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Analysis of DC Machines Performances

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Abstract: This paper presents torque/speed characteristics of electrical machine. Speed is not the same according to various type of electrical machine and field excitation voltage. And then, the speed of separately excited DC machine is inversely proportional to field excitation voltage that show in simulation results. The supply voltage is directly proportional to speed in series motor that show in simulation results. Impedance measurement from variable frequency of the three winding of rotating field machine is presented in this paper. Voltage and current values of Star/Delta conditions of Synchronous machine are simulated by using COM3LAB software, Main Unit, and Electrical Machine Module.

Keywords: Torque/speed; Star/delta; Electrical Machine Module; COM3LAB soft ware

1. INTRODUCTION

Electrical machines are energy converters based on electromagnetic principles. The construction of Electrical machine with moving parts differs from that of machines containing only stationary components. Using the type of energy fed or delivered as a basic three types of electrical machine can be defined:

(i)Motor; (ii) Generator and (iii) Transformer

Electrical machines use electromagnetic forces that appear between energized lines and magnetic fields. This experiment conducts a quantitative study of a rotating coil's dynamic effect in relation to the current. DC machine convert electrical power in the form of DC into mechanical power. They contain stator, rotor, commutator and brushes as the main components.

2. PARAMETERS OF ELECTRICAL MACHINE MODULE

The COM3LAB electrical machine system module is shown in Figure 1. There are included the following parameters;

(1)Stepping motor (200 step in full step operation)

(2) Machine test system (M1: Drive or brake, M2: Testing machine) is required external supply by 12VAC adapter.

(3) Spring balance (+ or – 100Nm, zero point center)

(4) Multichannel oscilloscope

(5)Current/voltage transformer

(6) Three phase generator for induction machines

(7) Asynchronous machine's junction plate

(8) Synchronous Machine's junction plate (the connections of the stator windings Z_1, Z_2 and Z_3)

(9) Synchronous machine: The synchronous machine consists of the following components

-Stator winding Z_1, Z_2, Z_3 and iron cores

-permanently excited rotor

-The reference position is 90 degree after the zero phase passage of the three phase generator

-Stator rotational field indicator

(10) Resistive Load

(11) DC supply for commutator machines (L+,L- :supply for the armature winding; 1L+,1L- : supply for the excitation winding

(12) DC machine's junction plate (A1, A2 : Armature winding,E1,E2 : Shunt winding; D1,D2 :Series winding; F1,F2 : winding for separate excitation)

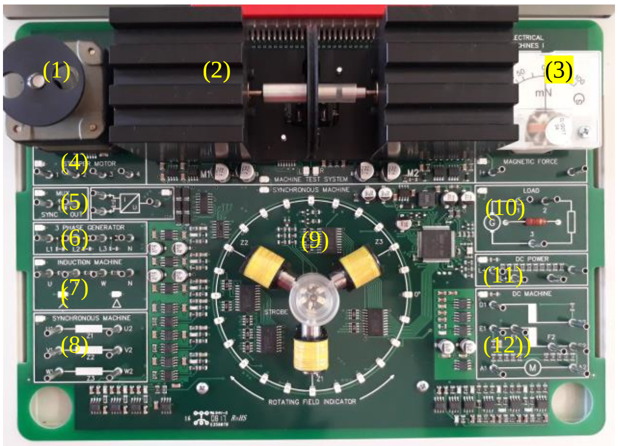

Figure 1. Components of three-phase technology module

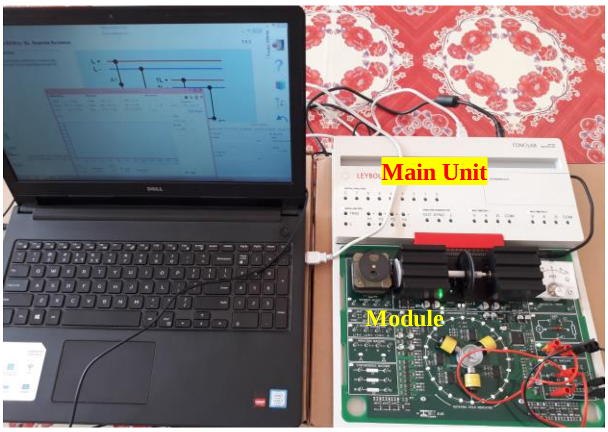

Figure 2.A complete set for simulation

The above Figure 2 is a complete set for simulation. These are Laptop Computer (above P-7), Main Unit, and electrical machine Module.

