

Festo Renewable Energies



Outline

1. Topic understanding

- High-School vs Vocational vs Engineering
- New vs Renewable
- Smart Grid

2. Learning Solutions

- Solar/Wind Equipment Set
- Nacelle & Hubs
- Solar/Wind Training System
- Solar Thermal

3. Reference



Topic understanding



Renewable Energies available for all levels



High-School

- Explore new sources of energy
- Small lab projects



Vocational

- Understanding of the energy
- Maintenance and installation tasks
- Residential, Commercial, Industrial



Technician/Engineer

- Design new systems
- Explore new possibilities
- Improve efficiency

New energy VS Renewable Energy

1. New Energy

- New sources
 - Biomass
 - Hydrogen
 - ...
- Does not mean it is green ?
 - Example: H₂ is as green as the energy needed to produce it

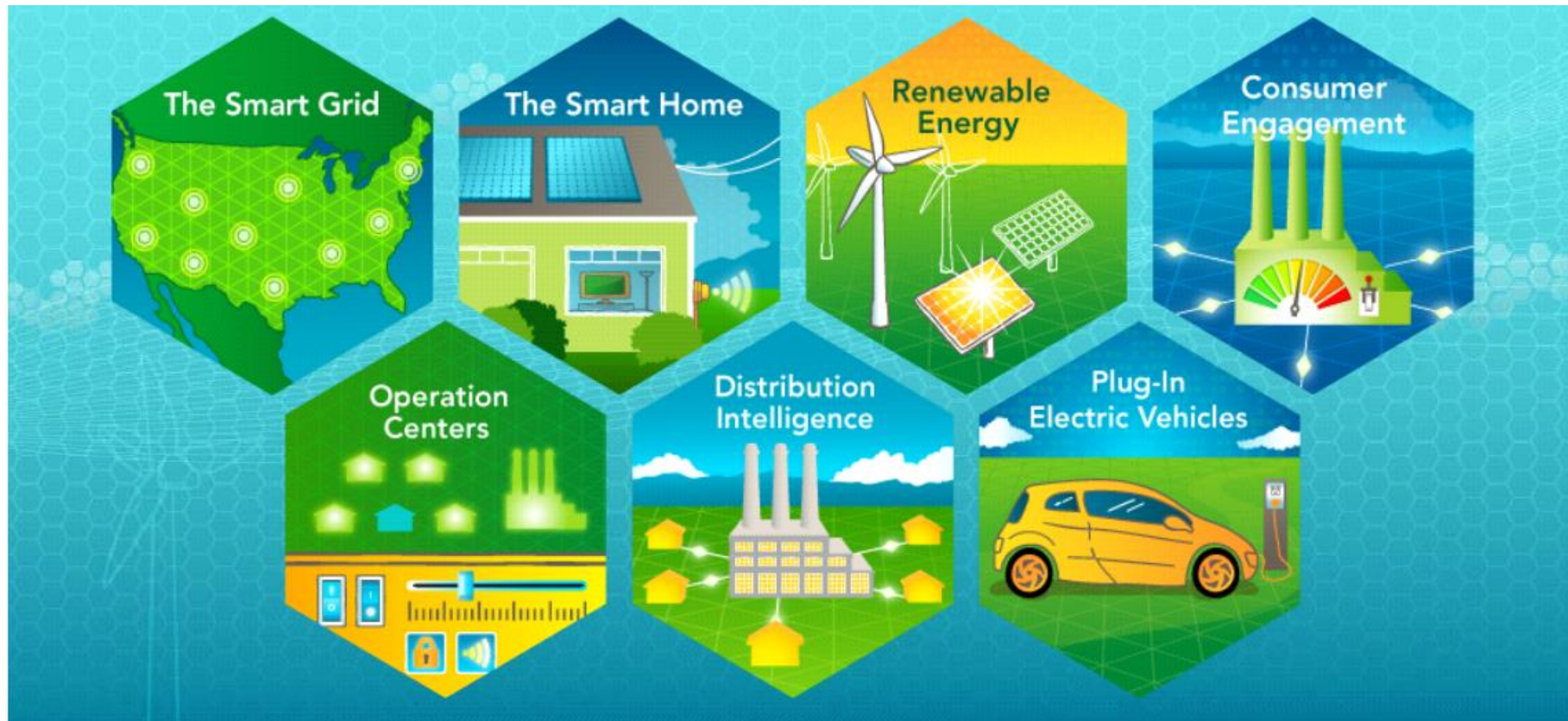


2. Renewable Energy

- Sustainable energy
 - Wind
 - Solar
 - Geothermal
 - Even hydropower could be considered RE



Smart Grid



Smart Grid vs. Dumb Grid

Example : A breaker is about to trip

- Dumb Grid
 - Once it is tripped, operators react by trying to find an alternate path for the electricity (up to 30 seconds)
- Smart Grid
 - The breaker can warn before tripping
 - The network can automatically re-route the power
 - Can even preempt tripping



Career



Type of programs

- Vocational
 - Wind power technology maintenance
 - Solar power technology maintenance
 - Residential energy management
- Technician
 - Electrical engineering technology
 - Power utility technician
 - Renewable energy technology
- University
 - Electrical engineering

Before talking about the renewable energy learning solutions...

Always remember this simple advice...

Every renewable energy training program must start with the BASICS!

What are the BASICS ?



Hydraulics



Industrial controls

What are the BASICS ?



Basic electricity
Power electronics
Motors/Generators

...



Mechanics

What are the BASICS ?



Industrial wiring



Rigging and safety

What are the BASICS ?



