4 JUNE 2017

EE462 – REPORT OF EXPERIMENT III

PERFORMANCE OF AN INDUCTION MOTOR DRIVE UNDER DIFFERENT LOAD CHARACTERISTICS

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GROUP 2

Contents

RESULTS

1)

Speed ref(rpm)	T(Nm)	N(rpm)	P1(kW)	Q1(kVAR)	P2(kW)	pf	V(Volts)	f(Hz)
75	1.3	75.5	0.41	0.73	0.26	0.24	23.2	5
200	9.3	200.1	0.7	0.99	0.515	0.19	60.4	13.4
300	20.68	299.1	1.24	1.49	1.04	0.264	89.6	20.15
400	36.9	399.1	2.24	2.32	2.03	0.37	117.6	27
500	57.6	500.1	3.92	3.66	3.65	0.52	142	34
600	83.2	599.7	6.45	5.32	6.15	0.65	162	41
720	120	720.5	11.1	6.83	10.7	0.71	191	50

Table 1: Pump Load Characteristics

Speed ref(rpm)	T(Nm)	N(rpm)	P1(kW)	Q1(kVAR)	P2(kW)	pf	V(Volts)	f(Hz)
75	51	74.8	0.92	1.2	0.726	0.6	26.3	5.5
200	58.4	200.1	1.87	2.08	1.67	0.55	60.5	14
300	66.4	300.4	2.88	2.8	2.63	0.6	87	20.8
400	76.4	400.5	4.18	3.83	3.89	0.63	111	27.6
500	88.1	500.7	5.83	4.98	5.52	0.67	136	34.5
600	101.6	599.6	7.9	6.15	7.53	0.7	161	41.4
720	120	719.4	11.12	6.84	10.7	0.71	191	49.9

Table 2: Electric Traction Load Characteristics

2)

Speed ref(rpm)	Pout(kW)	P2(kW)	Motor Efficiency(%)	P1(kW)	Overall Efficiency(%)
75	0.0103	0.26	0.04	0.41	0.025
200	0.195	0.515	37.8	0.7	27.86
300	0.648	1.04	62.31	1.24	52.26
400	1.542	2.03	75.96	2.24	68.83
500	3.017	3.65	82.66	3.92	76.96
600	5.225	6.15	84.5	6.45	81
720	9.054	10.7	84.62	11.1	81.57

Table 3: Efficiency rates of pump load

Speed ref(rpm)	Pout(kW)	P2(kW)	Motor Efficiency(%)	P1(kW)	Overall Efficiency(%)
75	0.399	0.726	54.86	0.92	43.37
200	1.223	1.67	73.23	1.87	65.40
300	2.089	2.63	79.43	2.88	72.53
400	3.204	3.89	82.37	4.18	76.65
500	4.619	5.52	83.67	5.83	79.23
600	6.379	7.53	84.71	7.9	80.75
720	9.04	10.7	84.49	11.12	81.3

Table 4: Efficiency rates of electric traction load

3)

