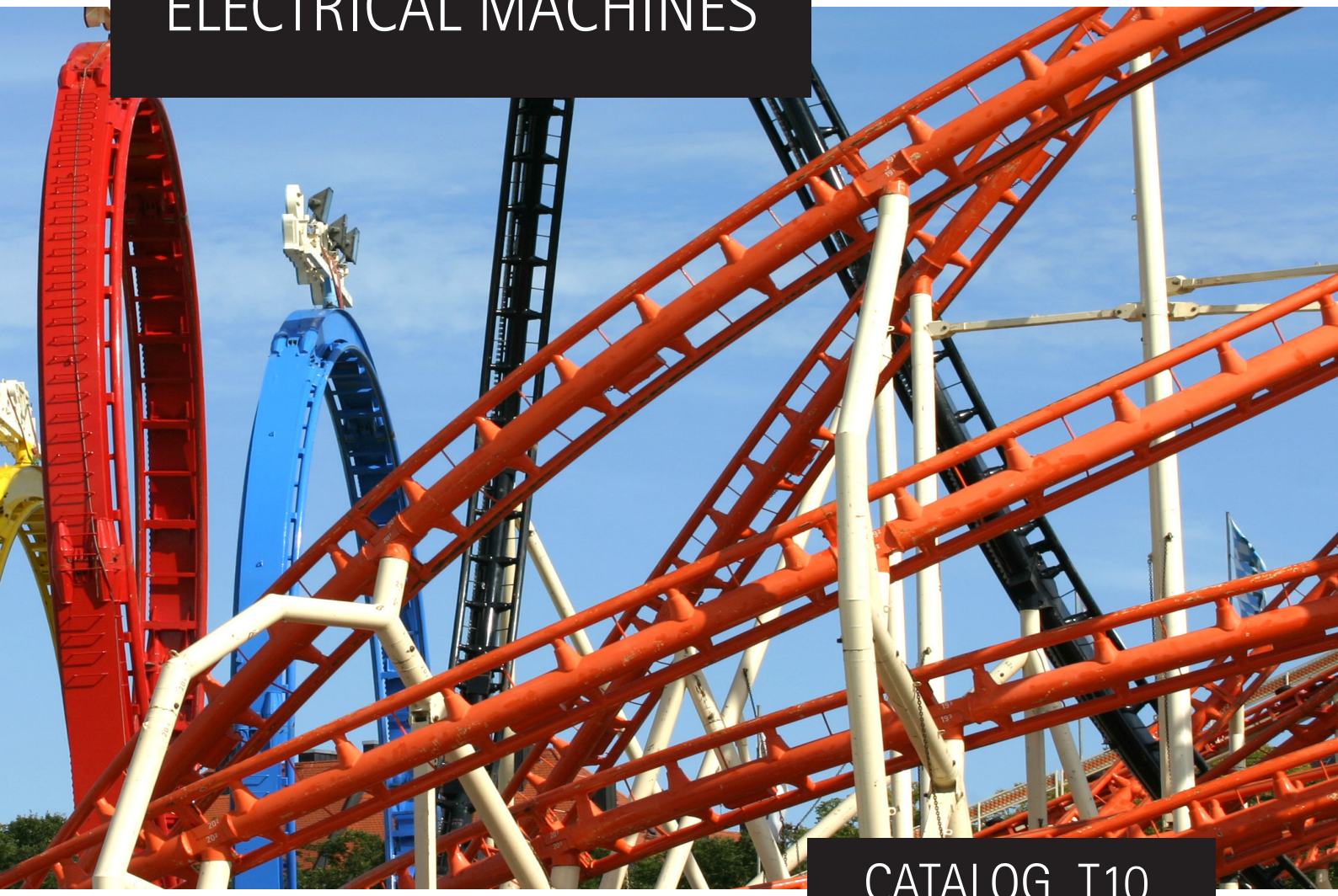
PHYSICS

CHEMISTRY
BIOLOGY

ENGINEERING

LD DIDACTIC

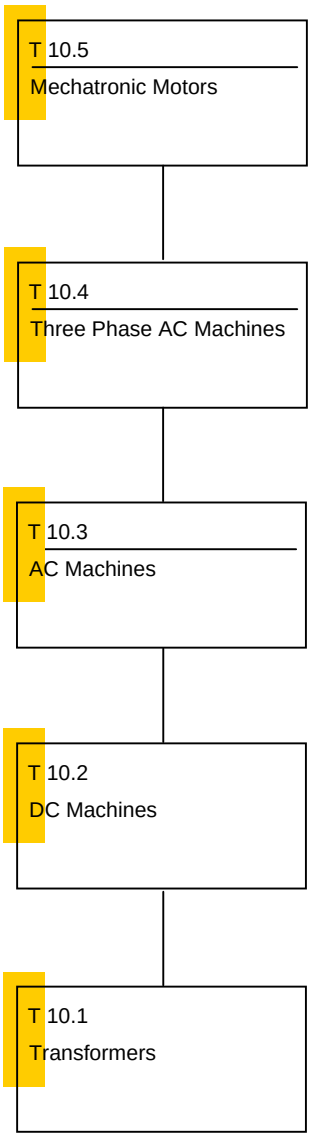
ELECTRICAL MACHINES



CATALOG T10

LEYBOLD®

Content


T 10.5
Mechatronic Motors
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Transformers

Content

Electrical Machines

Our Program T 10

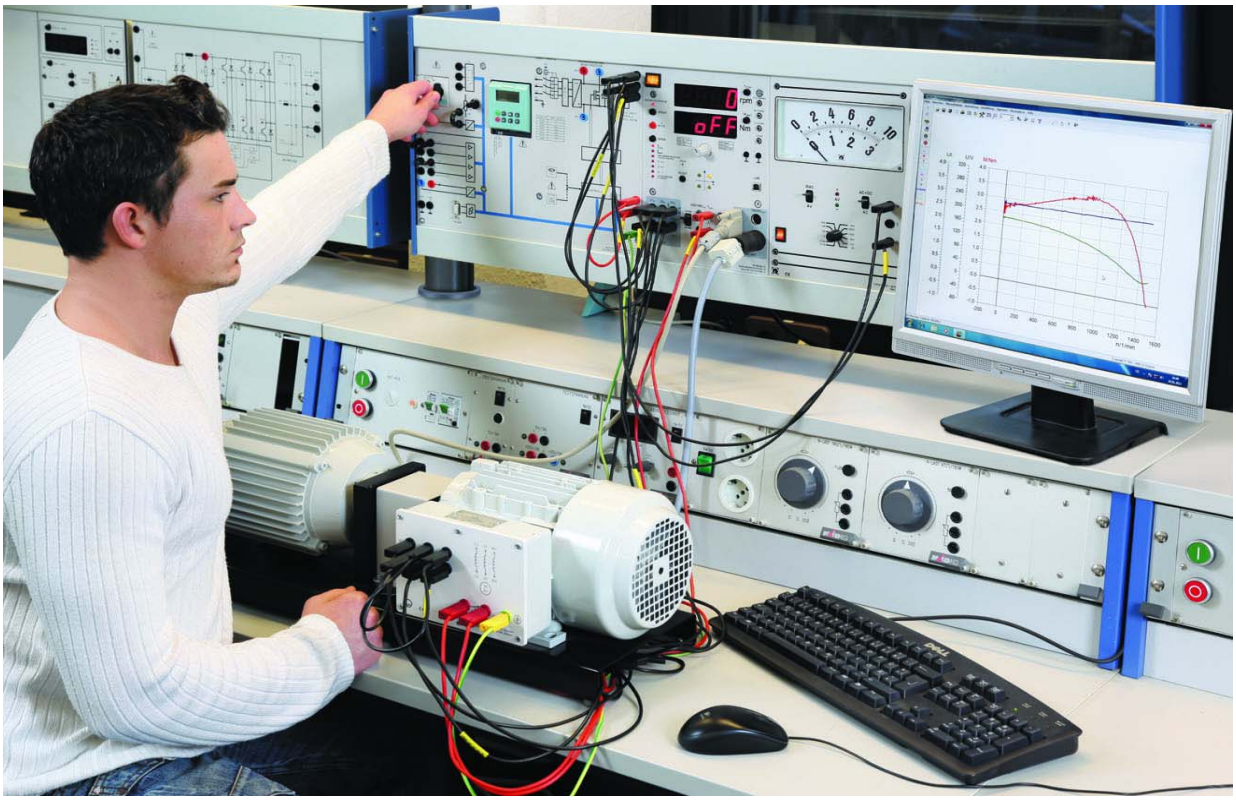
A 50 Hz, 730 MVA SIEMENS generator rotor weighting 2000 tons (16 meter diameter), put to use in 1984 in the hydro-electric power plant in Itaipú, South Americ

Training in the area of electrical machines from LD DIDACTIC for future-oriented instruction in vocational schools, industrial and government training facilities as well as technical colleges and universities Easy to operate, modularly-designed completesystems with short assembly times.