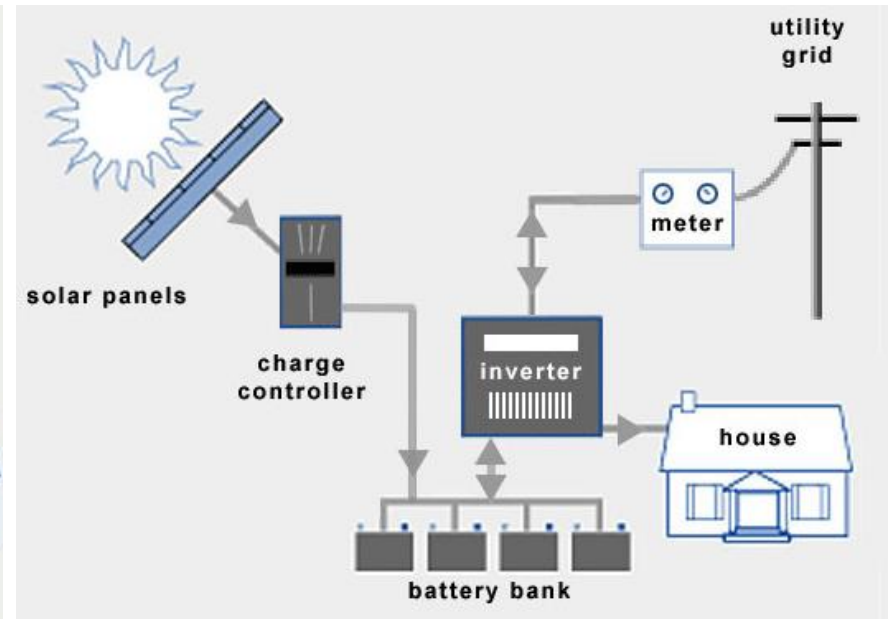
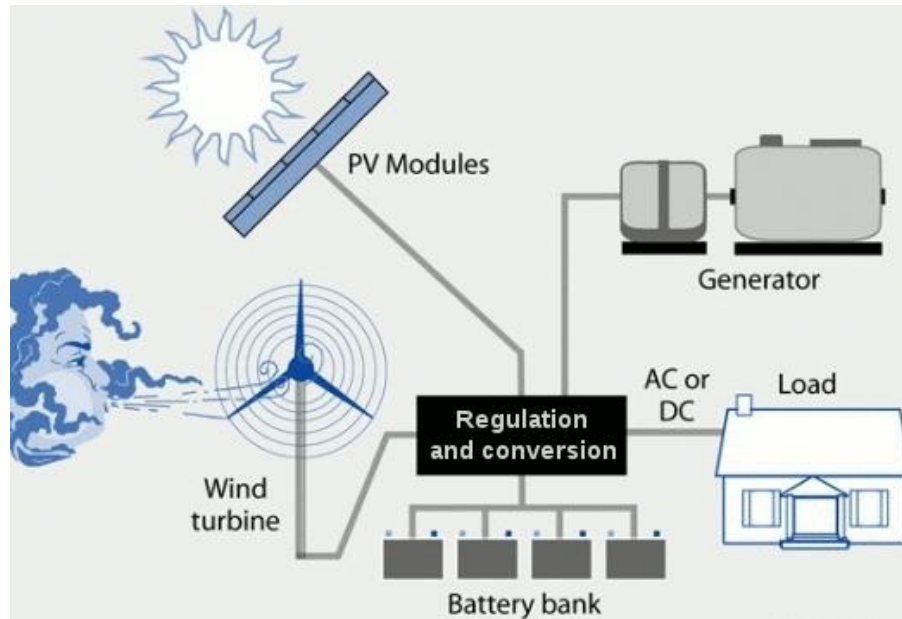
Automation

+ Many other possibilities...

Solar & Wind Power Training Packages



What do we teach ?



General concept

Our new Solar and Wind Training packages target training facilities teaching maintenance and operation as well as general concepts regarding solar and wind power production applied to the residential and commercial level



Features & Benefits

- Combination of real solar panels for understanding and flexible solar panel emulator for higher power
- Flexible hardware for addition of new topics and lower costs
- Real wind turbine emulation with real wind curves (P/T) + real parts used
- Stand-alone and grid-tied production scenarios
- Complete courseware with theory, manipulations, testing questions
- One software for both DACI and DYN0
- Safety (fail-safe operation) and robustness even on measurements
- Wind Turbine circuitry breakdown for better understanding
- Large batteries for higher realism
- 2 types of charge controllers (MPPT/PWM)
- ... more in the competitive argumentation

Solar Power Training Packages

Basic Package

Introduction of solar power production and photovoltaic panels
7 lab exercises (2-3 hr each)

- The Diode
- The Solar Panel (Photovoltaic Panel)
- Effect of Temperature on Solar Panel Performance
- Storing Energy from Solar Panels into Batteries
- Effect of Shading on Solar Panel Operation
- Solar Panel Orientation
- Solar Panel Performance versus Insolation

Based around one complete workbook



1x 12 V Lead-Acid Batteries«	595060
1x Solar Panel Test Bench	595057
1x Monocrystalline Silicon Solar Panel	595058
1x Solar Power (Instructor Guide)	593979

Advanced Package

Learn solar power production and usage either in stand-alone or grid-tied applications
4 lab exercises (2-3 hr each)

- Stand-Alone PV Systems for DC Loads
- Use of an MPPT Charge Controller in Stand-Alone PV Systems
- Stand-Alone PV Systems for AC Loads
- Grid-Tied PV Systems

Based around one complete workbook



1x DC 48V Lamps	595055
1x AC 230V Lamps	595056
2x 1AC Energy Meter	594904
1x 48V Lead-Acid Battery Pack	595059
1x DC 48V PWM Charge Controller	595051
1x DC 48V MPPT Charge Controller	595050
1x Single-Phase Power Supply	595930
1x AC 24V Power Supply	772050
1x 1AC 230V Stand-Alone Inverter	595052
1x 1AC 230V Grid-Tied Inverter	595053
1x 4-Quadrant Power Supply and Dynamometer Controller (including Manual and Computer-Based Control)	595028
1x Firmware Function (4Q Dynamometer/Power Supply): Pb-Acid Battery Charger	581438
1x Firmware Function (4Q Dynamometer/Power Supply): Ni-MH Battery Charger	581440
1x Data Acquisition and Control Interface (including computer-based instrumentation for 2x current inputs and 2x voltage inputs)	595912
1x Photovoltaic Systems (Instructor Guide)	593987