3. SEPARATELY EXCITED DC MACHINE

.A Separately excited DC machine as in Figure.3, armature and excitation windings have different power supplies (L+ and L- : DC source for armature,1L+ and 1L- : DC source for field winding) . The induced voltage Vi in the DC machine is proportional to the speed n. The torque T generated by the DC machine is proportional to the exciting flux $\emptyset_e$. The torque T is also proportional to the armature current I_A. The maximum torque T_{max} occurs at speed n=0 as the characteristics intersection with the torque's axis .If the excitation and armature voltage have the same polarity, the motor goes clockwise direction. If the excitation and armature voltage have different polarities, the motor goes counterclockwise direction. The torque and speed are proportional to the armature voltage.

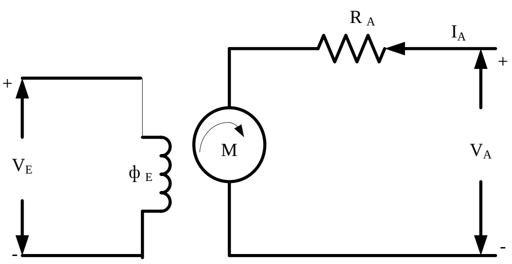

Figure 3. Equivalent circuit of separately excited DC machine

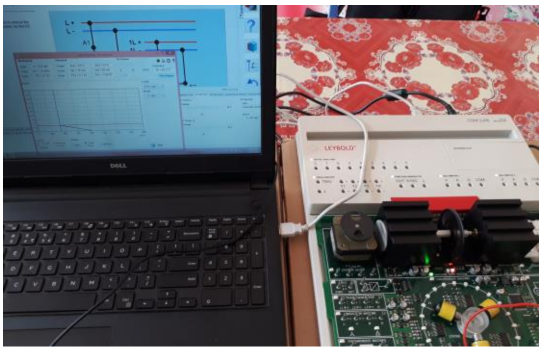

Figure 4. Simulation result of speed measurement

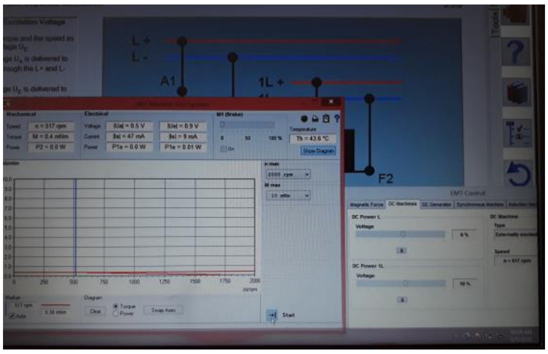

Figure 5. Simulation result of speed measurement

In Figure.4 the excitation voltage is 20% produce the speed is433 rpm. In Figure.5 show the excitation voltage is 10% produce the speed is 517 rpm. So, the speed is inversely proportional to the excitation flux.

4. SHUNT DC MACHINE

In the DC shunt wound operation, the excitation winding E1-E2 and the armature winding A1-A2 are connected in parallel. Due to their high starting torque, series motors used to often be used as railway traction motors. These machines now appear in many housed hold appliances and tools (vacuum cleaners, drills, circular saws, etc) in the form of universal motors. Series motor may not be operated without a load, since its speed would otherwise go unacceptably high. The speed reaches high values at low supply voltage. The torque depends highly on the speed. The torque is greatest at low speeds.

The constant armature voltage is delivered to the shunt motor from DC power through the L+ and L- terminals. The supply voltage 50% are produced the speed 486 rpm as shown inFigure.6.

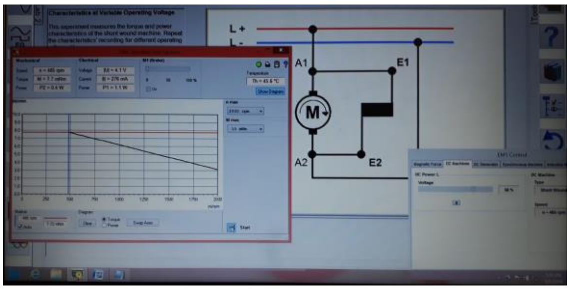

Figure 6. Measuring the speed of shunt DC motor

5. SERIES DC MACHINE

In case of a series motor the flux does not remain constant, or even approximately constant, because the field winding is in series with the load, so that as the load increases so also does the strength of the magnetic field. At first the flux increases approximately in proportion to the load, but as the field approaches saturation, owing to the heavier loads, the increase is not rapid. The effects of temperature changes and of armature reaction may be neglected.