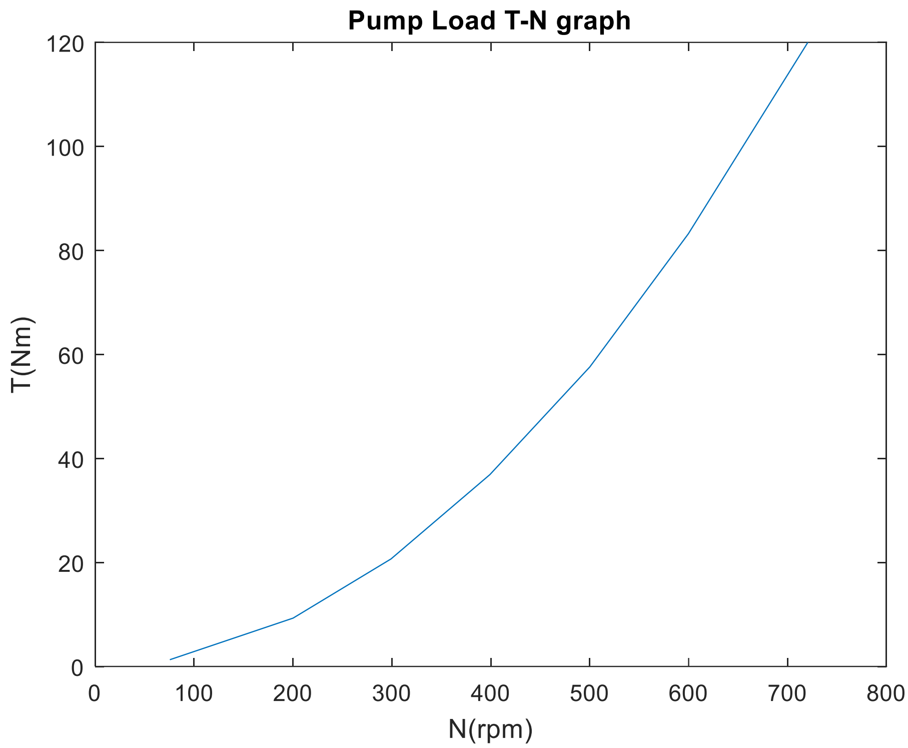


Figure 1: Pump Load Torque-Speed Graph

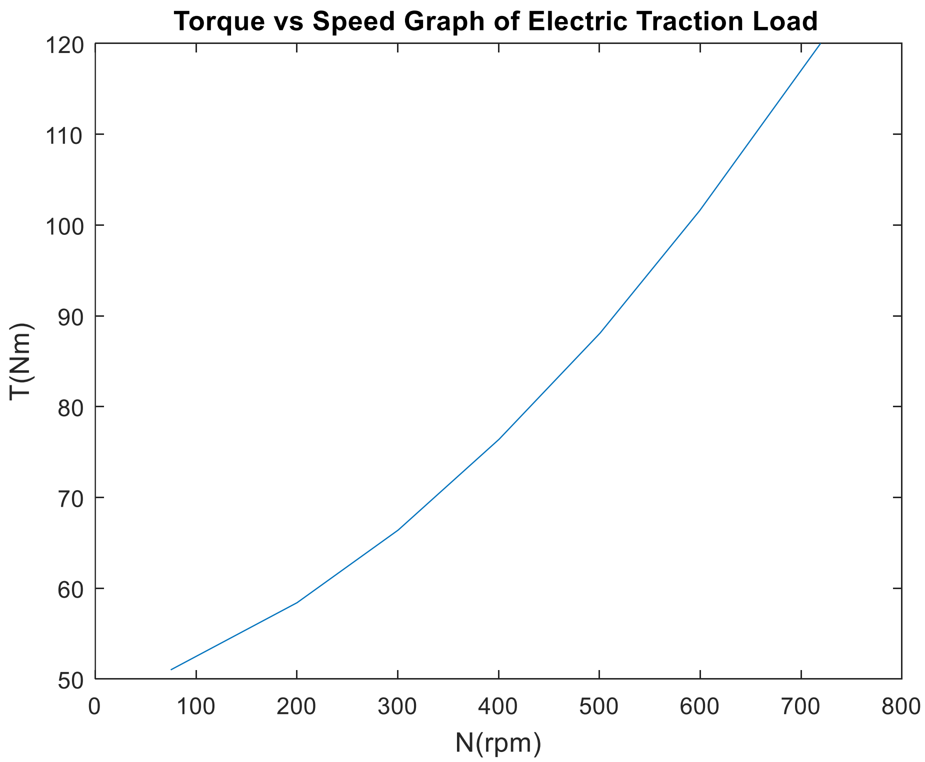