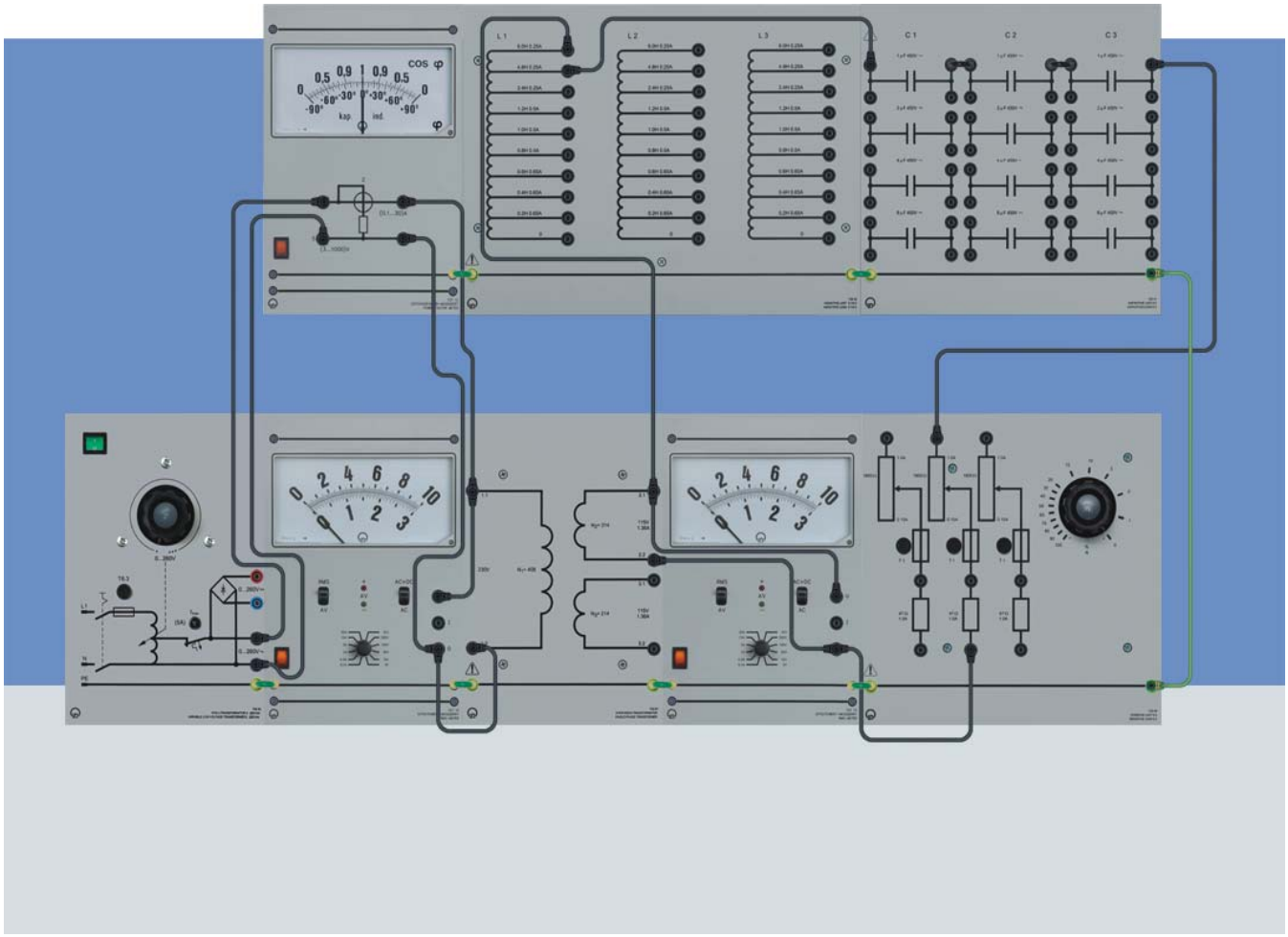
- All of the machines are built in 0.3 kW or 1.0 kW models and are designed with current standard syllabus and training objectives taken into account
- Use of the most modern genuine industrial machines in accordance with German DIN 0530, model B3, protective class IP 23/44 and IP 54, Insulation classes B and F
- Protection afforded both people and the machine using integrated temperature monitoring of all machines and consistent use of safety connecting leads
- Manual or computer-assisted experimenting
- Tried and tested experiment literature with training units, objectives, detailed exercises and solutions

Our Program T 10

You are holding the “EMS 10: Electrical Machines” system catalogue from LD DIDACTIC in your hands! In this catalogue we want to invite you to a fascinating journey through the world of electrical machines. Come along with us as we go from transformers to DC and AC machines and on to special machines, opening up for you the multitude of electromechanical power transformers. Based on the fundamentals acquired from “TPS 2.5: Electrical Machine Teaching Models”, the EMS 10 area focuses on investigating operating response and also covers aspects of the machine as it is used in drive technology dealt with in TPS 12. The Electrical Machine laboratory is increasingly being found in the classroom where the investigation of 15 kW machine sets is simply out of the question. For that reason compact, complete and at the same time flexible systems are needed which permit the use of genuine industrial machines in the classroom. We would like to present to you complete systems as well as individual components in 0.3 kW and 1.0 kW power classes with which you can realise your ideas in the area of electrical machine training and education. If you need more detailed information on any of the individual pieces of equipment do not hesitate to contact us at LD DIDACTIC. This is because LD DIDACTIC lifts the veil from electrical machines!



T 10.1 Single- and Three-phase Transformers



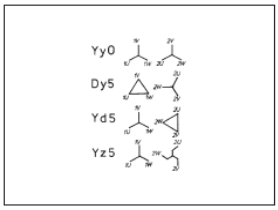
Topics

➔ Single-phase transformer
- No-load, short-circuit and load
- power dissipation, voltage change
- mutual inductance
- magnetic coupling and control
- efficiency

➔ Three-phase transformer
- Circuits and connection symbols
- parallel operation
- voltage equations and equivalent circuit
- no-load, short-circuit and load

T 10.1 Single- and Three-phase Transformers

The physics of the transformer make it an electrical machine albeit one that does notrotate. Transformers convert low electrical voltages low and extra-low voltages into medium and high voltages and vice versa. They are used anywhere from the mVA rangeright up to several MVA. LD DIDACTIC offers a broad product range for both AC as well as three-phase transformers in the extra-low voltage range. Diverse special models – autotransformers, Scott transformers or toroidal transformers -round off our offer. Starting with the physical fundamentals of the law of induction, the experiment literature investigates in depth on and- off switching as well as operating responses in normal and special operating states (no-load and short-circuit). There are transformers in the power classes 0.3 kW and 1.0 kW available to perform the experiments. Don't be left out when LD DIDACTIC gives a didactic presentation of the most unusual of all the electrical machines.



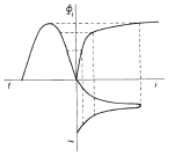
Standard circuits of three-phase transformers.
A selection from German VDE 0532

T10.1.1

Transformers 0,3 kW

	Kat.-Nr.	
1	733 90	3-Phase-Transformer 0,3
1	733 93	Scott Transformer
1	733 97	1-Phase- Transformer 0,3
1	733 98	1-Phase- toroidal core Transformer 0,3
1	733 99	1-Phase- auto - Transformer 0,3
1	569 2002L	Book: T 10.1 Transformers, Teacher Edition (in English)
1	569 2002S	Buch: T 10.1 Transformers, Student Edition (in English)

For getting the complete equipment list please look at a actual offer.