Complete Package

Includes all the above in one complete Solar Power learning solutions

Typical setups

Solar Power Basic

Photovoltaic
Panel

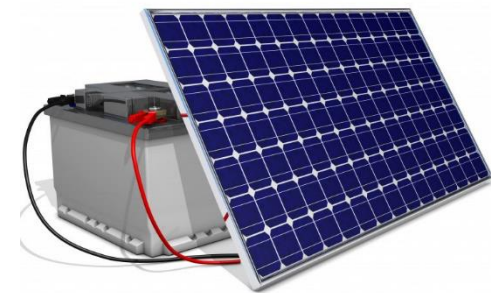
Solar Panel Test
Bench



Main Power



12 V Batteries





Typical setups

Solar Power Advanced

Solar Panel Emulator



Monitoring with DACI



Charge Controller



48V Batteries



AC Lamps



Stand-Alone Inverter





Wind Power Training Packages

Basic Package

Introduction of wind power and energy storage (batteries)

4 lab exercises (2-3 hr each)

- Voltage-Speed Characteristic of a Wind Turbine Generator
- Torque-Current Characteristic of a Wind Turbine Generator
- Power versus Wind Speed
- Storing Energy from a Wind Turbine into Batteries

Based around one complete workbook



1x Wind Turbine Generator / Controller	595061
1x Wind Turbine Load Resistors	594819
1x Resistive Load	594820
1x 12 V Lead-Acid Batteries	595060
1x 48V Lead-Acid Battery Pack	595059
1x 4-Quadrant Power Supply and Dynamometer Controller (including Manual and Computer-Based Control)	595028
1x 4 Quadrant Dynamometer Motor	595062
1x Firmware Function (4Q Dynamometer/Power Supply): Turbine Emulator	579783
1x Firmware Function (4Q Dynamometer/Power Supply): Pb-Acid Battery Charger	581438
1x Timing Belt	793140
1x Introduction to Wind Power (Instructor Guide)	593983

Advanced Package

Learn solar power production and usage either in stand-alone or grid-tied applications

4 lab exercises (2-3 hr each)

- Stand-Alone Wind Power Systems for DC Loads
- Stand-Alone Wind Power Systems for AC Loads

