Motor continued run as required.
TEST 4 Increased load on Motor to 50% while motor was running	Motor continued run as required.
TEST 5 Increased load on Motor to 100% while motor was running Motor run down after 5 minutes run.	Motor continued run as required.