Distortion in the magnetisation current resulting from the saturation of iron

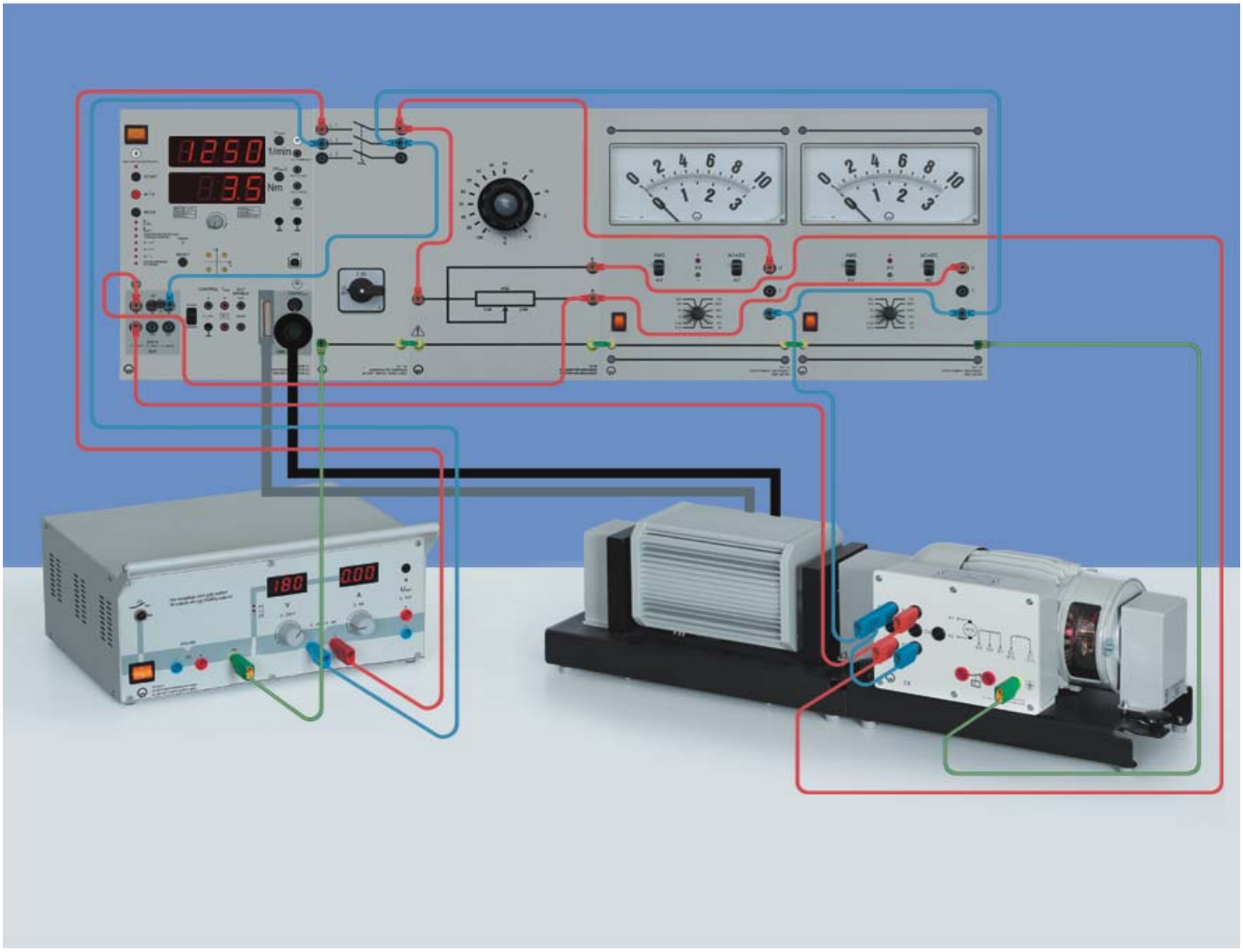
T10.1.2

Transformers 1,0 kW

	Kat.-Nr.	
1	733 91	3-Phase- Transformer 1,0
1	733 93	Scott Transformer
1	733 97	1-Phasen- Transformer 0,3
1	733 98	1-Phasen- toroidal core Transformer 0,3
1	733 99	1-Phasen- auto - Transformer 0,3
1	569 2002L	Book: T 10.1 Transformers, Teacher Edition (in English)
1	569 2002S	Buch: T 10.1 Transformers, Student Edition (in English)

For getting the complete equipment list please look at a actual offer.

T 10.2 DC Motors

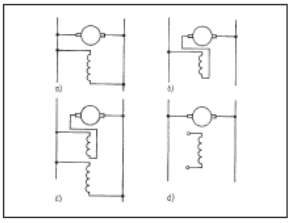


Topics

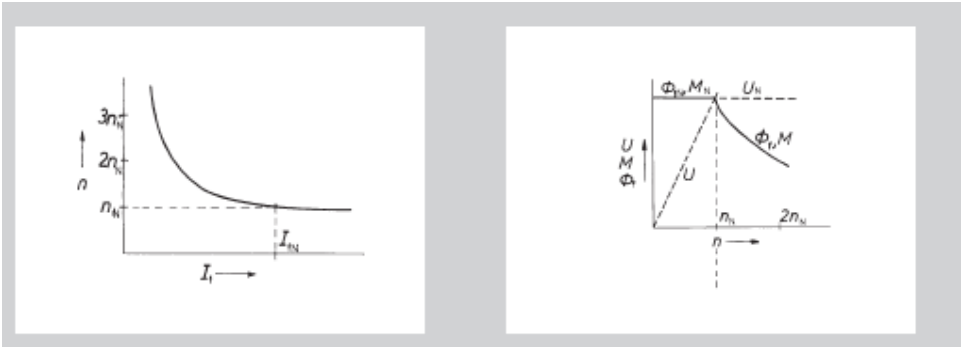
- Fundamentals
  - Design and function
  - how the commutator works
  - armature reaction and commutation
- Series-wound machine
  - Operation with constant voltage
  - possibilities of speed adjustment
  - starting and braking
  - energy conversion
- Shunt-wound machine
  - Operation with constant speed
  - self-excitation process
  - current-voltage characteristics
  - Operation with constant voltage,operating response, characteristics of motors, load characteristics, possibilities of speed adjustment and load setting
  - starting and braking
  - energy conversion

T 10.2 DC Motors

Although recently the DC machine has been getting more and more competition from asynchronous machines fed by frequency converters, it is still the machine of preference in some areas of drive technology. Whether it be for high-inertia starting, use in stonecrushers or cement works or in ironworks, the DC motors are indispensable. Their ability to handle high peaks in torque as well as the linearity of their speed characteristics over a broad range are areas where they excel. These machines can also still be found in the small motor range when there is only DC power available (e.g. automotive). LD DIDACTIC offers the entire spectrum of DC machines – shunt-wound, series-wound as well as compound-wound machines – in the power classes 0.3 kW and 1.0 kW. With its modular design there is a particular emphasis placed on conveying the fundamentals of rotating machines. Start up and operating circuits and auxiliary mechanisms as well as the determination of the mechanical and electrical characteristics complete the exercises. In TPS 12.3 “DC Drives” the DC machine is operated via a rectifier. Further investigations are made on its response to automatic current and speed control.



