ELECTRICAL POWER ENGINEERING
DL GTUTOT-S

Introduction:

Modern electric power systems have grown and expanded geographically becoming more complex over time. The planning, monitoring, and management of such systems, require advanced analysis and control techniques for network interconnection, energy management and storage, and the integration of distributed renewable energy sources in the future Smart Grid implementations.

The DL GTUTOT-S trainer has been designed to provide students with a fully comprehensive knowledge in Electrical Power Engineering systems, in a compact and flexible solution.

The laboratory is subdivided into four major study areas:

- Electric power generation
- Electric power transmission and distribution
- Electric power use
- Protection techniques

Ideal for 5 students to work simultaneously.

University and technical schools.

And applicable to courses in: Electric Machines, Electrical Power engineering.

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ELECTRIC POWER GENERATION

Introduction:

The three-phase power is the most commonly used for generation, transmission, distribution and use in the public energy sector. Three-phase systems are more economical than single-phase systems due to the reduced amount of conductor material needed to transmit the same amount of power making them suitable for high voltage transmission over long distances. Furthermore, it is ideal for consumers use in three-phase (motors, heavy loads) or single-phase applications.

The generation of electrical energy is performed almost exclusively by means of high-power synchronous machines, or alternators, whose construction design depends on the type of drive, which can normally be steam, gas or water. One major limitation of the electrical power is that it cannot be stored in large quantities and, therefore, it has to be generated as the consumer needs it. The synchronous generator can be operated in isolated mode, providing power to a single consumer, or it can be connected in parallel with a constant-voltage constant-frequency grid system.

In this laboratory the main characteristics of a synchronous generator are studied its synchronization as well to the main network and its behaviour under different load conditions.

Experiments:

Generator analysis

- Winding resistance measurement
- Generator no-load test
- Generator short-circuit test
- Conventional efficiency

Load characteristics

- Active power generation.
- Inductive reactive power generation.
- Capacitive reactive power generation.
- Regulation performance analysis.

Network synchronization

- Manual synchronization: Dark lamp synchronization method, Two Bright one dark synchronization method and parallel operation using a synchronoscope.
- Automatic synchronization using a synchronization relay.

Generator network operation

- Alternator and synchronous motor operation.
- Dynamic power factor control of the grid.

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POWER TRANSMISSION AND DISTRIBUTION

Introduction:

Today, the public electric power is supplied almost exclusively using three-phase systems with frequency of 50 or 60 Hz, depending on the country. The major advantage of AC three-phase over DC power systems is that the electrical power is generated economically in large power stations relatively far from the end users, transported at high voltage over long distances with very little power loss and finally made available to the consumers providing them with two different levels of voltage depending on the application needs.

The major components of electric power transmission and distribution systems are:

- Transformers: step up transformers increase the generated voltage to values suitable for high voltage transmission systems, isolation transformers are used to exchange power between networks, and step down transformers decrease the voltages to medium voltage level and further down to low voltage to be distributed to the consumer.
- Transmission lines: overhead power lines are mainly used to transmit electrical energy from the power stations to the consumers. However, in densely populated areas the power can only be supplied via cables. Various voltage levels are used for transmitting power; the levels are determined by the amount of power and the distance; the higher the transmission voltages, the lower the currents as well as the transmission losses. However, it must also be considered that network investment costs increase with the voltage.
- Busbars, disconnectors and power circuit breakers: they are the main components found in a switching station used for power distribution.

In this section, the basic circuits of power engineering, star-delta and delta-star connections, series and parallel connections of operating equipment (lines, transformers) and different network topologies are analysed.

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Experiments:

Power Distribution and transmission

Three-phase transformers

- Transformer vector group.
- Transformer no load performance.
- Transformer short-circuit performance and equivalent circuit.
- Load performance.
- Zero impedance.
- Asymmetrical load.
- Autotransformer.
- Parallel operation.