Based around one complete workbook

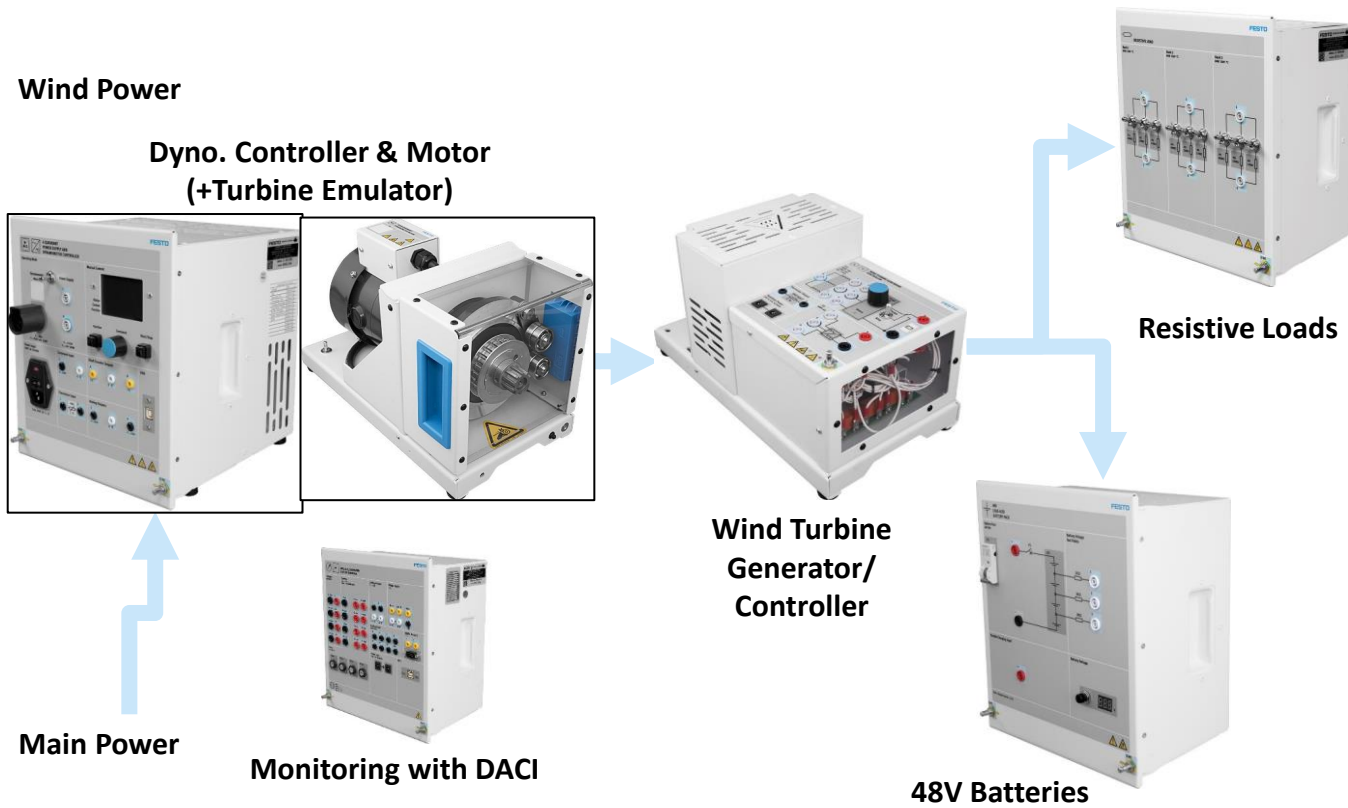


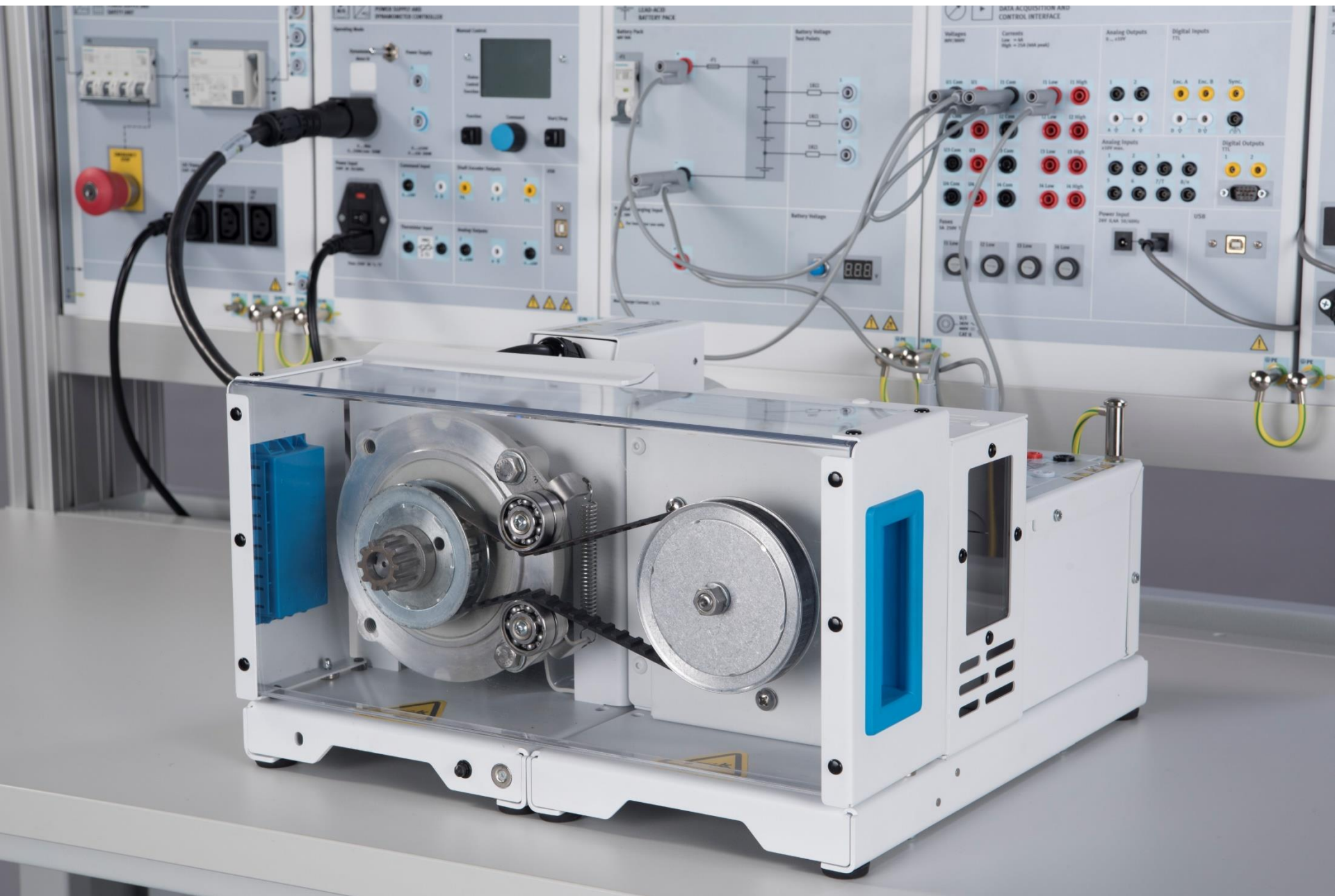
1x Wind Turbine Generator / Controller	595061
1x DC 48V Lamps	595055
1x AC 230V Lamps	595056
1x 48V Lead-Acid Battery Pack	595059
1x AC 24V Power Supply	772050
1x 1AC 230V Stand-Alone Inverter	595052
1x 4-Quadrant Power Supply and Dynamometer Controller (including Manual and Computer-Based Control)	595028
1x 4 Quadrant Dynamometer Motor	595062
1x Firmware Function (4Q Dynamometer/Power Supply): Turbine Emulator	579783
1x Firmware Function (4Q Dynamometer/Power Supply): Pb-Acid Battery Charger	581438
1x Data Acquisition and Control Interface (including computer-based instrumentation for 2x current inputs and 2x voltage inputs)	595912
1x Timing Belt	793140
1x Guard - Side-by-side	794195
1x Wind Power Systems (Instructor Guide)	593991

Complete Package

Includes all the above in one complete Wind Power learning solutions

Typical setups



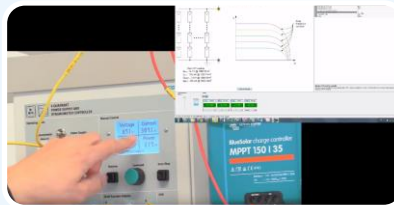


Lab experiments explained

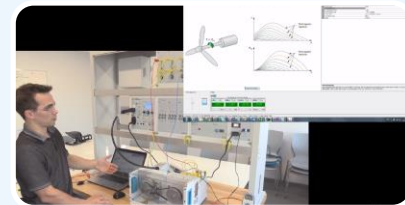
We have recorded 3 videos to explain you how the lab looks like and how the manipulations are performed with these new packages. Click on each to access the YouTube link.



