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Synchronous motor 2023

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1 Introduction

Electric motors play a fundamental role in modern society, powering a wide range of applications and systems that define our daily lives. In the field of electrical engineering, understanding the intricate workings of these motors is essential for advancing technology and improving the efficiency of numerous industrial processes. Synchronous motors are known for their precision and synchronization with the power supply frequency, making them crucial in applications where consistent speed control is paramount.

The report delves into an in-depth analysis of a specific synchronous motor's performance characteristics under varying conditions. By doing so, it contributes to the collective knowledge base of electrical engineering and serves as a testament to the importance of laboratory work in advancing our understanding of electric machines and systems.

2 Preliminary tasks:

2.1 How does a synchronous motor work? How does it differ from the operation of the induction motor?

How a Synchronous Motor Works:

1. Stator: Like other AC motors, a synchronous motor has a stator that consists of a stationary coil or winding. The stator produces a rotating magnetic field when connected to an AC power source.

2. Rotor: The rotor in a synchronous motor is different from that in an induction motor. It is designed with either permanent magnets or electromagnets. The rotor's magnetic field is created in such a way that it locks onto the rotating magnetic field produced by the stator.

3. Synchronization: The key feature of a synchronous motor is that it operates in perfect synchronization with the supply frequency. This means that the rotor rotates at a constant speed, which is directly proportional to the supply frequency. For example, in a region with a 60 Hz power supply, a synchronous motor will rotate at precisely 3600 RPM (revolutions per minute) if it is designed for that frequency.

4. Applications: Synchronous motors are used in applications where precise speed control is required, such as in clocks, timing devices, and some industrial processes.

Differences Between Synchronous and Induction Motors:

1. Operation Principle: The fundamental difference between synchronous and induction motors lies in their operating principles. Synchronous motors operate at a fixed speed determined by the supply frequency, while induction motors do not have a fixed synchronous speed and instead rely on slip to develop torque.

2. Starting Torque: Induction motors can develop starting torque even when they are at rest (zero speed). In contrast, synchronous motors typically require some external

means (e.g., a starting mechanism) to bring them up to their synchronous speed because they don't develop torque at standstill.

3. Speed Control: Synchronous motors are well-suited for applications that require precise speed control, whereas induction motors are often used in applications where speed variations are acceptable.

4. Complexity: Synchronous motors tend to be more complex and may require additional equipment for starting and maintaining synchronization. Induction motors are generally simpler and more rugged.

2.2 In what kind of applications synchronous motors are being used?

Synchronous motors find application in various industrial and commercial settings where precise control of motor speed and synchronization with the power supply frequency is essential. Here are some common applications of synchronous motors:

1. Clocks and Timing Devices: Synchronous motors are often used in clocks and timing devices to ensure accurate timekeeping. The motor's constant speed, tied to the power supply frequency, allows for precise timekeeping.

2. Industrial Processes: Synchronous motors are used in manufacturing processes that require a consistent and controlled rotational speed. Examples include conveyor systems, machine tools, and printing presses.

3. Textile Industry: Synchronous motors are employed in textile machinery, such as spinning and weaving machines, where maintaining a constant and synchronized speed is critical to producing quality textiles.

4. Power Plants: In power generation, synchronous generators (which are essentially synchronous motors operating in reverse) are used to produce electrical power at a

specific frequency. They are commonly found in hydroelectric, thermal, and nuclear power plants.

5. Air Conditioning and Heating Systems: Synchronous motors are used in some HVAC (heating, ventilation, and air conditioning) systems to control the speed of fans and blowers, ensuring proper air circulation and temperature regulation.

6. Electric Clocks: Apart from traditional mechanical clocks, synchronous motors are used in electric clocks and appliances with clock functions, such as microwave ovens and digital displays, to maintain accurate timekeeping.

7. Broadcasting Equipment: Synchronous motors are utilized in broadcasting equipment like television and radio transmitters to ensure accurate synchronization of broadcast signals.

8. Automated Manufacturing: Synchronous motors are integrated into automated manufacturing equipment, robotics, and CNC (computer numerical control) machines where precise control of rotational speed and synchronization is crucial for precise machining and assembly.

9. Astronomy: Synchronous motors are used in some telescope mounts to track celestial objects accurately as they move across the sky.

10. Aviation: In aircraft, synchronous motors are used in applications like instrument displays and navigation systems, where maintaining accurate time and synchronization is vital.

2.3 What is connected to connection points F1 and F2?

Connection points F1 and F2 in a synchronous motor are connected to the field winding, and they are used to control the excitation of the motor by supplying it with a direct current voltage. This control allows for the adjustment of the motor's speed and synchronization with the AC power supply frequency.

2.4 How to start a synchronous motor? (see Leybold Instruction and Annex p. 7, chapter 1.4.3 Explanation)

1. Initial State: When you switch on a synchronous motor, the stator (the stationary part) is energized with three-phase AC power from the mains, which creates a rotating magnetic field in the stator.

2. DC Field in Rotor: Inside the rotor (the rotating part), there is a DC field produced by a DC-excited winding. This DC field is necessary for the motor's operation.

3. Motor Terminal Board: The stator and rotor windings are connected to the motor terminal board.

4. Rotor Response to Stator Field: Initially, when the motor is switched on, the rotor is stationary. The rapidly rotating stator field exerts a force on the rotor's DC field poles, but due to the rotor's inertia, it cannot immediately follow the rapidly changing stator field direction.

5. Synchronization Process: The rotor's speed gradually increases, approaching the speed of the rotating stator magnetic field. It is important to note that synchronous motors cannot start independently because they rely on synchronous speed.

6. Locking to Stator Field: As the rotor's speed gets closer to the synchronous speed (the speed at which the stator field rotates), the rotor's DC field is eventually locked onto the stator's rotating magnetic field. When this synchronization occurs, the rotor is pulled into alignment with the stator field and starts rotating at the same speed.