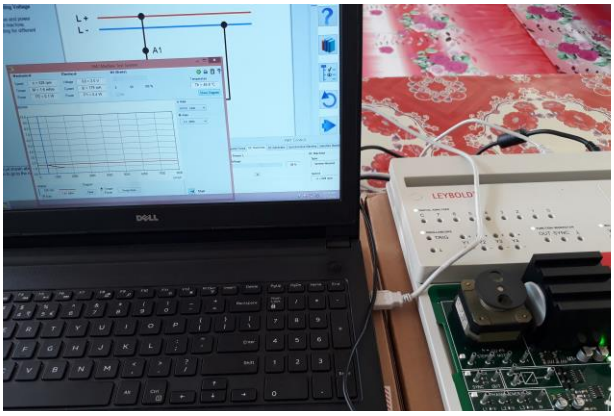

Figure 7. measuring result of speed for series DC motor

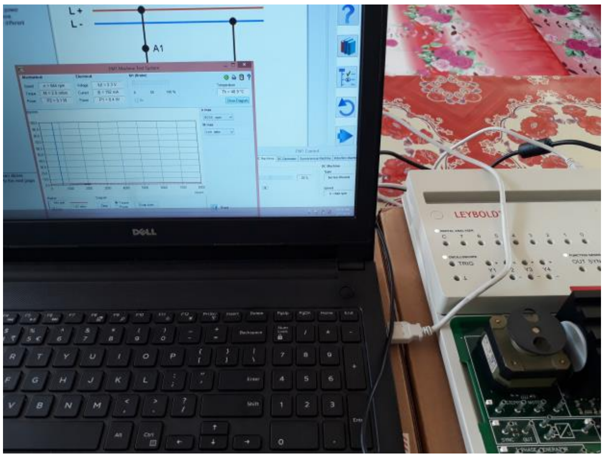

Figure 8. measuring result of speed for series DC motor

As the load torque increases the speed falls rapidly. At low torque the speed becomes very high and machine tends to race. The series motors are used in large starting torque. In Figure.7, DC voltage is 20% produce the speed is 528 rpm. In Figure.8 the DC voltage is 23% produce the speed is 633 rpm. So the speed is directly proportional to the supply DC voltage.

6. ROTATING FIELD MACHINE

Induction and synchronous machines require a revolving magnetic field in the airgap between the stator and the rotor. The rotating field in the airgap essentially determines all rotation field machines' operating behavior. The basic properties of rotating fields and three phase circuit in which the rotating field is a magnetic field whose orientation rotates continuously. The magnetic field's vector tip ideally describes a circular path. Then the magnetic field size's magnitude is constant and in particular independent of the field's direction. The three concentrated coils Z1, Z2 and Z3 generate a very inhomogeneous magnetic rotating field shown in Figure 9.

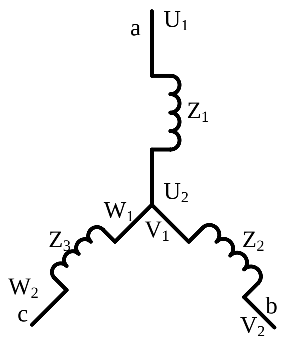

Figure.9 Stator with concentrated winding

The rotational direction changes only when switching two phases. The rotational direction is independent of the stator windings' operation mode. The choice of star or delta connection does not affect the rotational direction. The following Figure.10, measures the line voltages and current s of a star connection by using multimeter 1.The effective line voltages are the same in a balanced star connection. The current's effective values are also equal in all phase conductors.

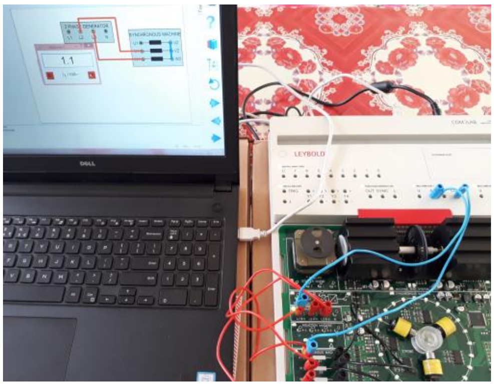

Figure.10 Star connection of rotating field machine

The effective line voltages are the same in a balanced delta connection. The current effective values are also equaled in all phase conductors by using Multimeter 2, measures the delta connection line voltage and line current as shown in Figure 11.