Understand
Solar Panel
Operation



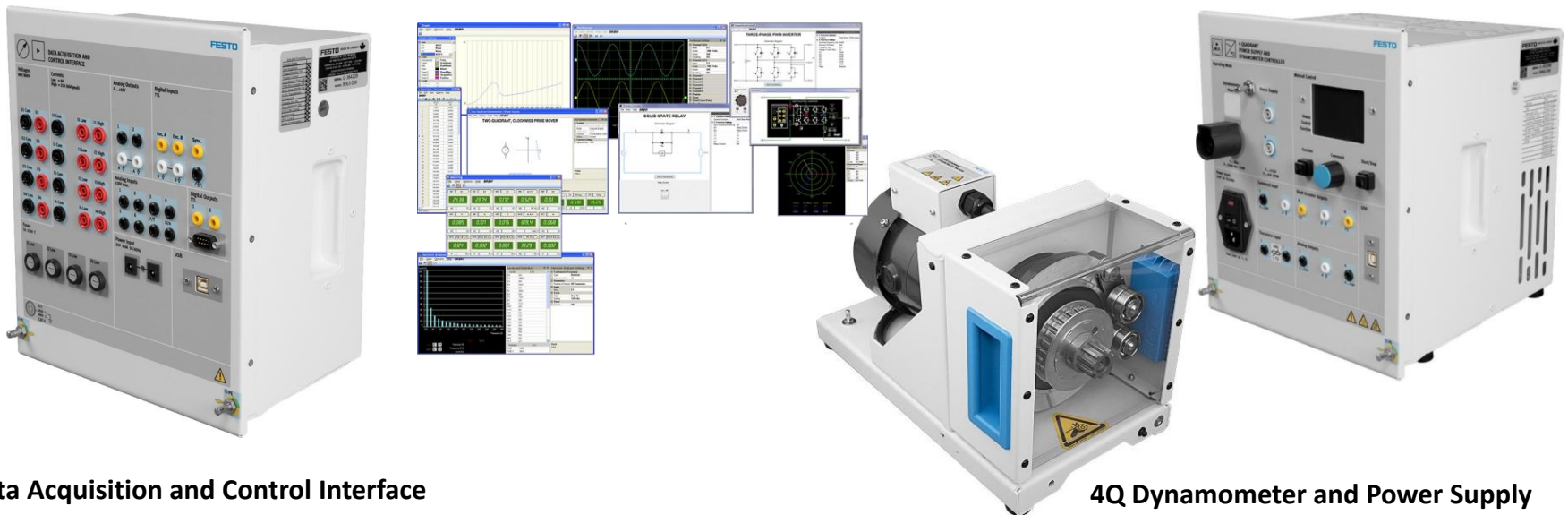
Use of an MPPT
charge
controller in
stand-alone PV
systems



Introduction to
Wind Power

Future expansion of the learning solution

The upcoming EMS courses will also use components that the Solar and Wind Training Packages are using. Specially those two:

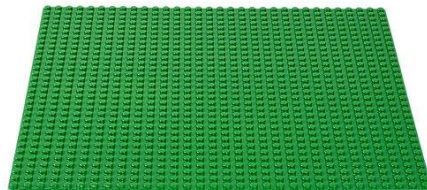


Data Acquisition and Control Interface

4Q Dynamometer and Power Supply

The advanced computerized tools are at the heart and reused through several courses (current pattern of EMS outside EU). The goal is to have learning solutions that can be easily merged or configured specific to the customer needs!

Data Acquisition and Control Interface



All DACI variations are based on the same « base » unit. The electronics is always the same



Computer-Based Instrumentation



Limited Computer-Based Instrumentation



Chopper/Inverter



Generator Control



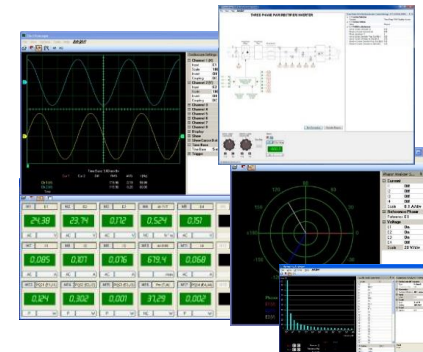
Thyristors



High-Voltage DC Transmission



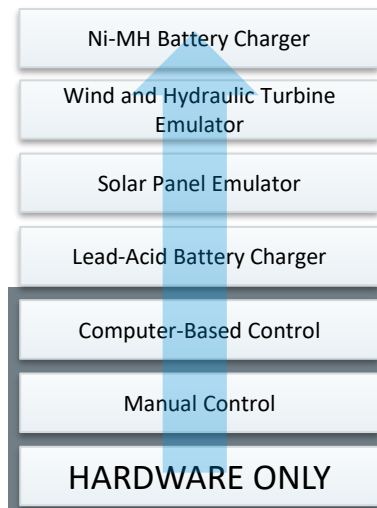
We offer a selection of firmware functions (feature keys) that evolve over time and that can be selected at any time by the customer



The unlocked/purchased firmware functions provides a certain set of functionality to the end user