7. Starting Help: As mentioned in the manual, synchronous motors cannot start independently due to their dependence on synchronous speed. Therefore, they require some form of starting help. This starting help can involve mechanical means (such as a prime mover or a pony motor) or control systems that ensure the rotor reaches synchronization speed.

2.5 How to change the direction of a synchronous motor? Draw a basic diagram?

Changing the direction of rotation of a synchronous motor typically involves reversing the direction of the rotating magnetic field produced by the stator. This can be achieved by interchanging any two of the three-phase power supply leads connected to the stator windings. However, it's important to note that changing the direction of a synchronous motor may require careful consideration of the motor's design and connections to ensure it operates correctly.

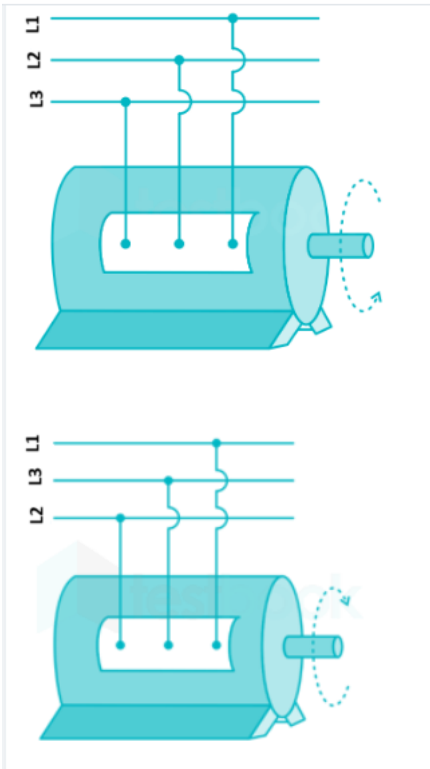

Figure 1 Changing the rotation direction of a synchronous motor.

3 Laboratory work:

Check the name plate of a synchronous motor 0.3 Machine No **732 36.**

Write down the values:

<table>
<tr><td colspan="4">TYP76236</td></tr>
<tr><td colspan="4">Y400V</td></tr>
<tr><td colspan="2">0.316W</td><td colspan="2">cosϕ
1|0,8</td></tr>
<tr><td colspan="2">1500 r/min</td><td colspan="2">50Hz</td></tr>
<tr><td>1P</td><td>20</td><td colspan="2">2472</td></tr>
<tr><td colspan="3">UERR = 1400V</td><td></td></tr>
<tr><td colspan="3">0-6710-43A</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
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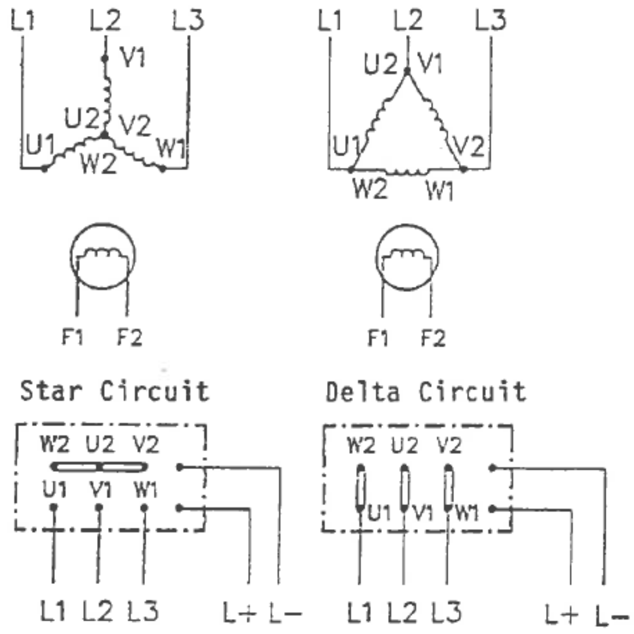
COUPLING AND REVERSAL OF DIRECTION

SCHEMATIC OF CONNECTION (alternating current)



Which connection type (star or delta) you should choose for this motor and why?

NOTE!! Maximum RATED ROTOR VOLTAGE = (from the engine plate)

How would you change the rotation direction?

Changing the direction of rotation of a synchronous motor typically involves reversing the direction of the rotating magnetic field produced by the stator. This can be achieved by interchanging any two of the three-phase power supply leads connected to the stator windings.

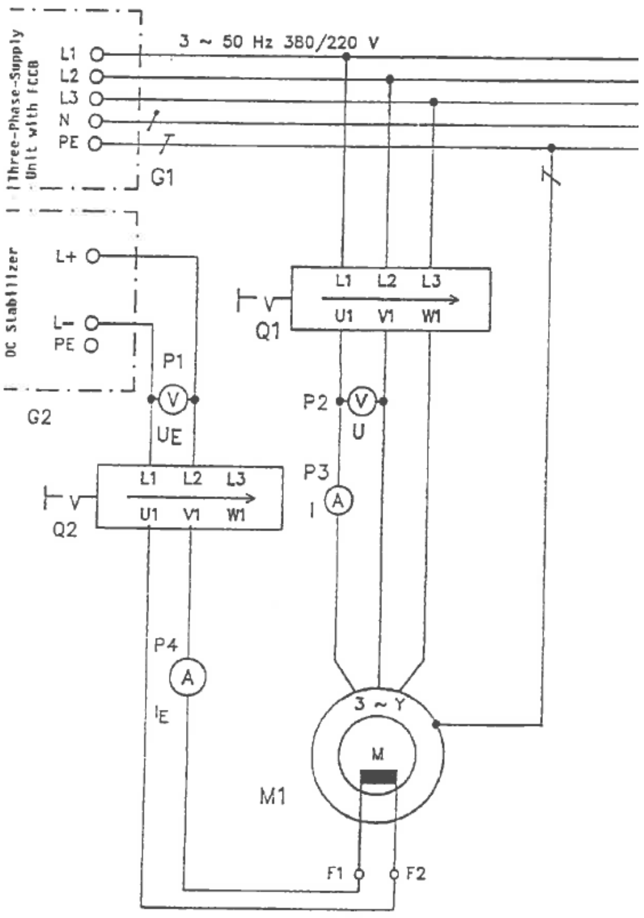
Draw below, the schematic drawing of reversing connection for this motor like. (How would you connect the motor to make it rotate the other way around?)