Figure 2: Electric Traction Load Torque-Speed Graph

4)

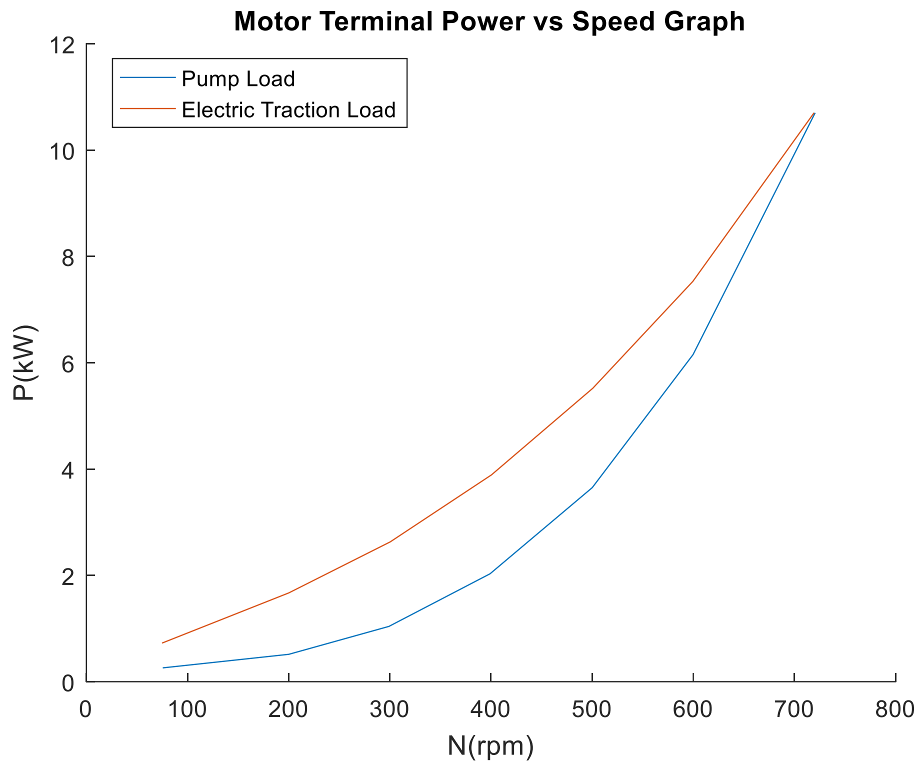
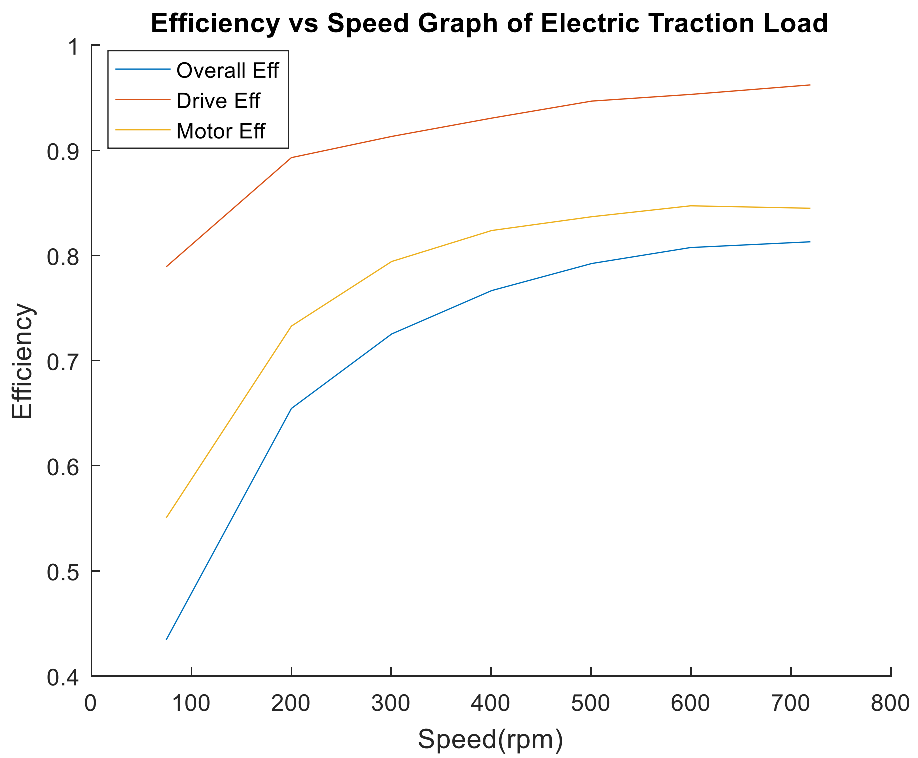