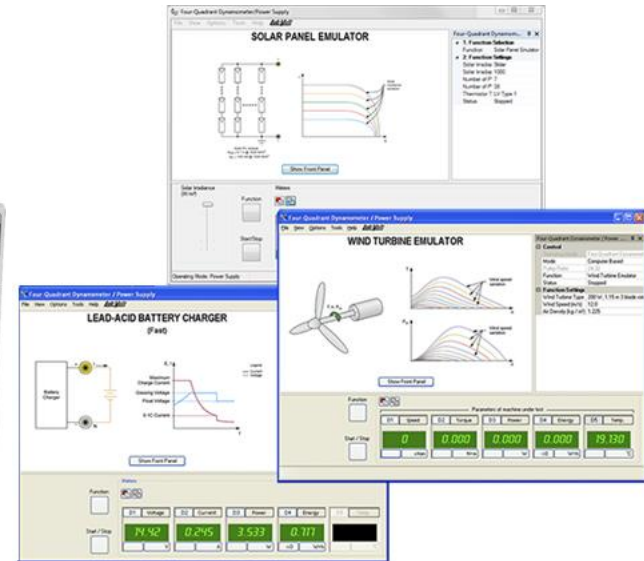
Dynamometer/Power Supply

Same concept as the DACI

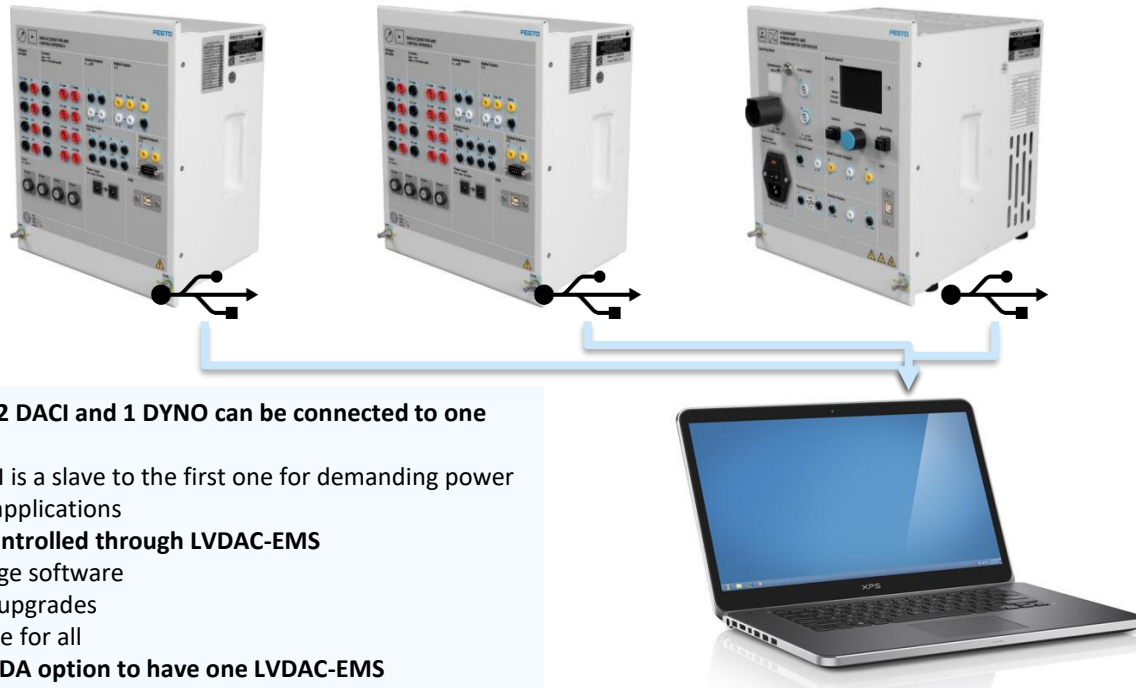


• Most popular package and basis of corresponding courses

• Not sellable



How do they connect to a computer



- **A maximum of 2 DACI and 1 DYNO can be connected to one computer**
 - Second DACI is a slave to the first one for demanding power electronics applications
- **Everything is controlled through LVDAC-EMS**
 - Free of charge software
 - Continuous upgrades
 - One software for all
- **Coming up: SCADA option to have one LVDAC-EMS software/computer controlling other LVDAC-EMS in one classroom via OPC server**

Wind Turbine Training Systems

Nacelle - Wind Turbine Learning System

Electrical Pitch Hub

Hydraulic Pitch Hub



Outline

1. Description the Nacelle
2. Demonstration
3. Product Features and Benefits
4. Complementary Products:
 - Electrical Pitch Hub
 - Hydraulic Pitch Hub



Description of the Nacelle

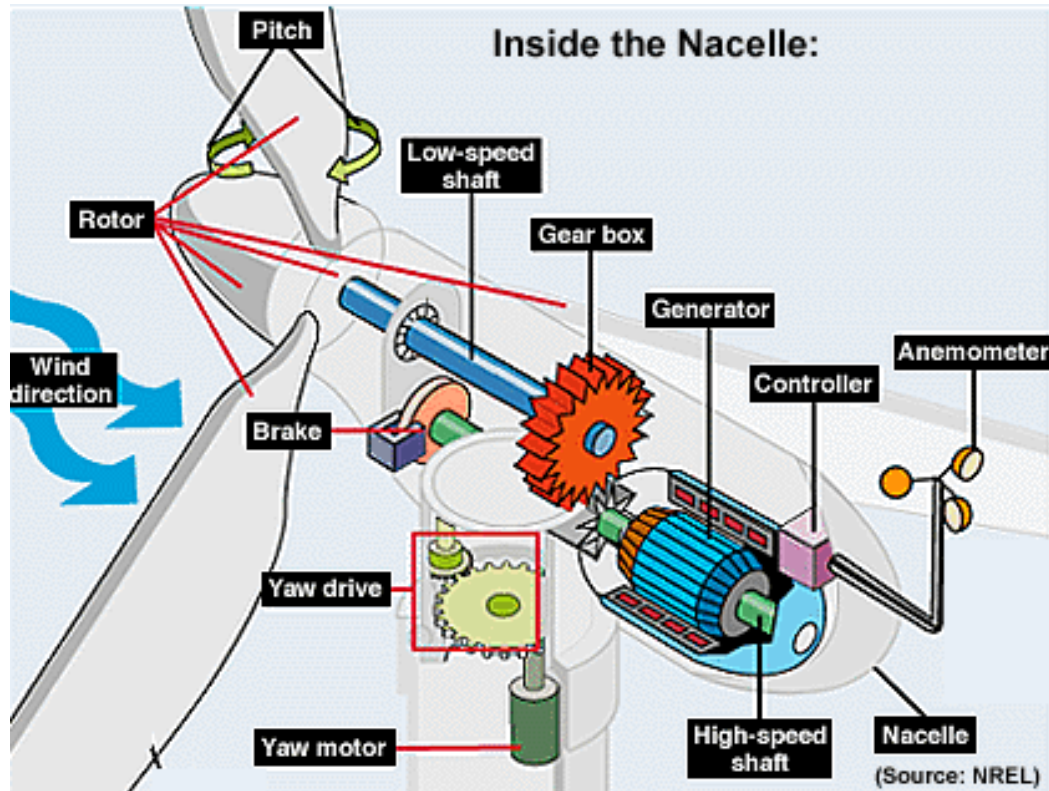
1. Part that sits on top of the wind turbine tower
2. Tracks wind to maximize energy production by:
 - Facing the wind
 - Changing the blade pitch angle
3. Moves to a safe position during adverse weather conditions



