A New Experimental Setup for Electric Motor Drives Laboratory with Mechanical Load Simulator

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***Abstract*—In this paper, a new experimental setup for electric motor drive systems laboratory is presented which acts as a simulator for several real-world mechanical loads. The experimental setup contains two three-phase AC electrical machines which are coupled via their shafts, off-the-shelf motor drive units, transducers and data acquisition system, and a control system constructed on Labview. One machine [?] which is a permanent magnet synchronous machine (PMSM) is used as a generator under torque control to simulate various mechanical load characteristics changing with speed while the other one which is a three-phase induction machine is operated as the motor to be driven by speed control. The main purpose of the experiment is to enable students who are 4th year undergraduates to implement speed control techniques for induction motors and analyze the behavior and characteristics of the motor and the drive while the motor is subjected to different simulated real-world mechanical loads which are difficult and expensive to build in a laboratory such as fan load, pump load, electric traction system etc. During the experiment, the students can observe variation of mechanical output torque, applied voltage and frequency, active and reactive power, efficiency as well as the effects of the motor drive to grid power quality and motor lifetime under these load conditions and make interpretations accordingly.**

***Index Terms*—electric motor drives, electrical engineering education, laboratory experiments, mechanical load simulator.**

I. Introduction

THE key part of an electric motor drive course laboratory is real-world mechanical loads.

65 of the electricity in European Union and 46 of the electricity in the who world is consumed by electric motors. Although not all of these drives contain a dedicated motor drive, considerable amount of applications require adjustable speed drives (ASD). In most of the universities, there exists an undergraduate course related to electric motor drives in electrical engineering departments. It plays a critical role in students' improvement toward being a power engineer or a researcher where the students are taught the significance of energy efficiency, reliability, etc

buray balayamadm.

Aadaki ksaltmalar bu section'da yapalm

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It is desired to have different kinds of mechanical loads in the laboratory to be able demonstrate motor drives' capabilities and limitations. In motor drive applications, most common load types are; pumps, compressors, fans, position controlled automation systems, electric vehicles, railway traction systems, wind-energy systems etc. The significance of motor drive studies is growing every day in today's world. As an example, the share of electric vehicles, which is a typical variable speed motor drive application, among all vehicles is estimated to be x percent in 20xx.

Burada electric vehicle reklam yapp rnekler mi versek? Tesla vs.

Multidisciplinary nature of electric motor drives ekleyelim

ASD neden nemli? Kullanlan teknikler neler bahsedelim

II. Background of the Electric Motor Drives Course

The Electric Motor Drives course is a must course for the 4th year undergraduate students which are to complete the requirements of Electrical Machines and Power Electronics area in the DEEE, at METU. The basic content of the course includes basic operating characteristics and classification of electrical drives, solid-state DC and AC motor drive and control techniques, dynamic behavior of electrical machines and selection of drives for various industrial applications. The main objectives of the course are:

- Understand the fundamental principles of motor drives and the mechanical systems.
- Analyze and design DC/AC motor drives (including power stage and control loops).
- Select motor drive systems for various industrial applications.
- Use multi-domain simulation software.
- Prepare design reports and use version control system to build online portfolio.
- Use commercial industrial motor drive systems through laboratory.

During the semester, the students are assigned 3 simulation projects which are to be conducted on MATLAB/Simulink to visualize the techniques that they have seen in lectures. Moreover, a hardware motor drive project is assigned at the end of the semester which uses hardware-in-the-loop (HIL) techniques. There have been three experiments with different types of mechanical loads most of which include variable speed driven (VSD) induction motors such as; fan load, pump load and crane-hoist load, as shown in Fig 1. A general block diagram of these setups is also shown in Fig 2.

Burada Deneyleri anlatcaz

The experiments are as follows:

- Fan Load Driven by Variable Frequency Drive (VFD)
- Variable Frequency Drive (VFD) Driven Crane Hoist with Speed Feedback
- Centrifugal Pump Load Driven by Variable Frequency Drive (VFD)
- (Demo) Hardware in the loop Motor Drive Controller

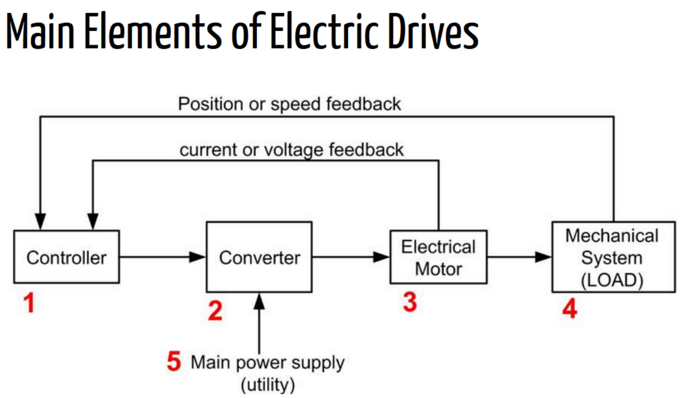

Fig. 1. Integrated modular motor drive examples

Fig.1.

Fig. 2.

Elimizdeki VSD'lerin devre emas ve blok diyagram

Deneylerde neler var nemli olarak? rn: fan yavalaynca zor souyor.

All of these experimental setups were constructed throughout the years with fundings from several research projects as they require expensive hardware and their installation takes time. With the new experimental setup presented in this paper, it is aimed to create a universal mechanical load simulator in which the torque vs. speed characteristics of the load can be adjusted.

III. The Experimental Setup

The experimental setup installed in Middle East Technical University Electrical Machinery Laboratory is shown in figure 1. As the block diagram of the setup at figure 2 illustrates, the test bench is consist of two electrical machines coupled to each other; an squirrel cage induction machine and a permanent magnet synchronous machine. The IM is supplied through an AC variable frequency drive connected to the grid. The PMSM is drove by a back-to-back AC-DC-AC converter which is also connected to the grid. The back-to-back power converter provides the ability of the two direction power flow to develop a variety of experiments on the setup. In order to control and monitor the experiment flow LABVIEW interface environment is used on the computer; a supervisory control and data acquisition program provided by National Instruments. An Ethernet connection is used to build a data communication between computer and the drives. The AC drives can be drove with torque or speed reference commands sent by operator of the experiment using the interface program. On the other side, during the experiment a set of data is measured and transmitted to the interface program. A torque transducer placed at the coupling point of IM and PMSM measures and sends the applied torque on the shaft and the rotating shaft speed to the computer. LEM voltage and current transducers are used to gather the electrical variables' data to be monitored at the supplying terminals of the machines. The all data monitoring and test bench controlling job is done via a user interface program seen in figure 3. Besides a power quality analyzer is connected to the grid connection point of the drives to study the harmonic distortion and the power quality issues.

The experimental setup installed in Middle East Technical University Electrical Machinery Laboratory is shown in figure 1.

IV. Methodology and Aims for Students

$$T_{core} = T_{amb} + p_c(T_{core})R_{th,c} \tag{1}$$

V. Results and Interpretation

Lifetime: high dv/dt insulation lifetime additional core losses Limit on the motor cable length Filter required. Common mode choke. Use ceramic bearing Bearing-shaft currents.

Mechanical resonance frequency (bunu labda grdk)

VI. Conclusions

The conclusion goes here.

Appendix A
Proof of the First Zonklar Equation

Appendix one text goes here.

Appendix B

Appendix two text goes here.

Acknowledgment

The authors would like to thank...

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.

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Michael Shell Biography text here.

John Doe Biography text here.

Jane Doe Biography text here.