Figure 3: Motor Terminal Power vs Speed Graph

5)



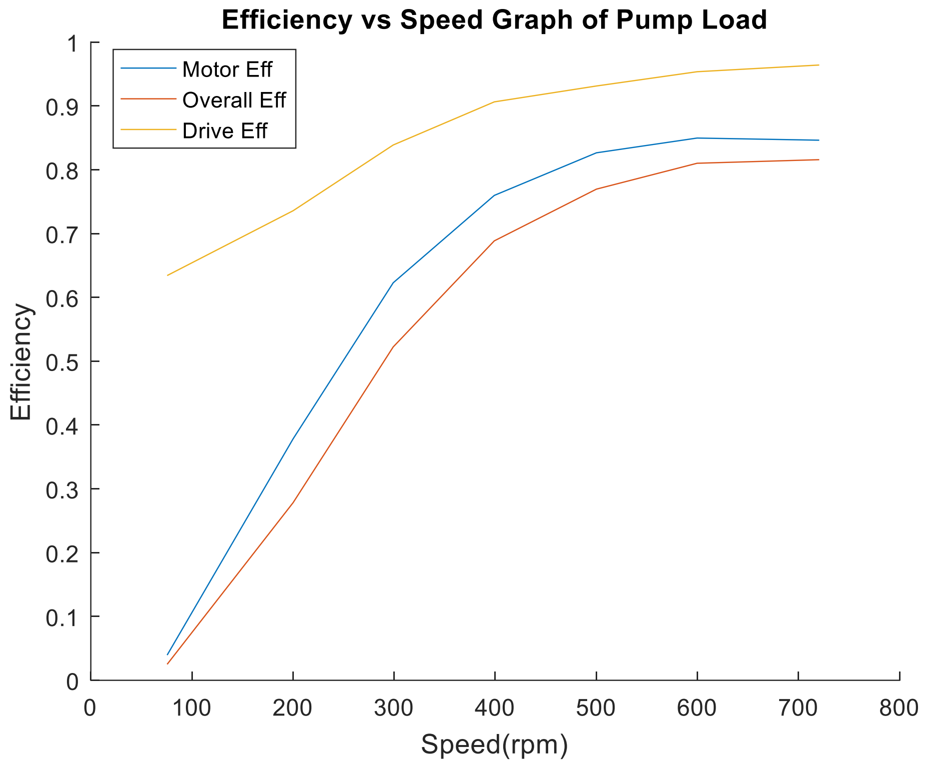


Figure 4: Efficiency vs Speed Graph of Pump Load

6)