3.1 Laboratory work 1:

Connect the SYNCRONIC MOTOR TO THE ELECTRICITY SUPPLY as shown in the figure below, **without load.**

A) START DIRECTLY LIKE A INDUCTION MOTOR (WITHOUT DC POWER TO THE ROTOR CIRCUIT)

-> WHEN THE MOTOR IS RUNNING NORMALLY -> CONNECT A DC VOLTAGE OF **120 V** TO THE ROTOR CIRCUIT (Note 140 V is the maximum voltage for the rotor circuit and shall not be exceeded!!)



3-PHASE NETWORK: MAIN VOLTAGE 400 V

CHECK whether you should connect in star or in delta.

NOTE! DC SUPPLY: MAXIMUM VOLTAGE = 140 V

Make connections for the SYNCRONOUS motor run clockwise and then counterclockwise.

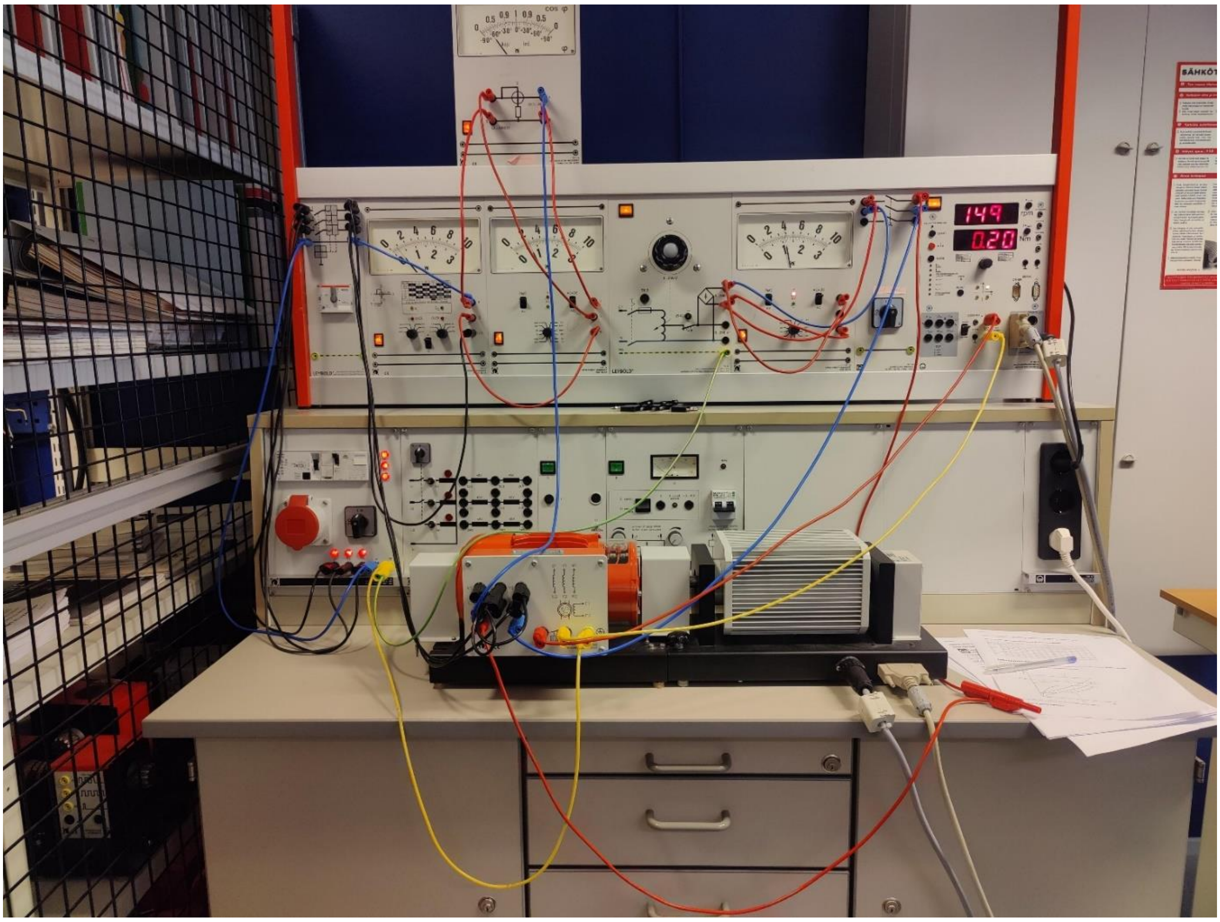


Figure 2 Laboratory connections 1

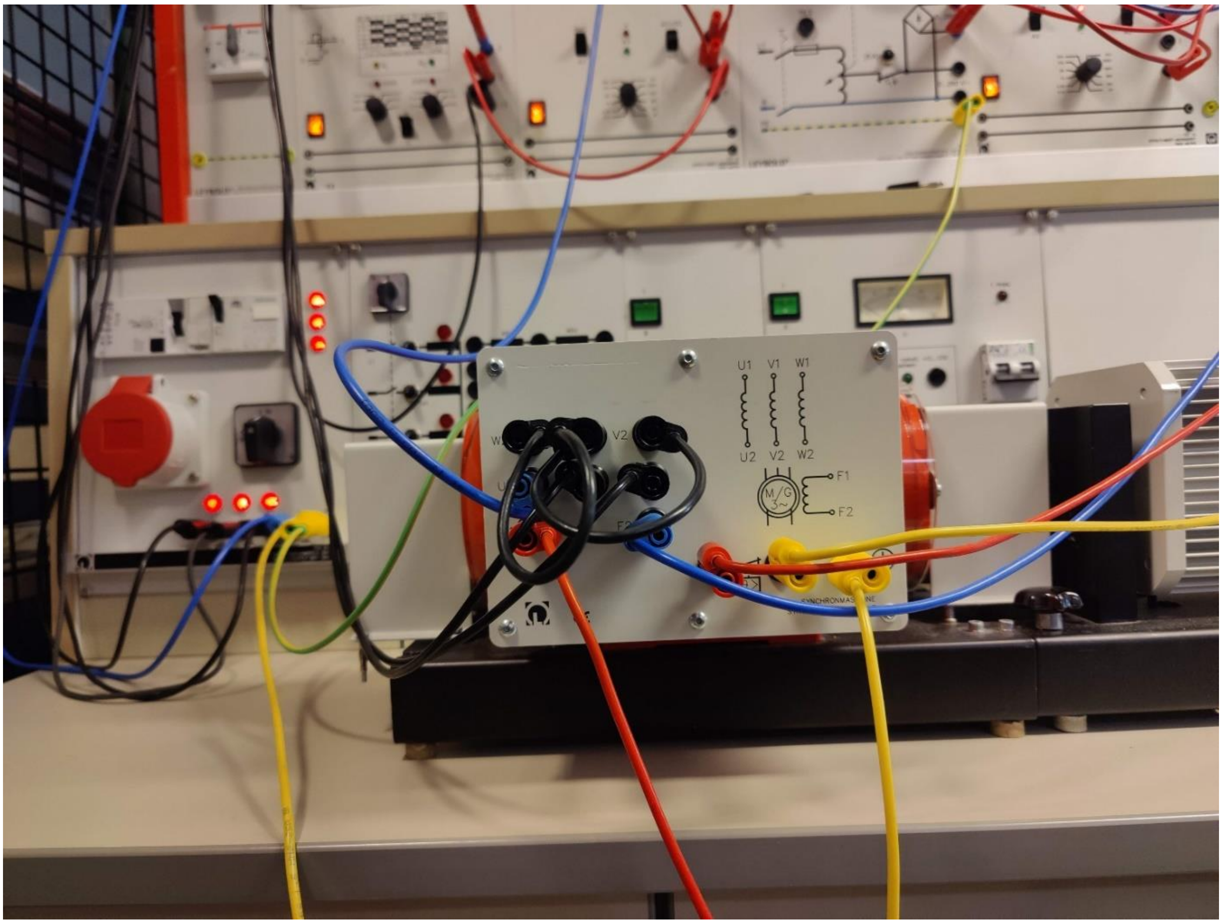


Figure 3 Laboratory connections 2

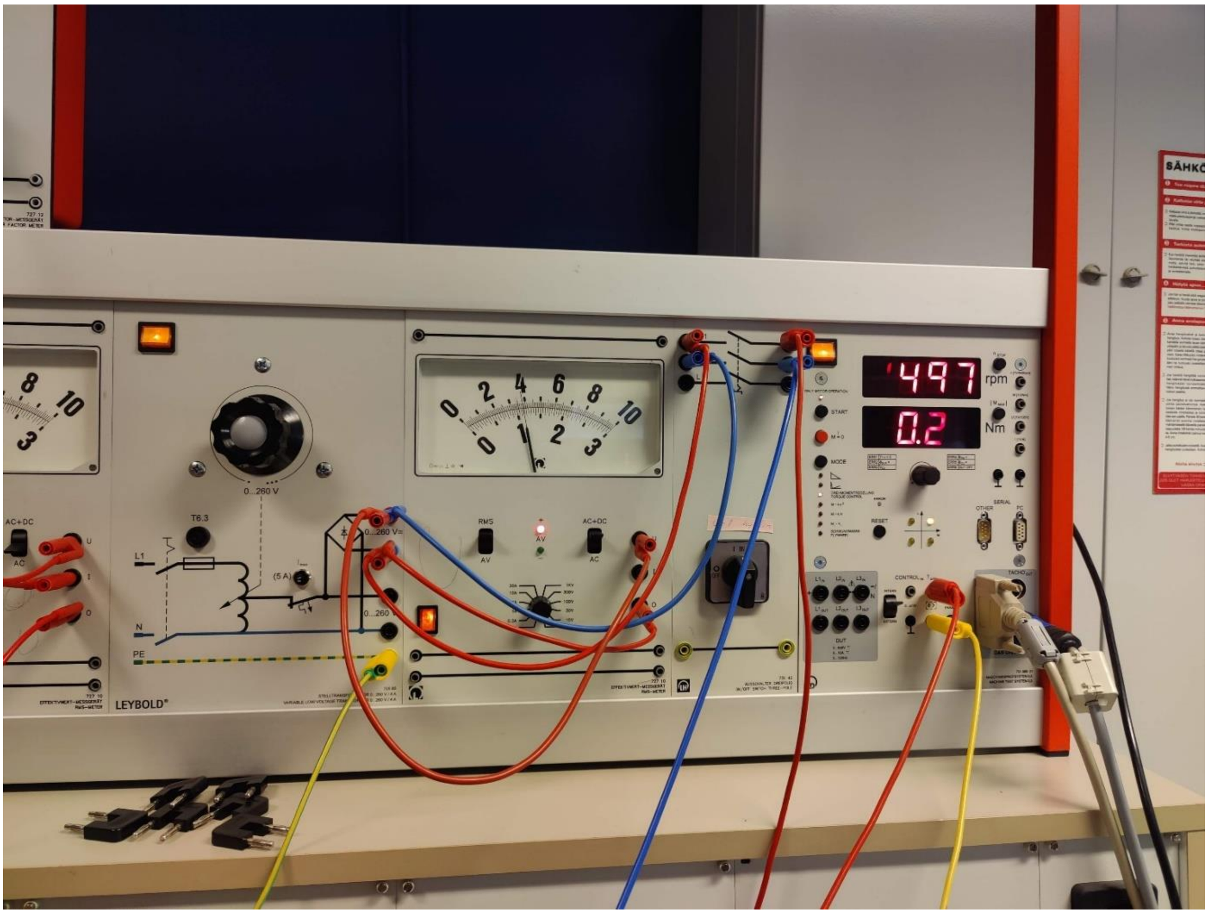


Figure 4 Laboratory connections 3

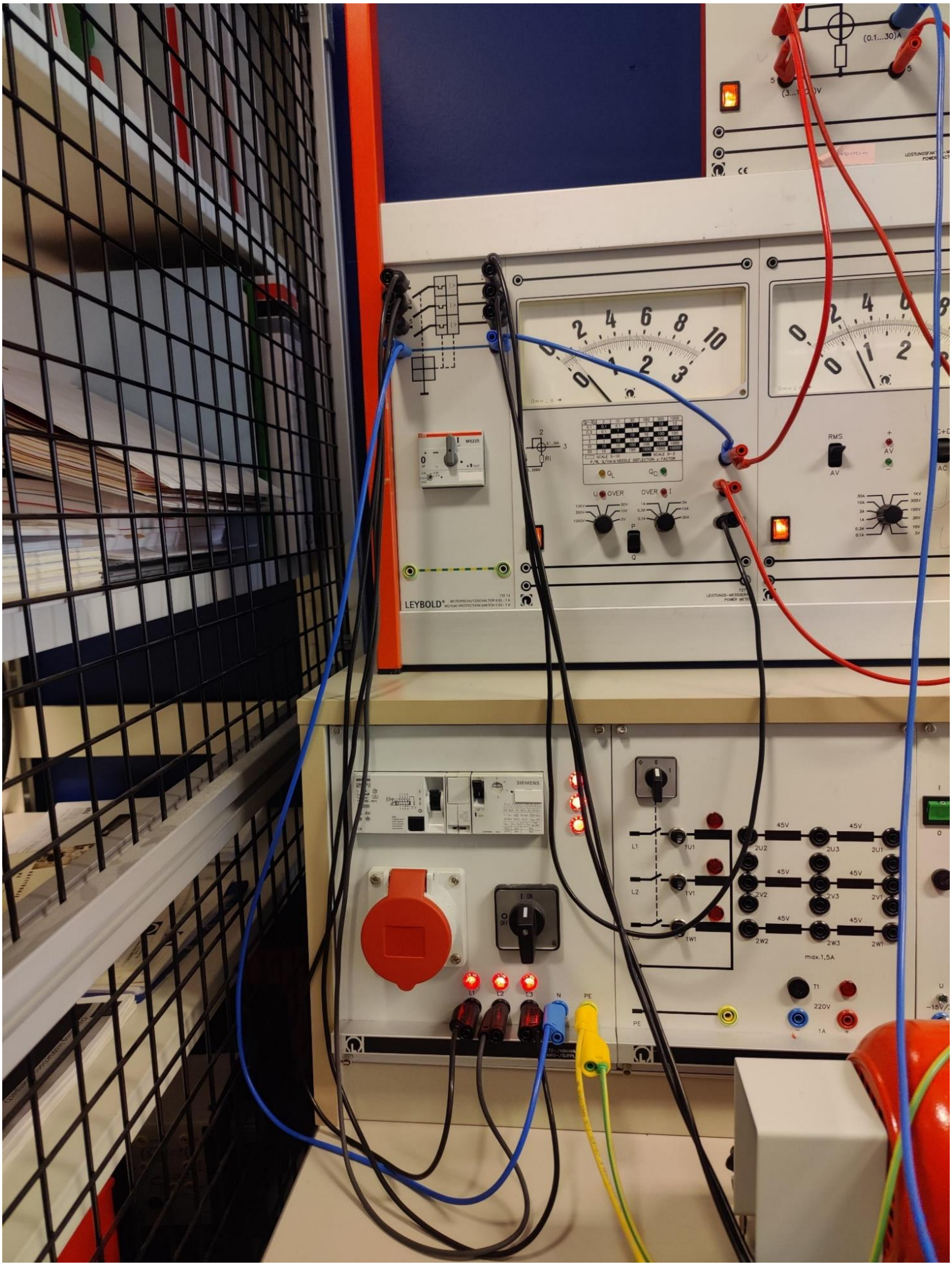
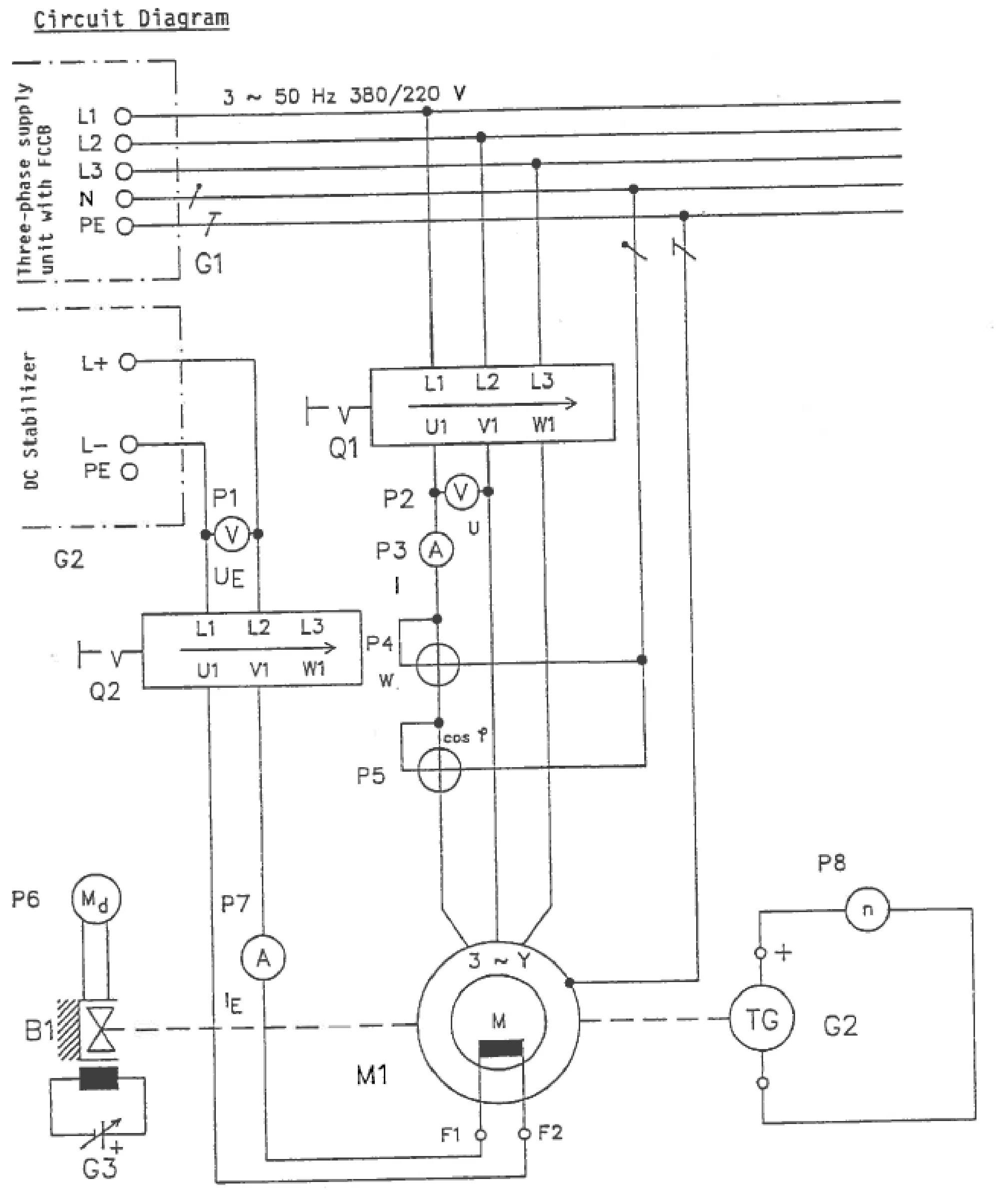