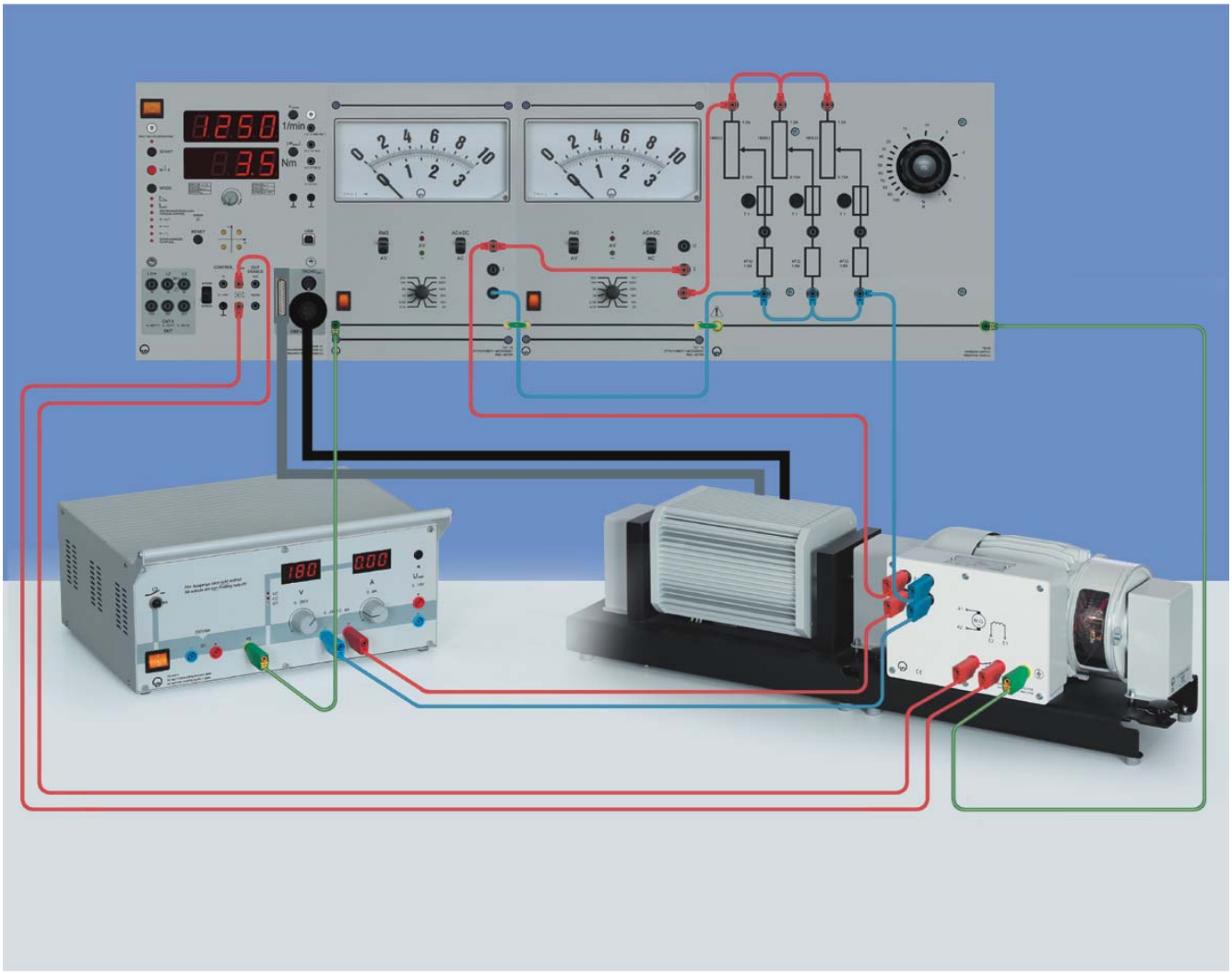
Exciter winding circuit for DC machines
a) Shunt-wound machine,
b) Series-wound machine,
c) Compound-wound machine,
d) separately-excited machine



Operating diagram of a speed-variable DC motor

Field-shunt characteristic of a DC shunt-wound machine

T 10.2 DC Generators

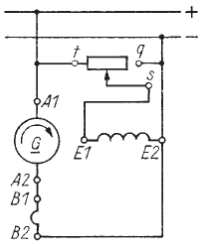


Topics

- Fundamentals of DC voltage generation
- design and function
- characteristics of generators:
  - no-load characteristics
  - self-excitation
  - load characteristics
- types of DC voltage generators:
  - shunt-wound generator
  - series-wound generator
- generators under load
- energy conversion
- power balance

T 10.2 DC Motors and Generators

The DC generator graphically demonstrates the practical application of the physical principle of electromagnetic induction. Although it is now only rarely seen, it helps convey essential information needed to understand how electrical machines operate in general. The conversion of mechanical into electrical energy and the required auxiliary energy, energy conversion and efficiency as well as typical machine components (e.g. commutators, commutating poles) are examined in the comprehensive experiment literature.



Circuit of the shunt-wound generator

T10.2.1

DC Machines 0.3 kW

	Kat.-Nr.	
1	731 86	Compound-wound machine 0,3
1	731 91	Shunt-wound machine0,3
1	731 92	Series-wound machine0,3
1	731 93	Doppelschlussmaschine 0,3
1	732 00	Universal motor 0,3
1	569 2102L	Book: T 10.2.1 DC Machines, Teacher edition (in English)
1	569 2102S	Book: T 10.2.1 DC Machines, Student edition (in English)

For getting the complete equipment list please look at a actual offer.

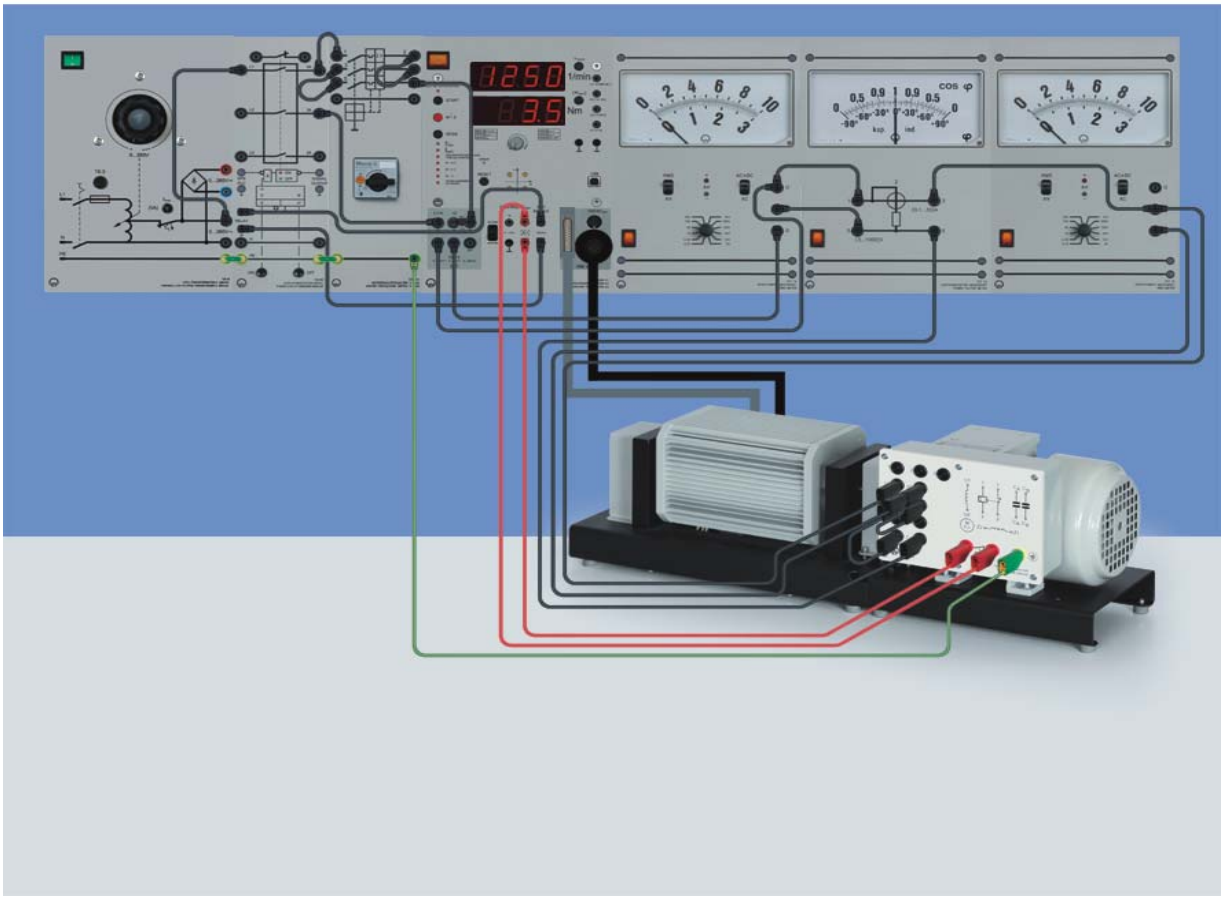
T10.2.2

DC Machines 1.0 kW

	Kat.-Nr.	
1	732 60	Compound-wound machine1,0
1	732 61	Shunt-wound machine1,0
1	732 62	Series-wound machine1,0
1	732 70	Universalmotor 1,0
1	569 2002L	Book: T 10.2.1 Compound-wound machine1,0, Teacher edition (in English)
1	569 2002S	Book: T 10.2.1 Compound-wound machine1,0, Student edition (in English)

For getting the complete equipment list please look at a actual offer.

T 10.3 AC Machines

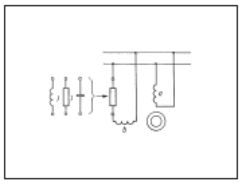


Topics

- Motor with capacitor auxiliary winding
  - Design and function
  - capacitor auxiliary winding
  - operating capacitor
  - starting response
  - current relay
  - centrifugal switch
  - load characteristics
  - Steinmetz circuit
  -
- Motor with auxiliary starting winding
  - Design and function
  - starting response
  - current relay
  - centrifugal switch
  - load characteristics
- Universal motor:
  - Design and function
  - operation on an AC mains
  - run-up
  - load characteristics
- Repulsion motor:
  - Design and function
  - run-up
  - influence of the carbon brush setting on the operating response

T 10.3 AC Machines

The single-phase asynchronous machine has been losing importance ever since the nearly wear-free squirrel-cage motor with frequencyconverter feed has been available in mass and at low cost. In low power classes – e.g. as a washing machine drive – the “real” AC motor is being used less and less but as an AC-fed universal motor it is still finding use particularly in the area of very low power categories, for example, in hair dryers or drills. Nevertheless, it is of vital importance for the understanding of some operating characteristics of induction machines.
LD DIDACTIC offers a diverse product range of AC motors whose design, connection to an AC power mains as well as starting and operating response are described in detail in the extensive experiment literature. With our program you are laying the foundation for a future-oriented training in electrical machines.