Inside a Nacelle



Inside a Nacelle



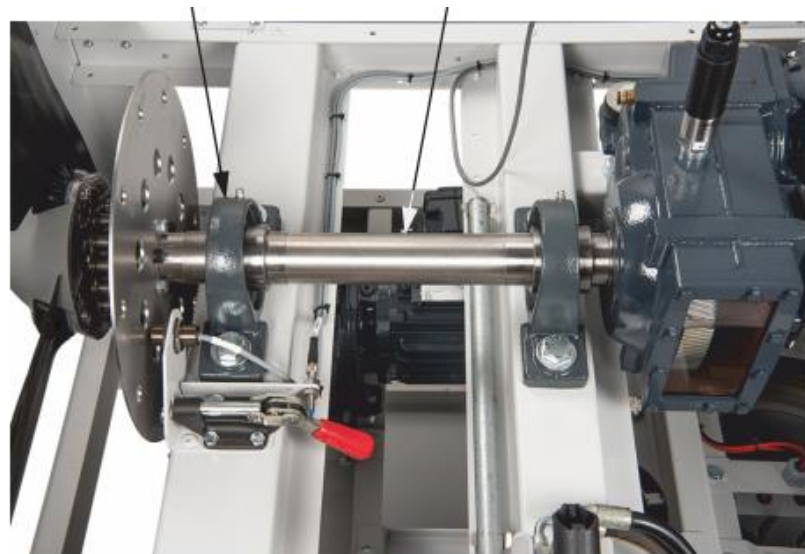
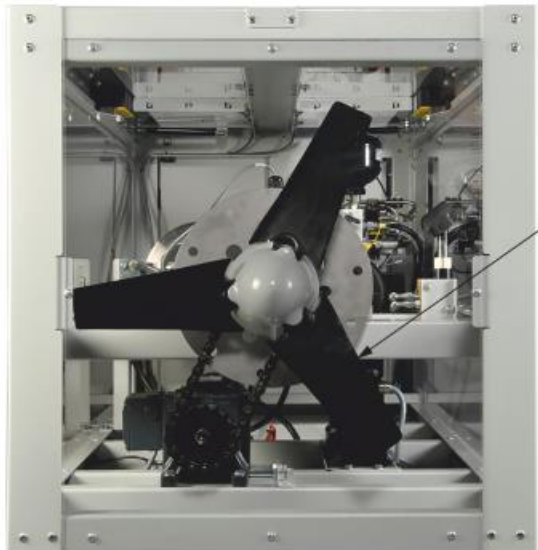
Description of the Nacelle,

1. A complete scaled-down version of commercial wind turbine nacelle
2. Train technicians without having access to a real nacelle which would be too big and \$
3. System simulates changing conditions:
 - Wind speed and direction
 - Faults: overheating, mechanical failures
4. Let's follow the transmission of power from wind to electrical to get a better understanding of the mechanical, electrical and software components



Description of the Nacelle: Rotor Hub and Low Speed Shaft

1. Chain driven rotor hub with inductive speed sensor and locking mechanism
2. Wind speed conditions imposed by controller but measured with sensor, real measurements
3. Rotor low speed shaft on pillow blocks, then enters wind turbine gear box



Description of the Nacelle: Gearbox and High Speed Shaft

1. Real wind turbine gearbox
2. Speed reduction to fit with electrical network frequency
3. Several manipulations: oil change, torque adjustment of shrink disc, inspection, alignment with generator
4. Temperature and vibration monitoring
5. Speed measurement at gearbox output with inductive sensor
6. Transparent cover to inspect gears and oil



Description of the Nacelle: Parking Disc Brake

1. To prevent the rotor from turning when conditions to generate are not met.
2. Spring keeps the brake applied. Hydraulic pressure required to release.
3. Trainees will have to inspect the disc, calipers and oil.



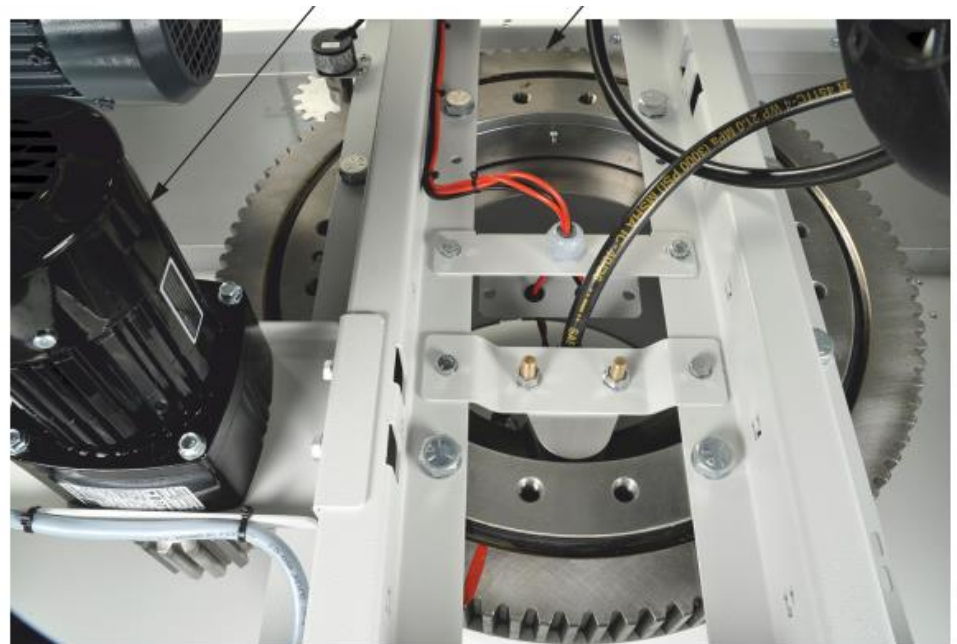
Description of the Nacelle: Generator

1. 250 W induction generator
2. Temperature and vibration monitoring
3. Power generation measurements are simulated and shown on the HMI