Figure 5 Laboratory connections 4

3.2 Laboratory work 2:

Connect the load, for SYNCRONOUS MOTOR. As a load, we are using *Three-phase pendelum machine 0.1/0.3 731 985/ Control unit 731988*. This is a sort of magnetic brake which we can use for different kinds of load simulations.

Make the connections shown below. Power measurement (P4) and Power factor measurement (P5) have been added to the circuit.



CALCULATE RATED (nominal) MOTOR TORQUE (Check the motor name plate…).

MEASURE AND CALCULATE THE RESULTS IN THE TABLE BELOW:

MEASUREMENT	M/Nm	0,2	0,4	0,6	0,8	1	1,2	1,4	1,6	1,8	1,91	2	2,2	2,4
	n/min^{-1}	1497	1500	1497	1496	1497	1499	1497	1497	1497	1497	1498	1497	1496
	I_1 / A	0,23	0,24	0,28	0,3	0,34	0,36	0,4	0,45	0,58	0,5	0,52	0,58	0,6
	cos φ	0,3	0,4	0,5	0,6	0,65	0,75	0,8	0,85	0,9	0,91	0,93	0,95	0,98
	P_{1phase}/W	7	20	31	42	55	70	78	90	100	110	130	140	150
CALCULATION	P_1 / w	21	60	93	126	165	210	234	270	300	330	390	420	450
	P_2 / W	31,35	62,83	94,05	125,32	156,75	188,36	219,46	250,81	282,16	299,4	313,72	344,86	375,96
	η	1,49	1,05	1,01	0,99	0,95	0,90	0,94	0,93	0,94	0,91	0,80	0,82	0,84

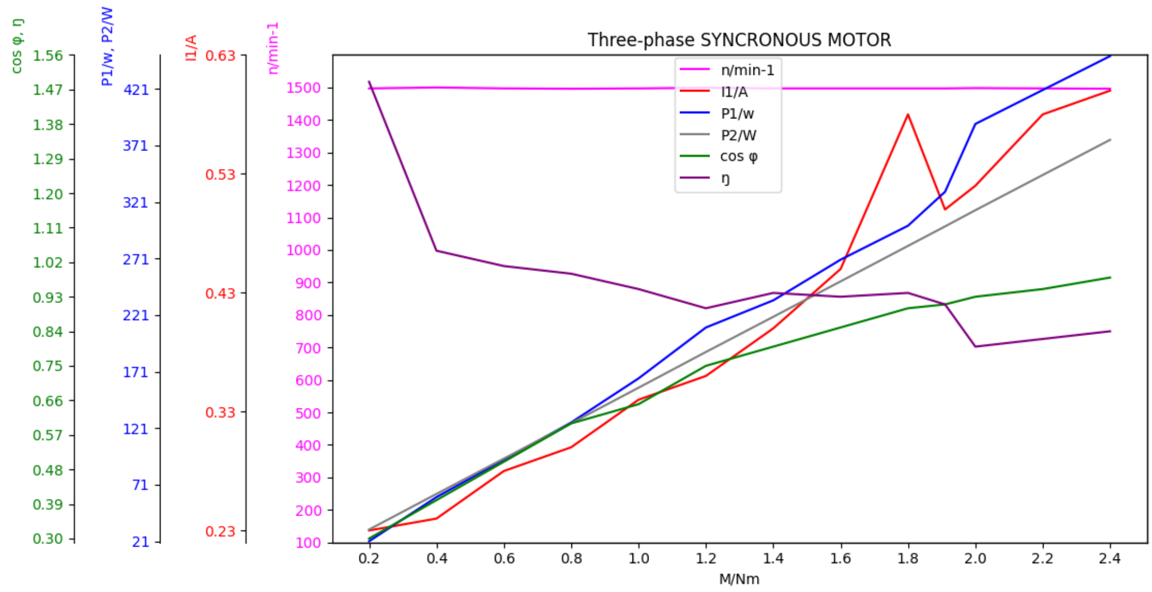


Figure 6 Three-phase SYNCRONOUS MOTOR

1. **Speed (‘n/min^{-1}’)**: The speed of a synchronous motor is constant and determined by the frequency of the power supply and the number of poles in the motor. In our data, the speed is around 1497 to 1500 RPM, which is close to the synchronous speed of a 4-pole motor running on a 50 Hz power supply (1500 RPM).
2. **Current (‘I1/A’)**: The current increases as the torque (‘M/Nm’) increases. This is expected as more torque requires more current.
3. **Power Factor (‘cos φ’)**: The power factor increases as the torque increases. This could be due to the motor becoming more efficient (converting more electrical power into mechanical power) at higher torques.
4. **Input Power (‘P1/w’) and Output Power (‘P2/W’)**: Both the input and output power increase as the torque increases. This is expected as more torque requires more power. The difference between the input and output power represents the power losses in the motor.
5. **Efficiency (‘ŋ’)**: The efficiency varies with the torque. It’s common for the efficiency of a motor to vary with the load, with maximum efficiency typically occurring at a specific load.