Single-phase asynchronous machine with auxiliary winding
a) primary winding
b) auxiliarywinding

T10.3.1

AC Machines 0.3 kW

	Kat.-Nr.	
1	732 00	Universal motor 0,3
1	732 06	Capacitor motor F 0,3
1	732 02	Repulsion motor 0,3
1	732 03	Bifilar wound motor R 0,3
1	732 04	Capacitor motor R 0,3
1	732 05	Bifilar wound motorF 0,3
1	569 2202L	Book: T 10.3.1 AC Machines, Teacher edition (in English)
1	569 2202S	Book : T 10.3.1 AC Machines, Student edition (in English)

For getting the complete equipment list please look at a actual offer.

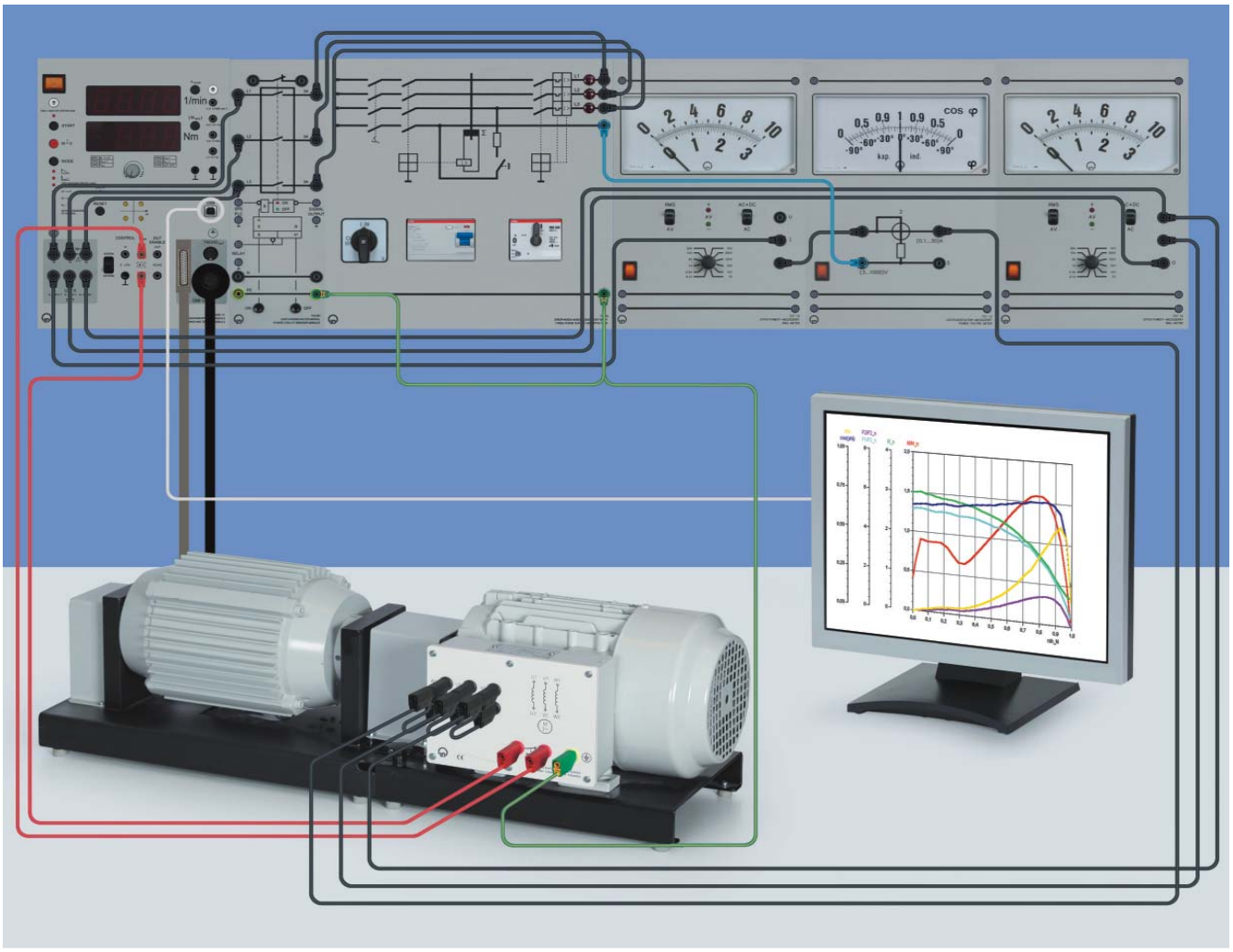
T10.3.2

AC Machines 1.0 kW

	Kat.-Nr.	
1	732 70	Universal motor 1,0
1	732 76	Capacitor motor F 1,0
1	732 72	Repulsion motor 1,0
1	732 73	Bifilar wound motor R 1,0
1	732 74	Capacitor motor R 1,0
1	566 911L	Buch: Universalmotor 1,0, Lehrerausgabe (in deutsch)
1	566 911S	Buch: Universalmotor 1,0, Schülerausgabe (in deutsch)
1	566 941L	Buch: Kondensatormotor F 1,0, Lehrerausgabe (in deutsch)
1	566 941S	Buch: Kondensatormotor F 1,0, Schülerausgabe (in deutsch)

For getting the complete equipment list please look at a actual offer.

T 10.4.1 Asynchronous Motors

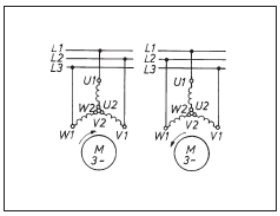


Topics

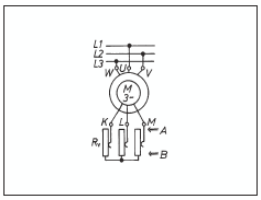
- Design and function
- operating response
- start-up
  - slip-ring rotor
  - deep-bar squirrel-cage motor
  - star/delta switch-on
  - switch-on via starting transformers
  - short-circuit smooth-starting circuit (KUSA)
- braking:
  - braking by reversal
  - DC braking
  - counter-torque lowering circuits
- power balance of the ideal rotating field machines
- power flux
- locus curve (Heyland circle)
- no-load experiment
- short-circuit experiment
- speed-variable asynchronous motors:
  - pole reversing circuit
  - Dahlander circuit
  - speed setting by means of slip
  - regulation
  - slip-ring rotor

T 10.4.1 Asynchronous Motors

The asynchronous machine is the machine of the future! Especially the low-maintenancesquirrel-cage motor with frequency-converter feed continues to make inroads into the application areas of DC and AC machines. With this degree of manipulation the asynchronous machine can be used in all power classes from small washing machine motors up to roller drives. They are characterised by their linear rotation speed/torque responses in the proximity of their nominal operating point as well as its excellent flexibility through constructive measures.



LD DIDACTIC offers the standard slip-ring and squirrel-cage motor models and also special types such as Dahlander motors or motors with separate windings in the 0.3 kW and 1.0 kW power classes. Experiments involving switch-on and start-up as well as runup of these machine are didactically prepared and covered in the experiment literature. The manual or computer-assisted recording of theoperating characteristics and current locus curves are also dealt with. In conjunction with a drive machine (AC pendulum machine 0.3 kW or 1.0 kW) the characteristics can be recorded in the 1st and 3rd operating quadrants for motor operation.



The asynchronous machine with frequencyconverter feed and its operating response is dealt with in greater depth in the topic area “Three-phase Drives” (T 12.4).