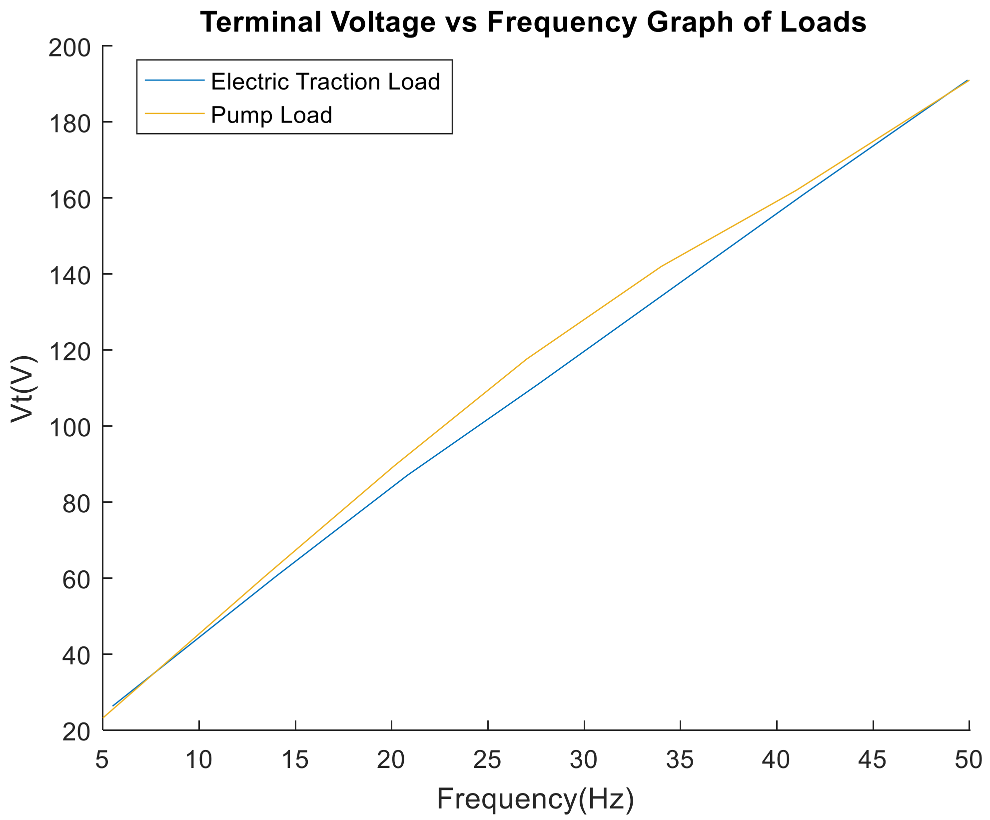


Figure 5: Terminal Voltage vs Frequency Graph of Loads

7)

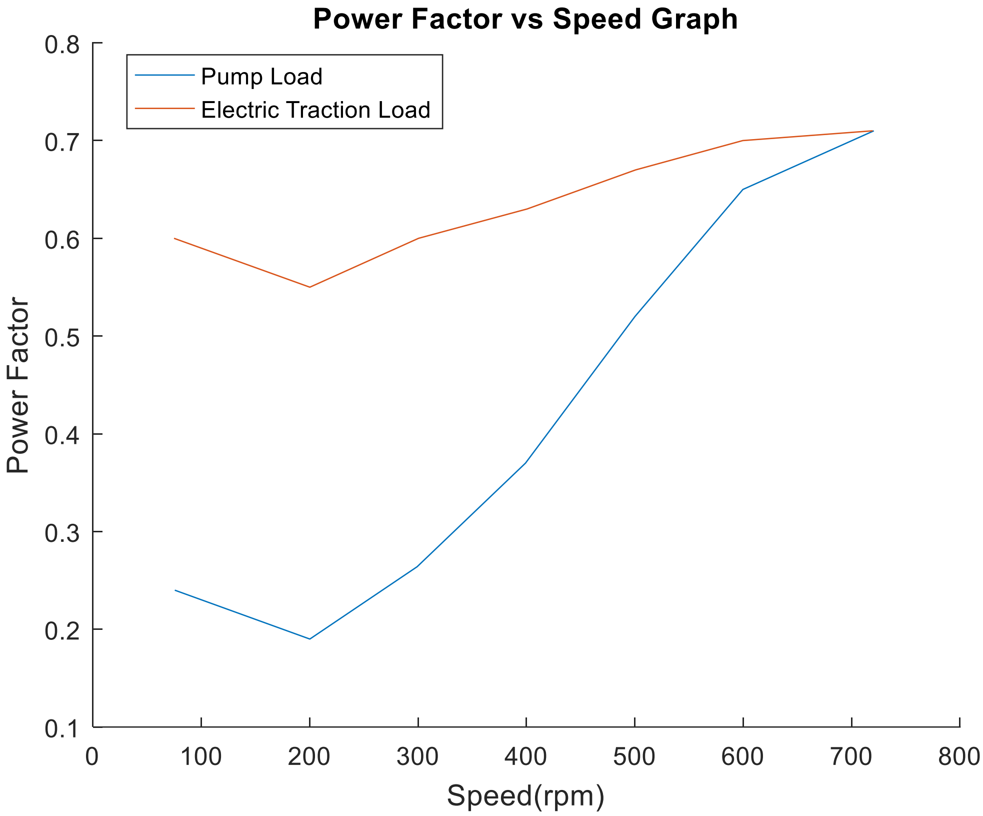


Figure 6: Power Factor vs Speed Graph of Loads

8)