Transmission lines

Studies on three-phase transmission lines

- No-load performance, Ferranti effect.
- Matched load performance.
- Three-phase symmetrical short-circuits.
- Resistive-inductive load.
- Resistive-capacitive load.
- Zero-phase impedance.
- Parallel compensation for a resistive-inductive load.
- Series compensation for a resistive-inductive load.
- Three-phase asymmetric short-circuit.

Parallel and series connection of transmission lines

- Series connection of two lines.
- Parallel connection of two lines.

Transmission line with earth-fault compensation

- Earth fault on a line with an isolated star point.
- Petersen suppression coil.

Power distribution

Three-pole double busbar systems

- Basic double busbar system.
- Double busbar system with load.
- Busbar coupling.

Network topologies

- Radial network.
- Meshed network.

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CURRENT AND VOLTAGE TRANSFORMERS

Introduction:

In electrical power supply systems, currents and voltages are constantly measured and monitored to ensure that they remain within certain limits. In general, the current and voltage values are so high that they cannot be measured directly.

Special transformers have to be used to reduce these values to a level that can be measured safely and economically. These values are needed in order to provide information on the health of the system, to calculate the amount of power supplied to a customer and to rapidly switch off sections of a network in case of a fault event to avoid its propagation that could result in the collapse of the entire power supply system.

Experiments:

Current transformer

- Single phase current transformer operation
- Single phase current transformer load test
- Three-phase current transformer
- Three-phase current transformer summing circuit - zero-phase sequence of a three phase system.
- Summation current transformer

Voltage transformer

- Single-phase voltage transformer – Transformation ratio and influence of load.
- Three-phase voltage transformers and fault to ground.
- Two single-pole voltage transformers.

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ENERGY MANAGEMENT

Introduction:

In some countries, the electric energy consumption levels have reached levels that exceed the available supply. There is an increasing need to optimize and reduce this level of use and find alternative, more efficient and renewable power sources.
Electric companies use electric meters installed at the consumers facilities to measure the power delivered to them for billing purposes. Modern solid state electricity meters are able to measure both active and reactive power, demand and maximum use of power, or allow different rates to be applied in different periods of the day.

Most electrical installations act as inductive loads on the mains network. These loads include equipment with coils or windings, such as motors and transformers that produce a time delay between the voltage and current variables. Energy consumers, in particular larger ones such as industrial plants, are obliged, either by contract or for economic reasons, to compensate the reactive power consumed by their equipment.

The integration of distributed renewable energy systems tied to the main grid create a bidirectional flow of energy that needs to be properly managed, using metering and advanced power electronics conversion techniques.

In this section, several types of user can be simulated using static and dynamic loads to study power factor compensation, energy consumption, load profiling and the optimization of electrical power use.

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Experiments

Complex loads, energy and power consumption

- Three-phase consumers with star and delta connections (R, L, C, RL, RC and RLC loads).
- Dynamic load:
  - Study of an asynchronous motor as three-phase load
  - Power measurement in the case of energy-flow reversal.
- Active energy consumption
- Reactive energy consumption:
  - for symmetric and asymmetric RL loads.
  - in the event of a phase failure.
  - in the event of over-compensation (RC load).
  - for active loads.
- Maximum power demand.

Power factor compensation

- Manual power factor compensation:
  - Calculating parameters for compensation capacitors.
  - Compensation using various capacitors.
- Automatic power factor compensation.

Energy Management

- Load profiling and efficiency
- Mixed load energy consumption analysis with and without power factor compensation.

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DL GTUTOT-S List of modules:

DL 10065N	Electric power measuring module	1
DL 2108T02A	Power circuit breaker	1
DL 2109T1T	Synchronization indicator	1
DL 2109T32	Synchronoscope	1
DL 2108T25	Generator synchronising relay	1
DL 1067S	Automatic voltage regulator	1
DL 2108T26	Brushless motor with controller	2
DL 2108T26BR	Braking resistor	2
DL 1013A	Universal base	2
DL 1026P4	Three Phase Synchronous Machine 4 poles	1
DL 1013T1MR	Motorized variable three-phase power supply	1
DL 1080TT	Three-phase transformer	2
DL 2109T29	Three-phase power meter	2
DL 2108T02	Power circuit breaker	4
DL 2109D51	Digital Vector group meter	1
DL 2109D30	Digital Power meter	1
DL 7901TT	Overhead line model	2
DL 7901TTS	Overhead line model 110Km	1
DL 2108T03	Line capacitor	2
DL 2108T04	Petersen Coil	1
DL 2108T02/2	Double busbar with two disconnectors	3
DL 2109T21	Single-phase current transformer	1
DL 2109T22	Three-phase current transformer	1
DL 2109T25	Summation current transformer	1
DL 2108T10	CT load	1
DL 2108T11	VT load	1
DL 2109T23	Single-phase voltage transformer	1
DL 2109T24	Three-phase voltage transformer	1
DL 2102AL	Three-phase supply unit	1
DL 1021/4	Three-phase asynchronous machine	1
DL 2108T19	Reactive power controller	1
DL 2108T20	Switchable capacitor battery	1
DL 1017R	Resistive load	1
DL 1017L	Inductive load	1
DL 1017C	Capacitive load	1
DL 4236	Load Manager	1
DL HMI	HMI	1
DL HUBRS485F	Communication MODBUS	1
DL PCGRID	All-in-One Computer	1
DL SCADA-512	SCADA Software with capacity limited to 512 tags	1
DL A120-3M	Frame with three levels, basic version	4
DL SP-A120-LED	Upper base with LED strip, for DL A120-3M	4
DL T12090_SK	120x90 working bench	4
DL T06090	60x90 working bench	2
DL 2600TTI	Three-phase isolation transformer	1
DL 1196	Holder for leads	1
TLGTU101	Cables	1
TLGTU102.T	Cables	1
TLGTU104	Cables	1

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PROTECTION RELAYS
DL GTUTOT-P

Introduction:

Dedicated protection relays are used for monitoring each section of the power system (generators, transformers and transmission lines). Their main role is to identify a damaged system component from a specific fault event (under/over voltage, under/over frequency, over-current, earth-fault, reverse power, etc.), and to disconnect it quickly and reliably, protecting humans and the other healthy parts of the system without interrupting the power distribution.

Adding the optional DL GTUTOT-P protection modules expansion kit to the DL GTUTOT-S configuration, the available list of experiments and system capabilities are extended, allowing the study of protection techniques and strategies applied to each section of the power distribution network.

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Experiments

Generation protection

- *Paramenter configuration, fault simulation, relay response measurement and oscillograph recording for the following protections:*
  - Overcurrent protection
  - Over-voltage and under-voltage protection
  - Over-frequency and under-frequency protection
  - Unbalanced load protection
  - Stator-earth fault protection
  - Reverse power protection
  - Generator differential protection

Transmission line protection

- *Paramenter configuration, fault simulation, relay response measurement and oscillograph recording for the following protections:*
  - Instant time overcurrent protection
  - Definite time overcurrent protection
  - Inverse time overcurrent protection
  - Earth-fault protection
  - Undervoltage and overvoltage protection
  - Unbalanced load protection
  - Directional power protection
  - Protection of parallel connected lines

Transformer protection

- *Paramenter configuration, fault simulation, relay response measurement and oscillograph recording for the following protections:*
  - Time overcurrent protection
  - Transformer differential protection

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DL GTUTOT-P List of modules:

DL 2108T23	Feeder manager relay	1
DL 2109T22	Three-phase current transformer	1
DL 2108T24	Percentage biased generator differential relay	1
DL 2108T21	Differential transformer relay	1
DL 2108T18	Earth-fault relay	1
DL 2108T13	Inverse time overcurrent relay	1

Expansion kit

Adding the optional DL 2108T22 module to the configurations DL GTUTOT-S and DL GTUTOT-P, the available list of experiments and system capabilities are expanded:

Experiment List

DL 2108T22 Distance Protection

- *Paramenter configuration, fault simulation, relay response measurement and recording for the following protections:*
  - Overcurrent protection
  - Unbalanced load protection
  - Distance protection

Modules:

DL 2108T22	Distance protection relay	1

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