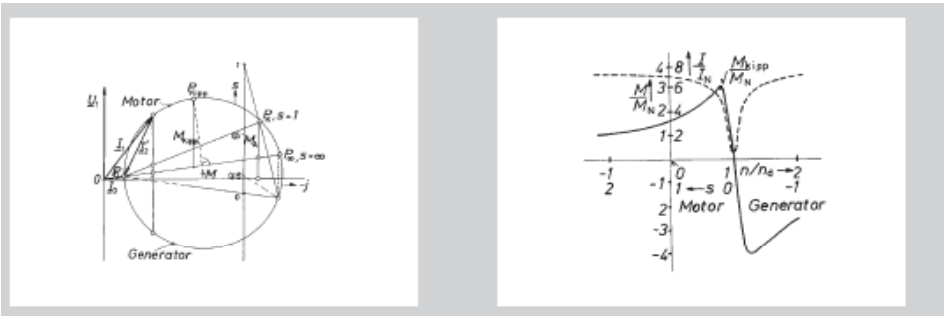
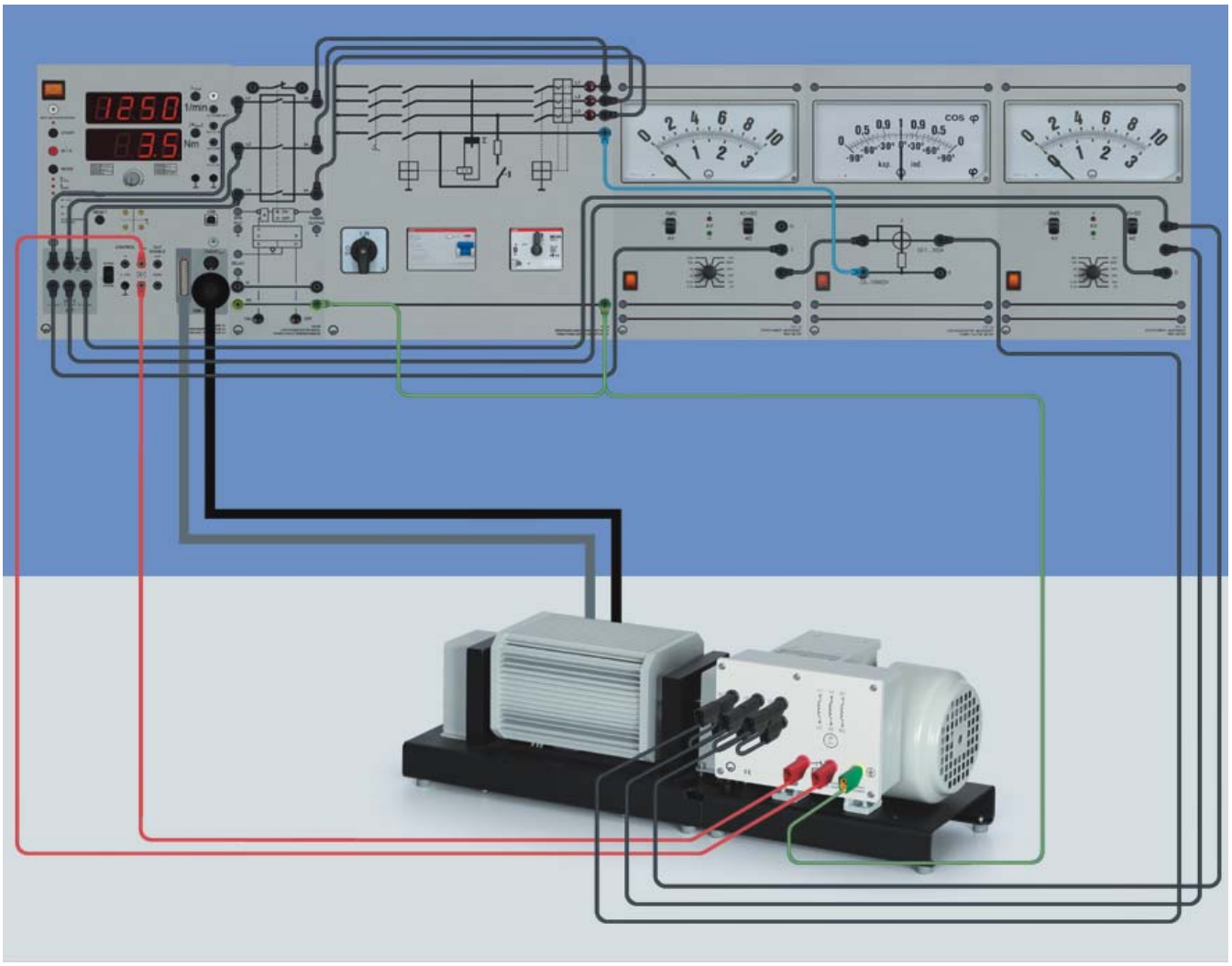


Diagram of the stator current

Torque and current characteristic of an asynchronous machine as a function of the speed

T 10.4.1 Asynchronous Generators

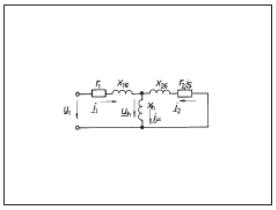


Topics

- Design and function
- Fundamentals of the 3-phase generator
  - operating characteristics
  - generator slip
- self-excitation of the asynchronous generator
- current locus curve
- voltage stability
- area of application
  - operation on a constant-voltage
  - constant-frequency system
  - stand-alone operation
- power balance

T 10.4.1 Asynchronous Generators

The asynchronous machine is not only used as a motor but also as a generator of medium power (up to 2.5 MW). Such generators, primarily used in wind power stations, are generators of electrical energy which function without needing additional auxiliary DC voltage power. Characteristics can be recorded in the 2nd and 4th operating quadrants for generator operation in conjunction with a drive machine . Measurements of energy demand as well as efficiency round off the experiments described in the literature. As a supplement to these experiments the asynchronous machine can be investigated in the “braking” modus. The electromechanical principle which this is based on – the so-called “dynamic lowering circuit” – is still being used in hoisting gear. By supplementing all this with computer-assisted measurements the entire system lives up to the requirements made of modern electrical machine laboratory.
Have a look for yourself – LD DIDACTIC will make the world of asynchronous machines clear!



T10.4.1

Asynchronous machines 0.3 kW

	Kat.-Nr.	
1	732 11	Squirrel-cage motor400/690 V 0,3
1	732 24	Squirrel-cage motorD 0,3
1	732 26	Squirrel-cage motorGW 0,3
1	732 28	Multi function machine 0,3
1	732 33	Slip-ring motor 0,3
1	732 104	Squirrel-cage motor230/400 V 0,3
1	569 2301L	Buch: T 10.4.1 Asynchronmaschinen; Lehrerausgabe (in deutsch)
1	569 2301S	Buch: T 10.4.1 Asynchronmaschinen; Schülerausgabe (in deutsch)

For getting the complete equipment list please look at a actual offer.

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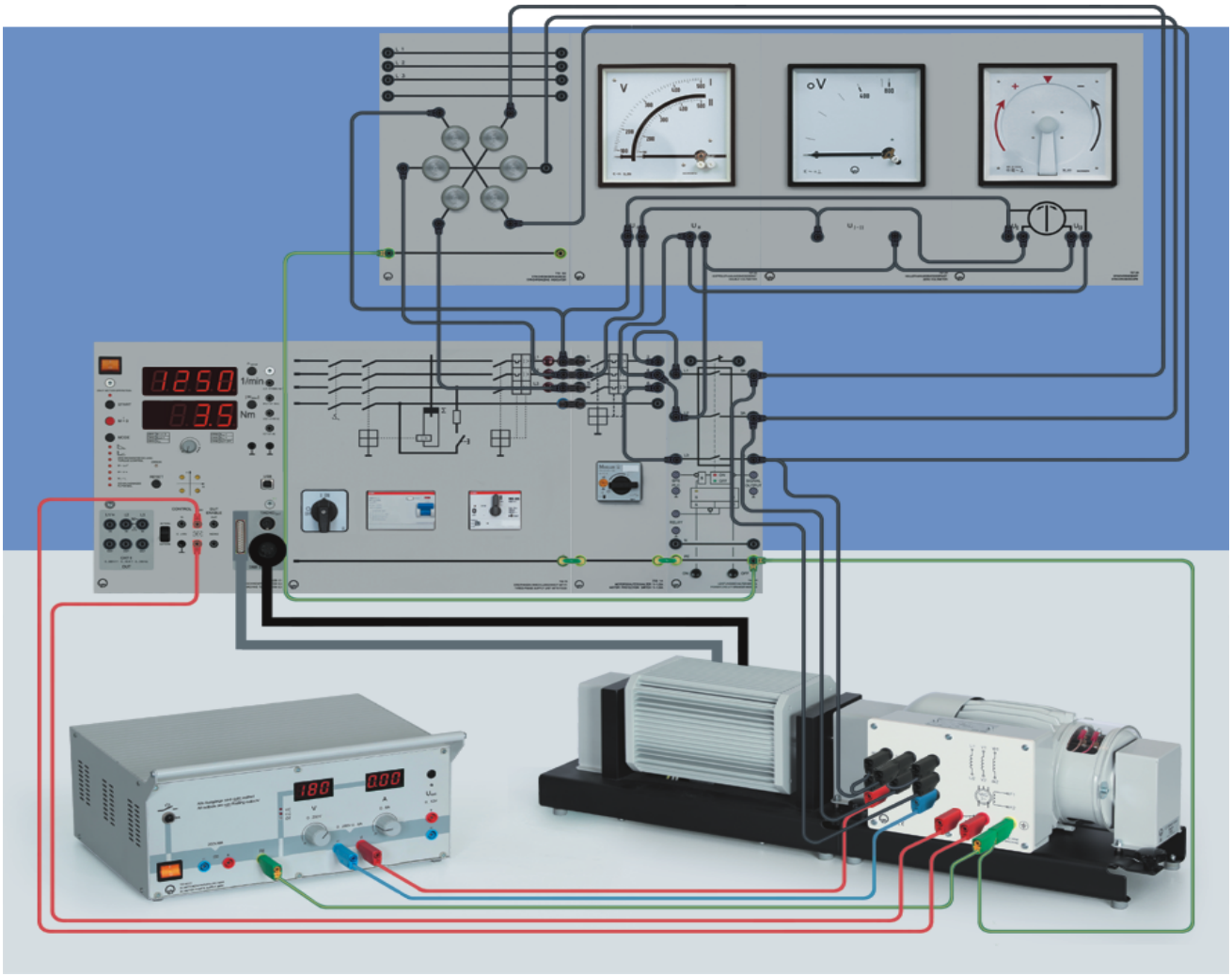
T10.4.1