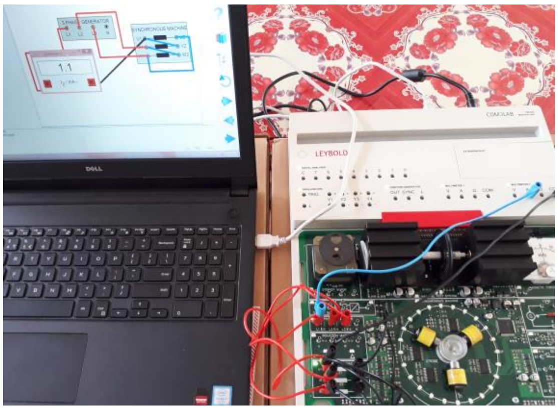

Figure.11 Delta connection of rotating field machine

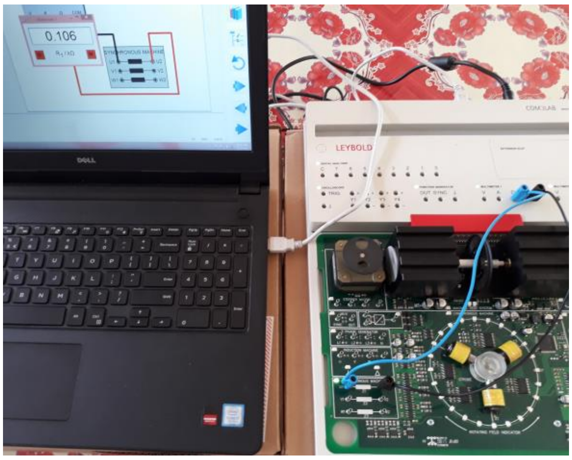

Figure.12 Ohmic resistance measurement of winding U1-U2

The ohmic resistance on the effective resistance of winding Z_1 is 106 ohm as shown in Figure 12. To determine the reactance of winding Z_1, measure the voltage and current using the multimeter 1 and 2. The impedance measurement result of variable frequency for winding U_1-U_2, V_1-V_2 and W_1-W_2 are as shown in Table 1. The reactance X proportionally increase to the frequency shown in Table 1.

Table.1. Impedance measurement of variable frequency

Winding	f/Hz	Z/Ω	R/Ω	X/Ω
U_1-U_2 (Z1)	200	852	535	663
	500	1751	541	1665
	1000	3431	513	3392
V_1-V_2 (Z_2)	200	863	524	686
	500	1796	501	1725
	1000	3535	529	3495
W_1-W_2 (Z_3)	200	878	516	71
	500	1843	516	71
	1000	3608	452	3579

6.1 Measuring Power for Star and Delta Connection of Rotating Field Machine

For a measuring power in delta connection and star connection is shown in Figure 13 and 14.