3.3 Laboratory work 3:

Load the SYNCRONOUS MOTOR with its nominal torque and measure the current, power and cosϕ

TYPICAL LOAD CHARASTERISTICS FOR SYNCRONOUS MOTOR:

Nominal speed(n): 1500rpm

Nominal power(P_2): 300W

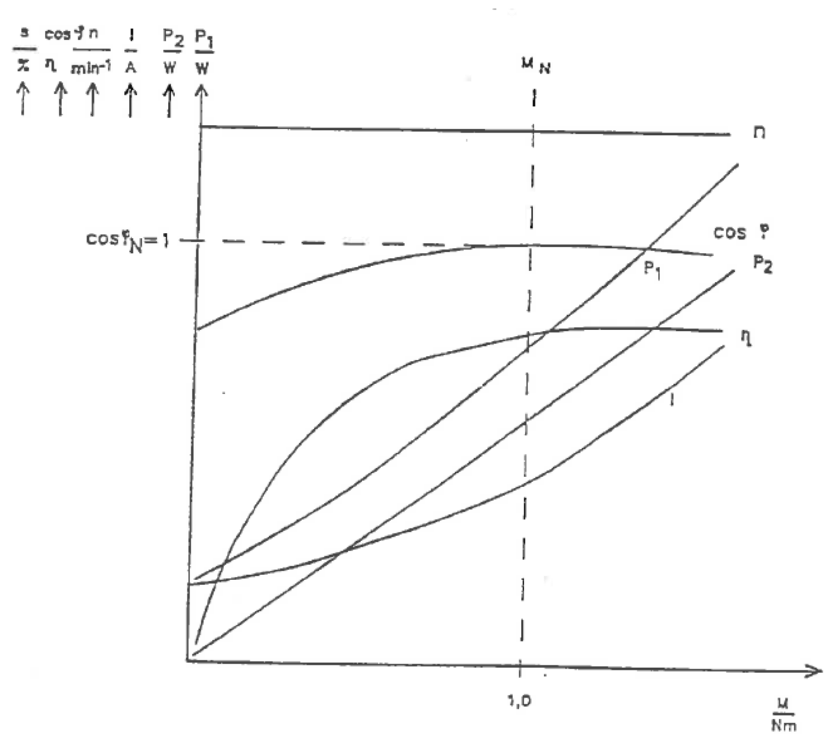
$P_2 = M * n / 9,55$

➔ M = 1,9 Nm

I = 0,5A

$P_{1phase} = 110W$

cos φ = 0,92

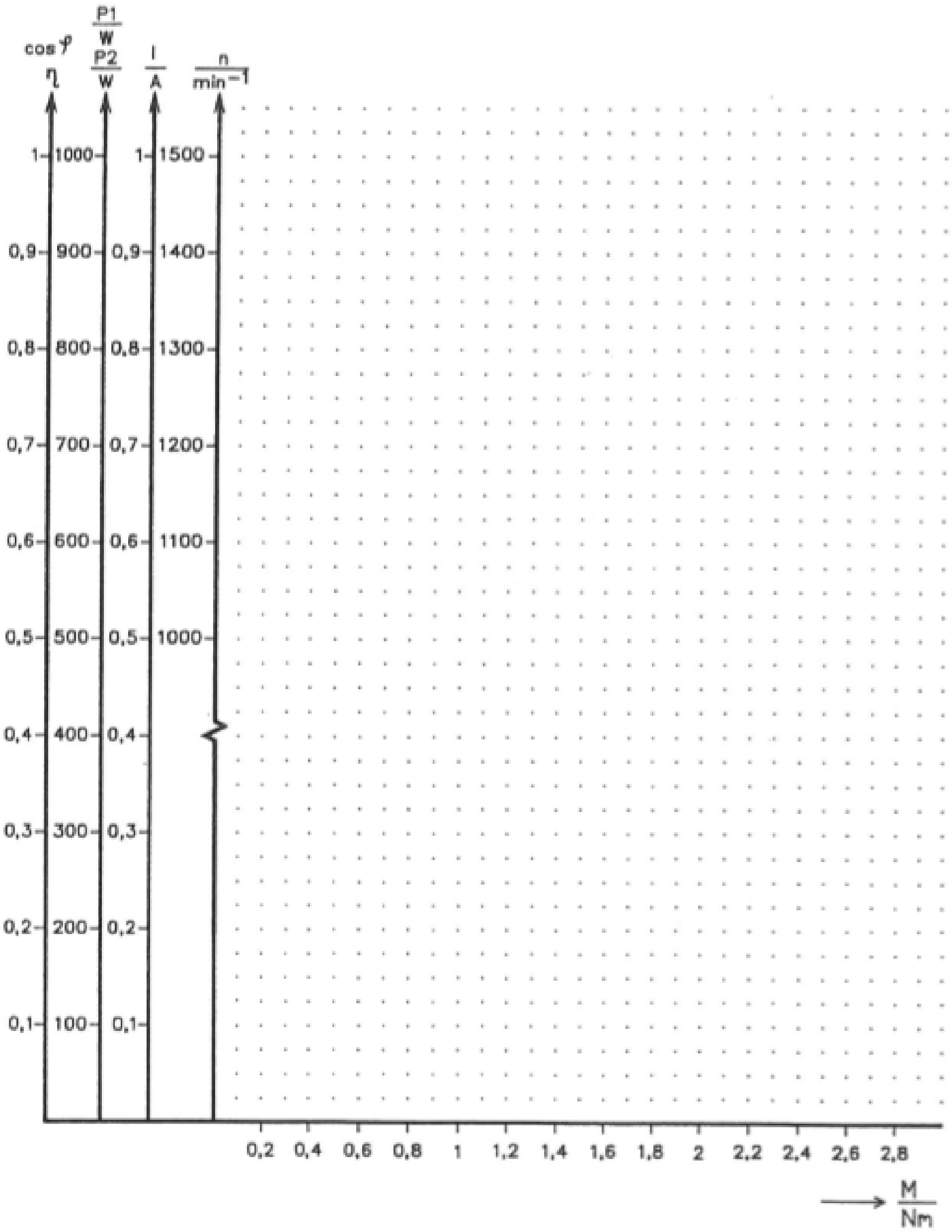


Load Characteristics of the Synchronous Motor

NOTE! X-AXIS IS TORQUE!!

FEATURE GRAPH

2.5.5.1 Load Characteristics n, I, cosφ, η, P_1, P_2 = f(M) at
$\cos\varphi_N$ = 1
Synchronous Motor: 0.3



TYPE CHARACTERISTIC CURVE

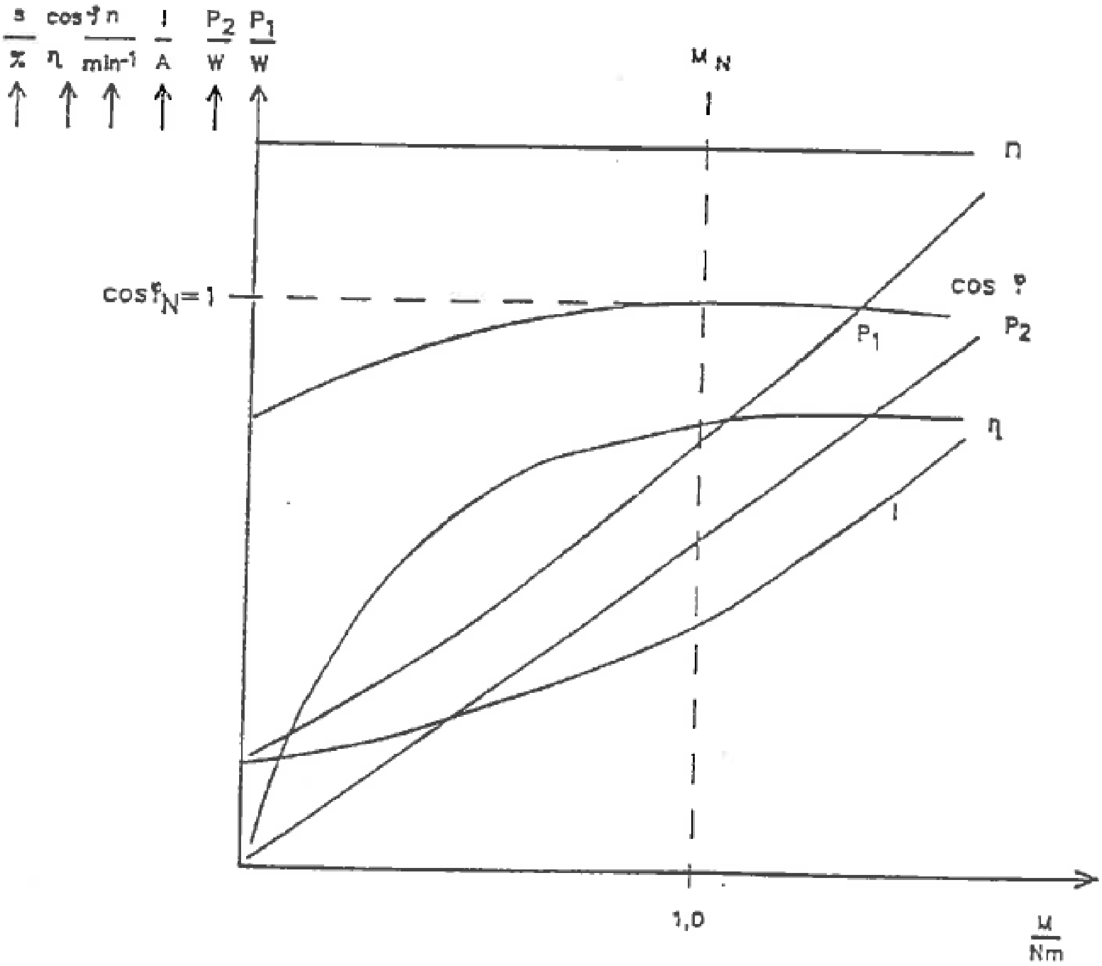


Fig.4 Load Characteristics of the Synchronous Motor

4 Conclusion

The culmination of our laboratory work on synchronous motors in the autumn of 2023 has yielded valuable insights into these remarkable electrical machines. The results and observations drawn from our experiments provide a comprehensive understanding of the principles, applications, and behavior of synchronous motors.

Our investigation confirmed that synchronous motors are indispensable in applications requiring precise speed control and synchronization with the power supply frequency. From timekeeping devices to manufacturing processes, power generation to aviation, these motors ensure consistent and dependable operation, aligning perfectly with the demands of their respective applications.

Additionally, our analysis of a specific synchronous motor's performance characteristics under varying loads revealed several key findings. Notably, as torque increased, current, power factor, input power, and output power exhibited a proportional rise, highlighting the motor's ability to adapt to varying loads. We also observed that efficiency fluctuated with load, with an optimal operating point at a specific load, a common feature in many electrical machines.

In conclusion, the knowledge gained through our laboratory work not only advances our understanding of synchronous motors but also contributes to the broader field of electrical engineering. Our findings underscore the significance of laboratory experiments in shaping our comprehension of electric machines and systems, and their implications for various industries.

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