Asynchronous machines 1.0 kW

	Kat.-Nr.	
1	732 81	Squirrel-cage motor400/690 V 1,0
1	732 94	Squirrel-cage motorD 1,0
1	732 96	Squirrel-cage motorGW 1,0
1	732 98	Multifunktion machine 1,0
1	733 03	Slip-ring motor 1,0
1	732 804	Squirrel-cage motor230/400 V 1,0
1	566 822L	Book: Squirrel-cage motor 380/660V 1,0, Teacher edition (in English)
1	566 823S	Book: Squirrel-cage motor 380/660V 1,0, Student edition (in English)

For getting the complete equipment list please look at a actual offer.

T 10.4.2 Synchronous Motors and -Generators



Topics

➔ Synchronous motor:

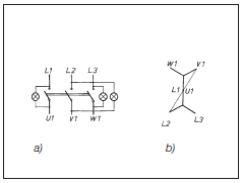
- Non-salient pole and salient pole rotor
- voltage equations,
- equivalent circuit diagram and vector diagram
- no-load and three-pole sustained short-circuit
- locus curves and control characteristics
- torque and load
- Potier reactance triangle and armature
- reaction
- synchronisation and parallel switching
- starting response for synchronous motors
- control of the reactance

➔ Synchronous generator:

- voltage generation
- excitation of the synchronous machine
- operating response
- armature current and torque,
- braking operation and locus curve
- starting and synchronisation
- single-phase generator

T 10.4.2 Synchronous Motors and -Generators

Three-phase machines also include synchronous machines. In contrast to asynchronous machines they run at constant speed and are dependent solely on the frequency of the revolving field. Thus they are independent of the load torque. Besides being operated as a motor – e.g. conveyor belts, textile machines, paper and other winding or reeling machines – it is also used as a socalled “phase-shifter”. Here the effect is exploited that both inductive as well as capacitive reactance can be tapped from the mains feed. For that reason it is used instead of large capacitors to compensate for inductive reactance – as it arises, for example, when machines are in operation.



Synchronisation mechanisms
a) synchronisingdark-method
b) vector diagram for synchronizing dark-method

However, the area where synchronous machines are really used is generator operation. They are used today anywhere from the small shaft generators of a ship’s power supply (several kW) up to the hydrogen-cooled power generators (several MW). Investigations are undertaken on run-up, excitation as well as efficiency and the various types of load. As drive machines you can use the AC pendulum machine for the 0.3 kW power class or the DC pendulum machine for the 1.0 kW class. Also of interest in this context is the topic of “power station control” which is dealt with in the subject area T 11 “Electrical Power Engineering”.

T10.4.2

Synchronous machines 0,3 kW

	Kat.-Nr.	
1	732 36	Synchronous machine SP 0,3
1	732 28	Multifunction machine 0,3
1	732 37	Synchronous machine VP 0,3
1	732 45	Reluctance Motor
1	569 2352L	Book: T 10.4.2 Synchronous machines 0,3 , Teacher edition (in English)
1	569 2352S	Book: T 10.4.2 Synchronous machines 0,3 , Student edition (in English)

For getting the complete equipment list please look at a actual offer.

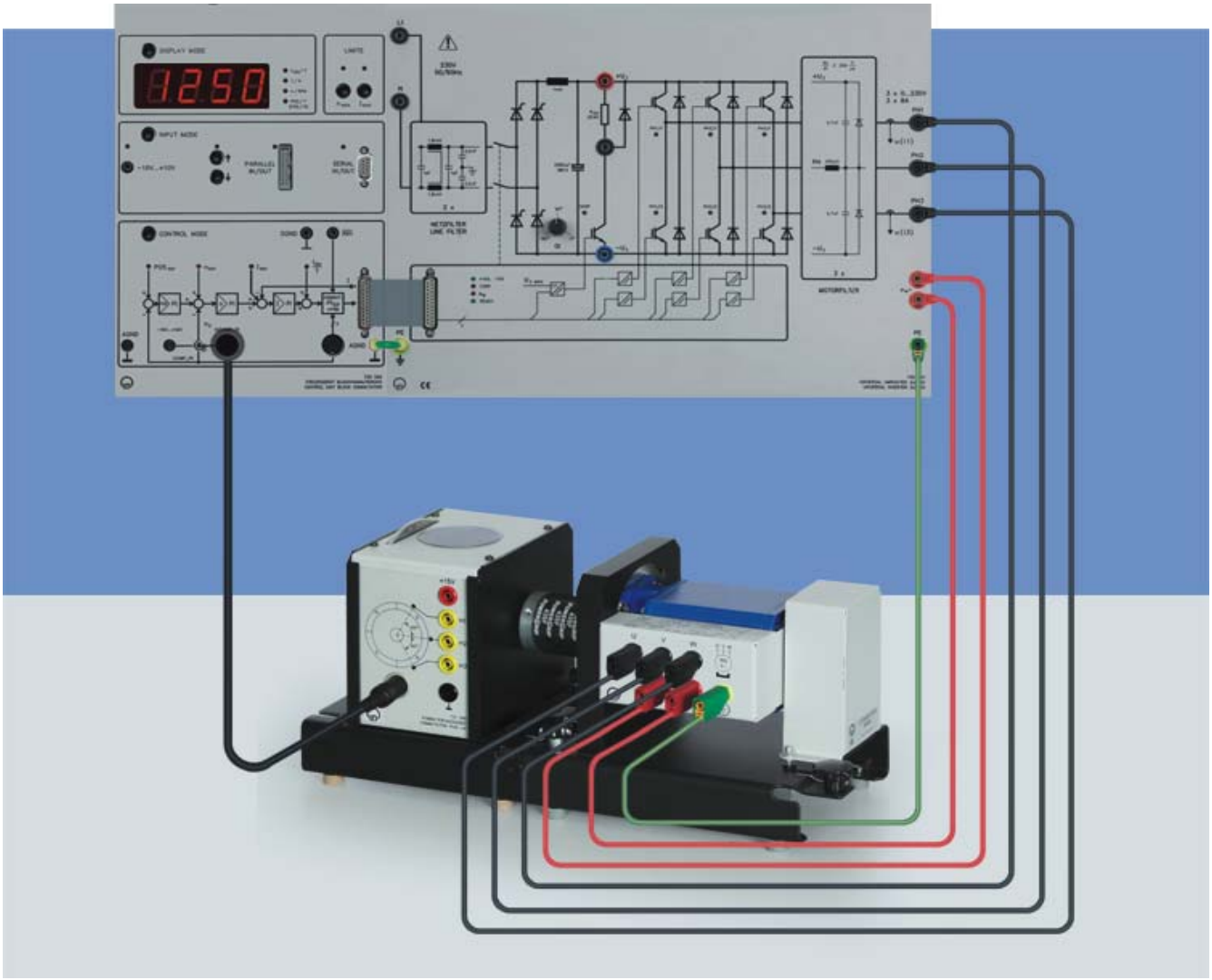
T10.4.2

Synchronous machines 1,0 kW

	Kat.-Nr.	
1	733 06	Synchronous machine SP 1,0
1	732 98	Multifunction machine 1,0
1	733 07	Synchronous machine VP 1,0
1	569 2352L	Book: T 10.4.2 Synchronous machines 1,0 , Teacher edition (in English)
1	569 2352S	Book: T 10.4.2 Synchronous machines 1,0 , Student edition (in English))

For getting the complete equipment list please look at a actual offer.