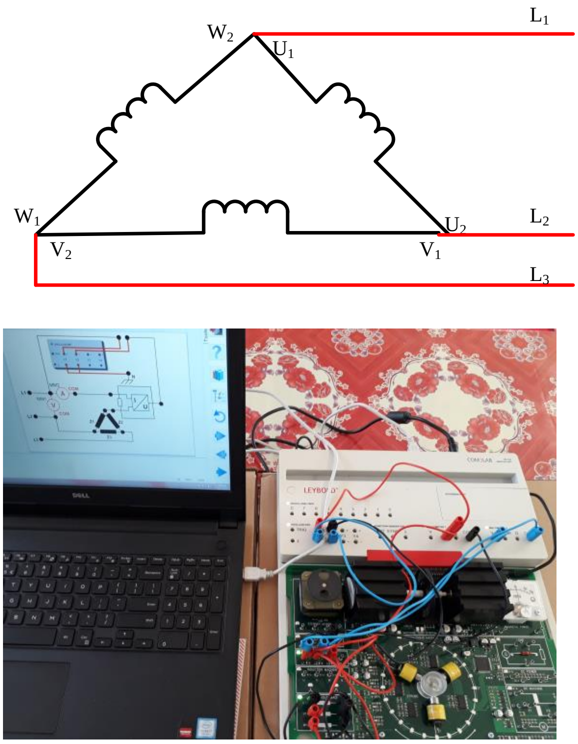

Figure.13 Voltage and current measurement of delta connection

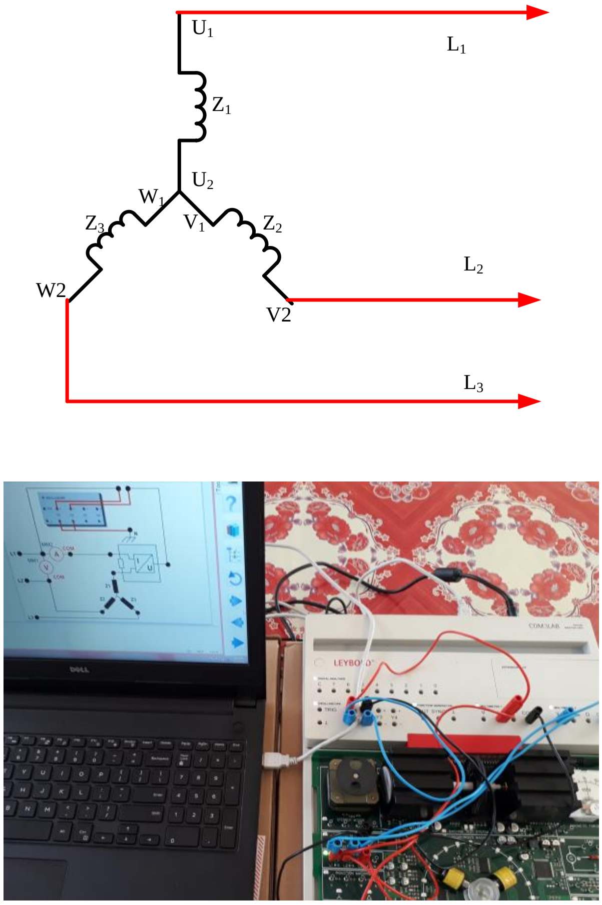

Figure.14 Voltage and current measurement of star connection

$$P = \sqrt{3} \times V_L \times I_L \times \cos\phi \qquad \text{(Watt)}$$

$$\Phi = \Delta t / T \times 360 \qquad \text{(degree)}$$

Compare of the measurement results of voltage and current for winding Z_1 (U_1-U_2 terminals) from the above Figure 13 and 14 are presented in the following Table 2.

Table 2. Comparison of voltage and current measurement

Connection	$V_{L1\text{-}L2}$/V	I_1/mA	P/mW
Star (Z_1)	5.2	50	423.17
Delta (Z1)	5.2	150	1271.12

In the three phase load circuit, the supply alternator delivers a constant line to line voltage (in this case $V_{L1\text{-}L2}$ = 5.2V). The line current in delta connection is three times greater than in star connection. The stator in delta connection thus absorbs three times as much active power.

7. SYNCHRONOUS MACHINE

The synchronous machine is an induction machine whose rotor always turns at a perfectly constant speed under a load. The SM's synchronous speed is determined by the stator value's frequency f1 and the machine's number of pore pair p.

The fixed default speed significantly distinguishes the SM's operating behavior from the asynchronous machine's. The synchronous machine consists in a stator with rotating field winding and a rotor whose operation generates a magnetic DC field. In low power machines, permanent magnets generates the rotor's magnetic DC field .The stator resistance R_1 can be neglected for large SM in Figure15.

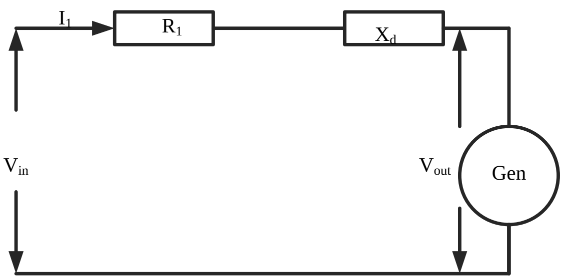

Figure.15. Equavilent circuit of Synchronous machine

In this case , the stator impedance alone is reduced to the synchronous reactance X_d. But this statement does not apply to the COM3LAB software. SM are made for powers above 1GW and are put to use as generators in power stations. Synchronous motors with permanent excitation for small power (1 to 20 kW). SM's can also be used for reactive power compensation.