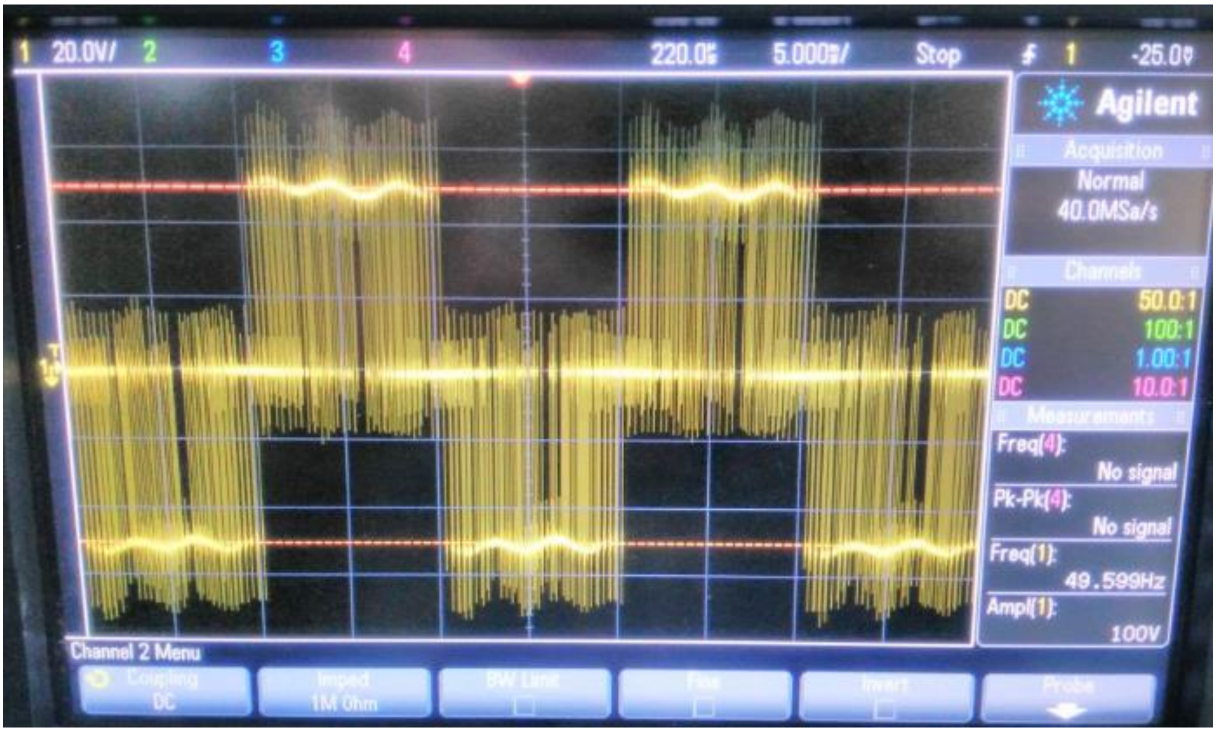


Figure 7: Motor Line to Line Voltage

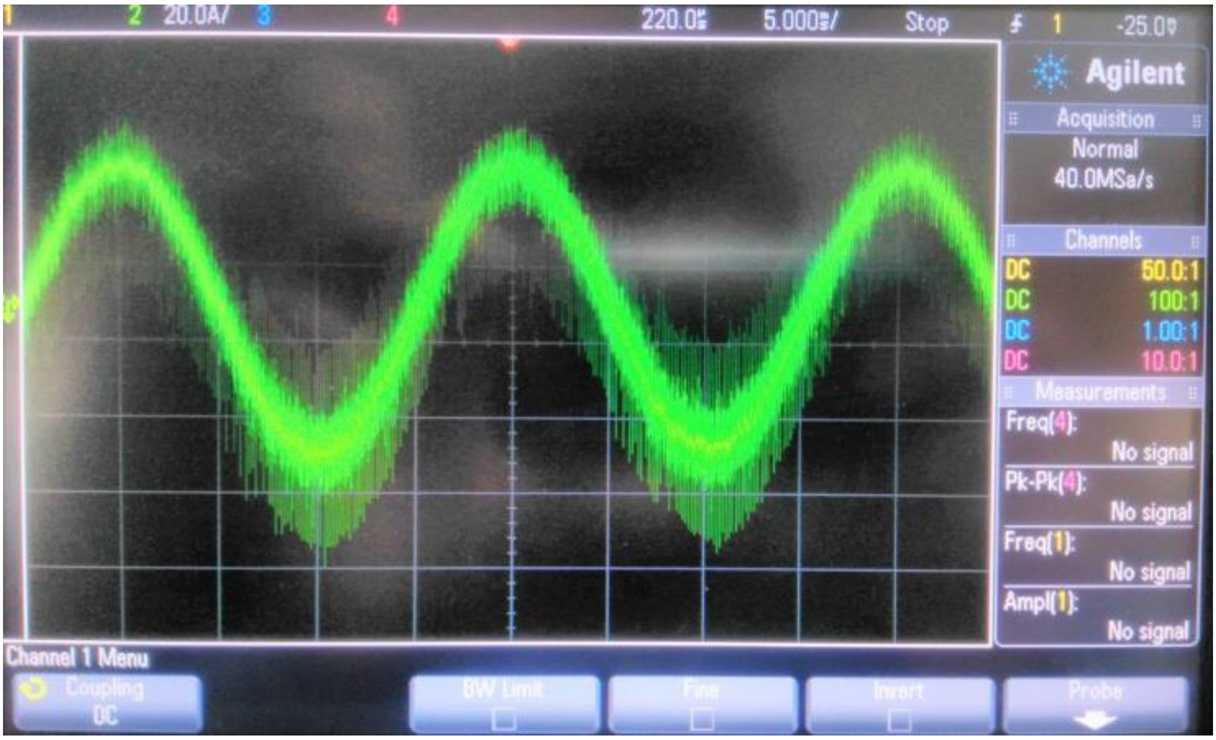


Figure 8: Motor Line Current Waveform

Figure 9: Motor Earth Current Waveform

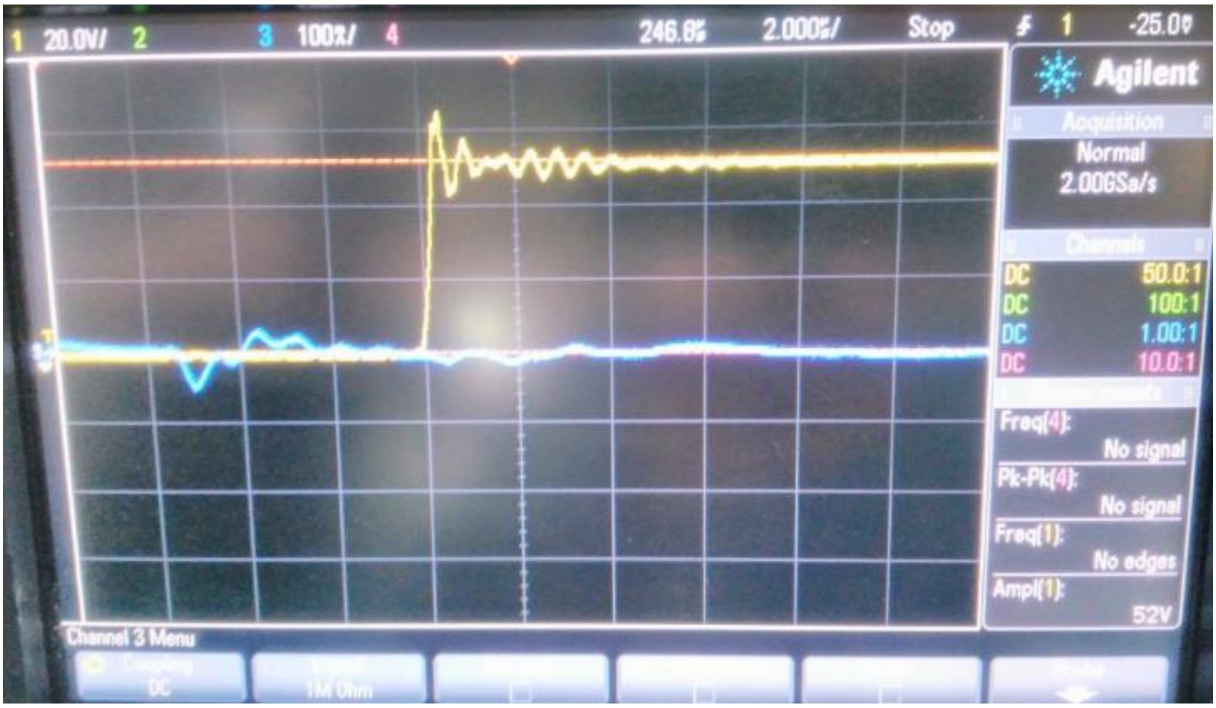


Figure 10: Motor Earth Current Zoomed

Figure 11: Motor Grid Side Line Current

9)

Harmonic Components			
3	3.5	**13**	7
5	52	**15**	0.3
7	30	**17**	4.2
9	1.1	**19**	4.2
11	6.5	**21**	0.2
Total Harmonic Distortion			61.4