T 10.5 Mechatronic Motors



Topics

➔ AC servo motor

- Design and function
- operation on a power amplifier
- current and voltage curves
- load characteristics
- automatic current, speed and position control
- dynamic response and reversing rotation direction
- regulating the speed and the load

➔ FCC Motor

- Design and function
- operation on a power amplifier
- run-up and
- load characteristics
- speed dependency of the frequency
- speed dependency of the load, ventilator/pump, winder or flywheel

T 10.5 Mechatronic Motors

What is a mechatronic motor. The answer is simple: a motor suitable for use in the areas of automation engineering. This means that here classification is not based on physical principles of function but according to utalisation. From the area of synchronous machines we need only mention the AC servo motor and from the asynchronous machines the frequency converter motor. Both types of machine are used with low and medium power classes e.g. for positioning operations and require a power electronic component for control.

LD DIDACTIC offers the AC servo motor with 0.3 kW and the frequency converter motor with either 0.3 kW or 1.0 kW.

In the experiment literature peculiar operating responses and features re dealt with and contrasted with the corresponding machine types without power electronic control. More detailed topics such as automatic position servo control or non-linear load characteristics (winders, ventilators etc.) are investigated in the more detailed area of „Drive Technology“ (T 12.4-5). Machines for the applications of the future- presented by LD Didactic!

T10.5.1

Servo motor 0.3 kW

	Kat.-Nr.	
1	731 096	Kommutierungsgeber 0,1/0,3
1	731 994	AC-Servo motor 0,3
1	735 292	Control device
1	735 297	Universal-Converter 3x230 V
1	565 452	Book: Power Electronic and Drive Technology, T 12.5.1 (in English)

For getting the complete equipment list please look at a actual offer.

T10.5.2.1

Frequency Converter Motor 0.3 W

	Kat.-Nr.	
1	732 46	Frequency Converter Motor 0,3
1	735 314	LCP2

For getting the complete equipment list please look at a actual offer.

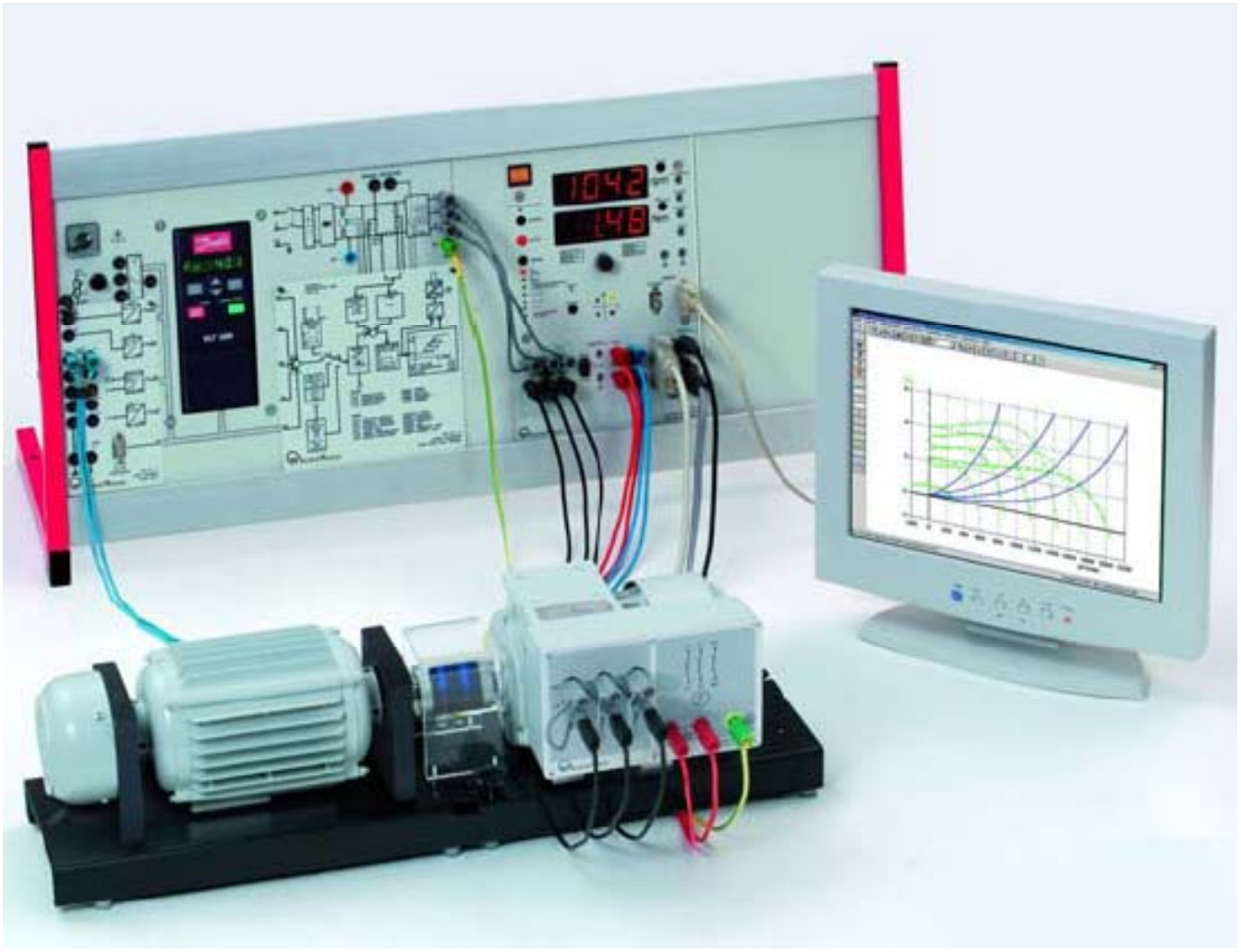
T10.5.2.2

Frequency Converter Motor 1.0 kW

	Kat.-Nr.	
1	732 49	Frequency Converter Motor 1,0
1	735 314	LCP2

For getting the complete equipment list please look at a actual offer.

Machine Test System

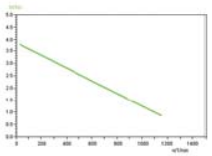


Topics

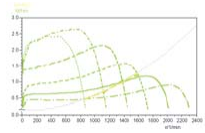
- record mechanical and electrical characteristics of DC, AC and three-phase machines
- subject the DUT to loads with automatic torque and speed control
- drive the DUT with automatic torque and speed control
- Torque control
- Typical load characteristics
  - ventilator/pump
  - winder
  - flywheel
  - free function M = f(n)

Machine Test System

For braking, driving or working machines: the three-phase pendulum machine systems are universally applicable in the 0.3 kW and 1 kW power class. With the aid of a cradle-mounted frequency-converter-fed machine it is possible to brake and drive machines under test (DUTs) in both rotation directions and at variable speed. The control unit is compact, straightforward and easy to connect to the pendulum machine. This ensures that set-up times are short and that faulty operation is avoided thus allowing the student to focus on the essential. Torque measurement is performed realistically with flexing rods and the corresponding electronics inside the pendulum machine. The speed is detected with an incremental sensor. The control unit measures the rms values of current and voltage across the DUT. The evaluation of these variables can be performed manually or in a modern fashion using a PC. For this all the measured values can be transmitted via the USB port. Ventilators, lifting or winding drives normally do not exist in a laboratory. For the pendulum machine with intelligent microcomputer control it is no problem simulating the response of these kinds of machines so that whole new dimensions in drive technology training and education can be explored.



Speed-torque characteristic of an AC servo motor



Frequency-dependent speed-torque characteristics of a FCC motor

Machine Test System 0.3 kW

	Kat.-Nr.	
1	731 989USB	Machine Test System 0.3 kW
		recommended:
1	728 421	CBM10-Characteristics of electrical machines

Machine Test System 1.0 kW

Anzahl	Kat.-Nr.	Bezeichnung
1	732 689USB	Machine Test System 1,0 kW
		recommended:
1	728 421	CBM10-Characteristics of electrical machines

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