The three coils of permanently excited synchronous machine Z_1,Z_2 and Z_3 , physically displaced from each other by 120 degree, from an induction machine's stator.An alternator supplies electric energy to the stator coils, which generate a magnetic rotating field at the center of the coils' axles. An enclosed compass needle functions as a rotor in the rotating field shown in Figure 16.

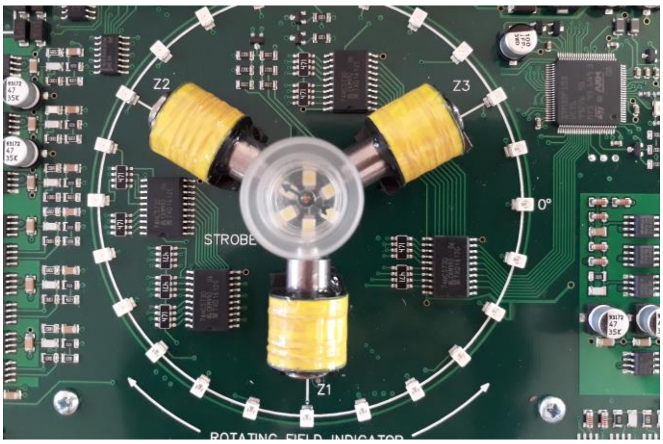

Figure 16. Three coils of synchronous machine with compass needle

In this open setup of the synchronous machine allows for measuring the magnetic field's orientation as a function of current and voltage on the windings. The rotating field show interesting difference between star and delta connections. The synchronous machine has a star connection. Measure the voltage and current of delta and star connection synchronous machine representatively in winding Z_1 as shown in Figure 17 and 18 by using multimeter 1 and 2 .

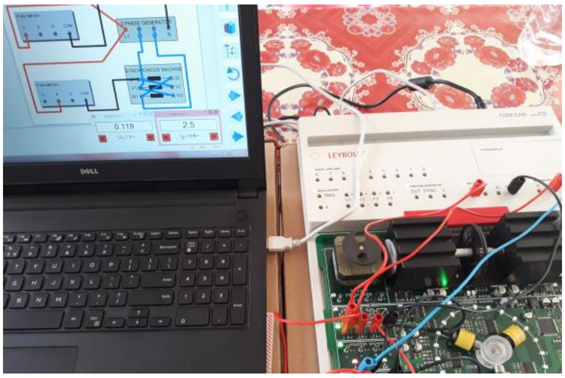

Figure.17.voltage and current measurement of Delta connection

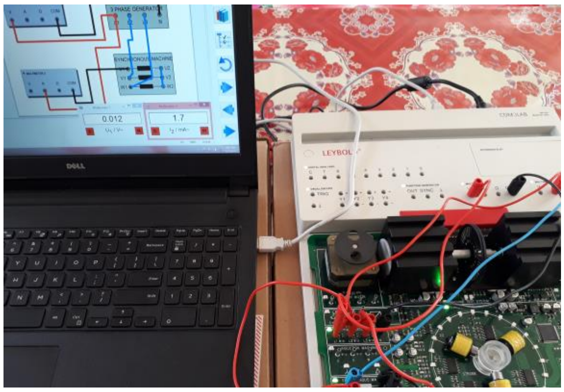

Figure.18.voltage and current measurement of Star connection

The current and voltage can also be measured in the other winding. The concentration factor between star and delta connection is $\sqrt{3}$ for three phase current. The phase in delta connection is delayed by 30degree compared to the star connection. The delta line current is three time greater than in star connection.

8. CONCLUSIONS

In this paper, the first approach with the use of parameters of Electrical Machine Module and Input/Output, Function generator, Multimeter 1 and 2 and Oscilloscope in Master Unit. The second approach with the analysis of electrical machine performance such as separately excited DC machine from various speed simulation results, shunt DC machine and series DC machine performance test. Finally, the comparison of voltage and current measurement for star and delta connection of rotating field machine and synchronous machine. Through this paper analysis of Star symmetrical load, Star asymmetrical load, Delta symmetrical load and delta asymmetrical load was done by simulations.

But in this paper, simulation software of COM3LAB is used to contribute with simulation results. This module is compact and safe for demonstration to technological students because of electrical machine is actually large in range.

9. ACKNOWLEDGMENTS
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