Table 5: Harmonic Components

CONCLUSIONS

1) We see that the pump load starts from low torque value for lower speed; on the other hand, the electric traction load starts from a level of torque for zero speed. This different occurs because for the traction load, there is the static friction at the beginning which need to be exceeded to start accelerating. We also see that both characteristics increases torque demand as parabolic ratio of increasing speed. We already know that the pump load torque is defined as $T=k*n^2$, so the obtained result is complying with this formula. Moreover, we observe the traction load has the same increase pattern. It is because of the air windage which is proportional to cube of the speed. As a result, both loads have the torque speed graphs complying with theory.
2) For both pump load and electric traction load the drive efficiency is higher than the motor efficiency which shows that the motor driver is more capable of transferring power from grid side to the motor. However, the motor is less capable of transfer power from terminals to the shaft. The motor losses occur due to friction and windage, core losses and stator & rotor losses with these all loss mechanisms, motor is more lossy than driver. Moreover, we see that for higher speed values the efficiency increases for both drive and motor. Because, increasing the speed the loading increases; as a result, more current is drawn. Therefore, the loss mechanisms become less dominant with respect to load which results in increasing efficiency.
3) In driver, losses occur basically due to conduction and switching loss. For both of the loads, switching loss is the same. However, the conduction loss is different. Since the electric traction load desired more torque, the drawn current is higher. Therefore, the amount of the conduction loss is high but the conduction loss becomes less significant comparing to the output power which results in higher efficiency for traction load. Consequently, it is seen that if the loading increases, even though the amount of losses increase, the percentage effect decreases, so higher efficiency rate is obtained.
4) It is seen that there is constant Volts/Hertz rate exists for both of the loads. Since both of the loads driven by the same driver their Volts/Hertz graph coincides with each other.
5) For lower speeds low PF is obtained for both loads because the VFD controller tries to keep the magnetization current constant. Therefore, if the speed is lower where the output power is low, the reactive will be consumed relatively high and as a result the power factor will decrease. If it would be a PMSM, there is no need to magnetize the core with a supply current, so the reactive power won't be consumed and as a result the PF will not be that much lower.
6) In VFD, motor line to line voltage is a typical inverter output voltage and the line current has sinusoidal waveform with distortion. If the motor would be controlled by DOL, the output voltage will be a sine because in DOL control, the grid is directly connected to the motor terminals. The current will be higher at the starting moment and it will attenuate to the load current, resulting waveform will be like in Figure 12. The current waveform will be nearly a sine wave.

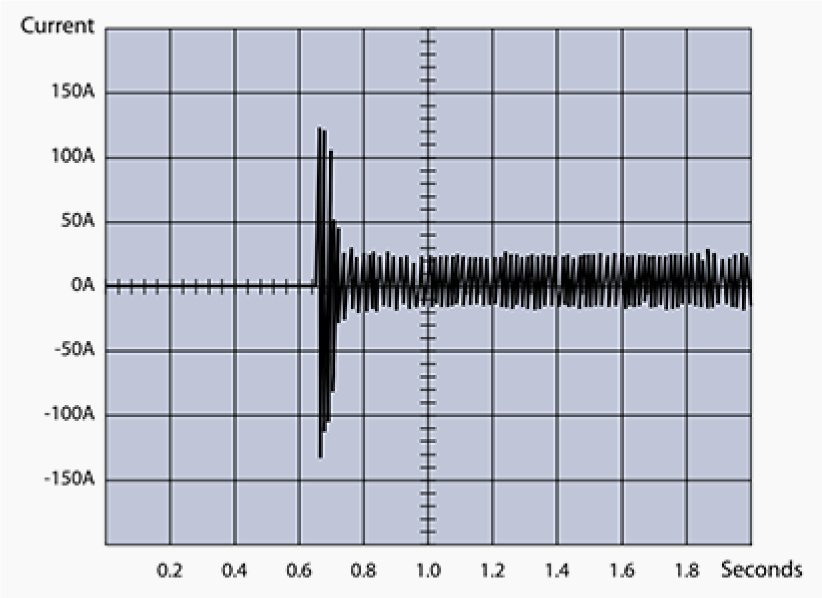


Figure 12: DOL Line Current[1]

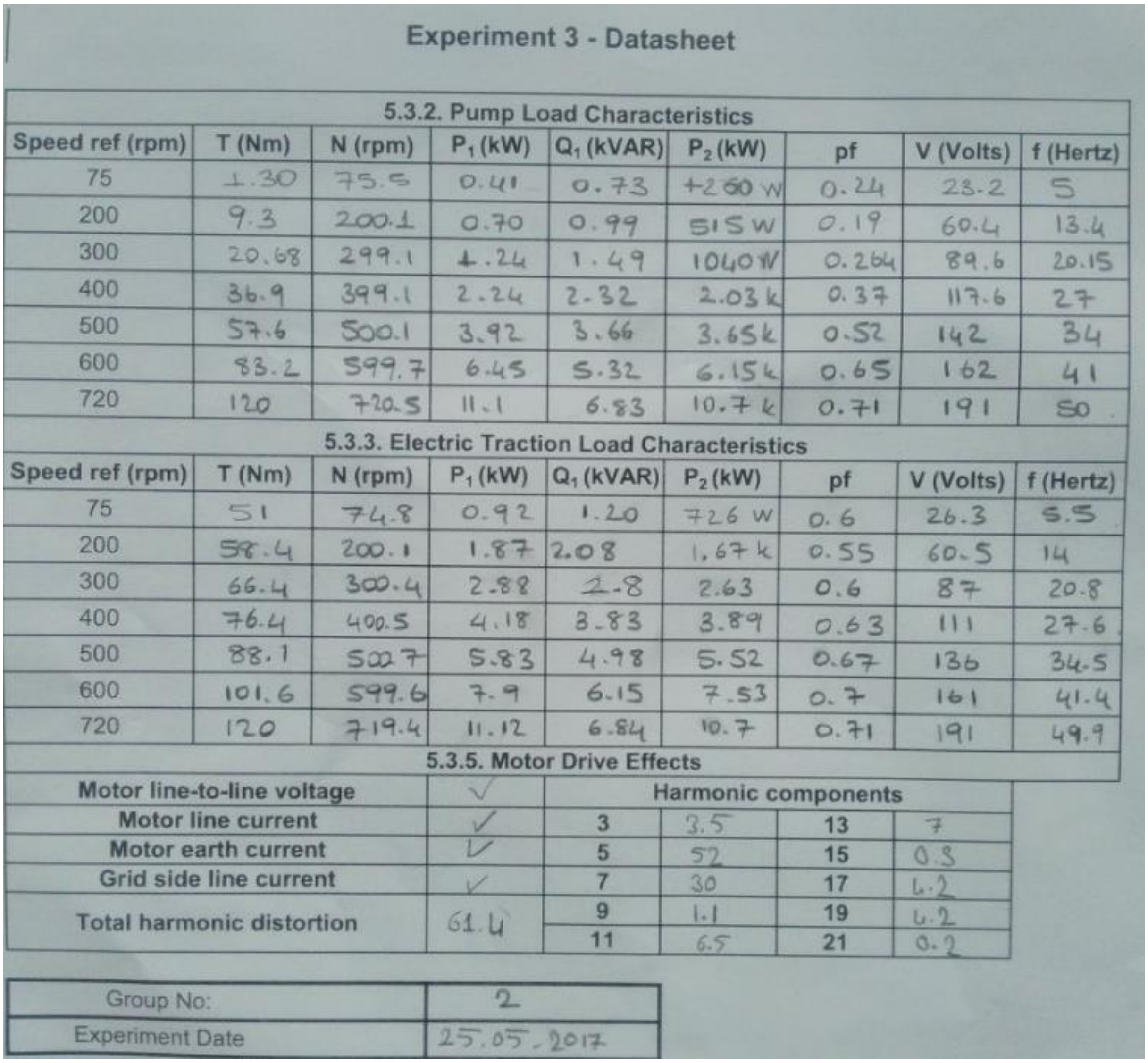
7) In a balanced three phase system the earth current is zero. When the system goes out of balance, earth current flows. Here in our case, we observe at the switching moments earth current flows. This is because of that at the switching moment due to the resonance of the switches in inverter, the balance is destabilized. Therefore, earth current flows as seen in Figure 9 & Figure 10. This current may be harmful in long-term application. The motor chase is shorted to ground, so when a current flows on earth line it is coming from the chase. This current flow will damage the insulations and chase.

8) 61.9% THD value is not applicable, this is a reason behind the low power factor. The current ripple is high which decreases the quality of the power. If it would be DOL control, the current ripple will be much lower than VFD control. Because, in DOL control motor terminal has a well-shaped sinus voltage. Therefore, the drawn current from the grid is much closer to sinusoidal waveform. As a conclusion, we observe here a trade-off. If a sensitive speed control is desired, the VFD control is better to apply but the waveform quality will be much lower.

9) If we investigate the grid line current waveforms, we see a square wave current drawn with additional ripple. Therefore, as expected, we observe odd harmonics. However, the triple harmonics don't exist because this is a 3-phase system. In a pure square wave, the k^{th} harmonic's magnitude is 1/k of the fundamental one. However, since the grid line current is not a square wave, the fifth and seventh harmonics are greater.

[1] http://electrical-engineering-portal.com/comparision-of-direct-on-line-dol-and-star-delta-motor-starting

EXPERIMENTAL RESULTS



Experiment 3 - Datasheet

5.3.2. Pump Load Characteristics								
Speed ref (rpm)	T (Nm)	N (rpm)	P_1 (kW)	Q_1 (kVAR)	P_2 (kW)	pf	V (Volts)	f (Hertz)
75	1.30	75.5	0.41	0.73	+260 W	0.24	23.2	5
200	9.3	200.1	0.70	0.99	515 W	0.19	60.4	13.4
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600	83.2	599.7	6.45	5.32	6.15 k	0.65	162	41
720	120	720.5	11.1	6.83	10.7 k	0.71	191	50

5.3.3. Electric Traction Load Characteristics								
Speed ref (rpm)	T (Nm)	N (rpm)	P_1 (kW)	Q_1 (kVAR)	P_2 (kW)	pf	V (Volts)	f (Hertz)
75	51	74.8	0.92	1.20	726 W	0.6	26.3	5.5
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400	76.4	400.5	4.18	3.83	3.89	0.63	111	27.6
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600	101.6	599.6	7.9	6.15	7.53	0.7	161	41.4
720	120	719.4	11.12	6.84	10.7	0.71	191	49.9

5.3.5. Motor Drive Effects					
Motor line-to-line voltage	✓	Harmonic components			
Motor line current	✓	3	3.5	13	7
Motor earth current	✓	5	52	15	0.8
Grid side line current	✓	7	30	17	6.2
Total harmonic distortion	61.4	9	1.1	19	6.2
		11	6.5	21	0.2

Group No:	2
Experiment Date	25.05.2017

Figure 13: Data

Figure 14: Harmonics