Description of the Nacelle: Yaw

1. To align the nacelle with wind, only the bottom part turns
2. Equipped with a real slewing ring
3. Driven by a gear motor
4. A cable twist sensor (limit switch) is installed
5. Position Indicator and encoder
6. Locked in position using a hydraulic brake



Description of the Nacelle: Hydraulic Unit

1. Custom manifold to supply oil to parking and yaw brakes
2. Each valve of the manifold can be controlled manually or from the HMI
3. Hand pump for power failure
4. Mobile pressure gauges
5. Trainees will have to change the oil and oil filter



Description of the Nacelle: Weather Sensors

1. Wind vane for measuring wind direction
2. Anemometer for wind speed
3. Driven from electrical panel, but real signal used in control algorithms
4. FAA lighting



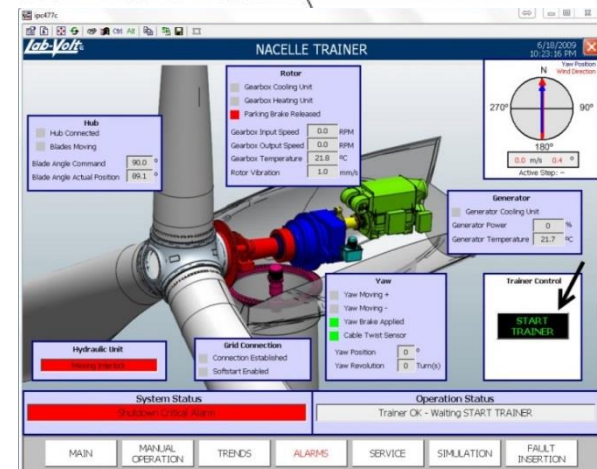
Description of the Nacelle: Electrical Panel

1. Connection point for all simulated and measured signals
2. Inputs for thermocouples, accelerometer, shaft speed, cable twists and pressure sensors. Wind direction and speed sensors are also found in this panel.
3. Outputs for rotor, yaw movements and pump of hydraulic unit through 3 VFD or variable speed drives
4. Location for all power supplies, contactors and breakers



Description of the Nacelle: Monitoring and Control

1. SIEMENS touch-screen interface to configure simulation parameters and monitor energy production, alarms and sensor outputs, SCADA
2. Instructor can use it to insert password-protected timed faults
3. Uses well-known industrial communication protocols such as PROFINET and PROFIBUS for drives and field devices



Description of the Nacelle: Safety Features

1. High-pressures and rotating parts requires protective equipment
2. Transparent protective guards fitted with magnetic contact switches, de-energize the trainer when a panel is open
3. Two emergency push-buttons are available and will stop all drives and apply the brakes on the rotor and yaw
4. Lockout/tagout procedure for the main switch when working on the station



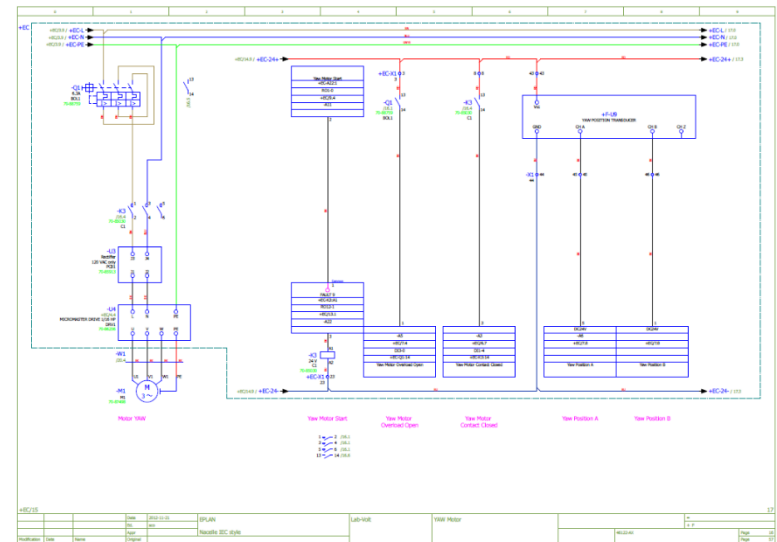
Description of the Nacelle: Student and Instructor Manuals, Electrical Drawings

1. Manual divided into 6 units with focus on hands-on :

- Introduction to Wind Turbines
- From Wind to Electrical Power
- Hydraulic Braking System
- Wind Turbine Operation
- Electrical System
- Maintenance and Troubleshooting

2. Theoretical knowledge to perform exercises at the beginning of each exercise , no outside reference textbook is required

3. Detailed electrical schematics (IEC standards) have same layout as schematics found in the wind turbine industry.



Nacelle: Product Features and Benefits

1. Most important components of a real nacelle are installed and can be used
2. Rugged equipment, steel frame, and even some actual small wind turbine parts: gearbox, slewing bearing
3. Lots of hands-on interactions with the unit in the exercises, not only a demonstrator
4. Safe learning environment with lockout/tagout, emergency stop buttons and protective panels
5. Most possible behaviors of a real nacelle have been programmed
6. Use it to teach maintenance, performance, design and troubleshooting
7. Industry-standard electrical and hydraulic schematics provided
8. 9 full lab exercises (2½ hours each) for a total of 25 hours of laboratory time
9. Relevant exercises on:
 - Safety
 - Tool handling
 - Maintenance
 - Wind turbine behavior
 - Using and understanding SCADA

Electrical Pitch Hub

1. To teach electrical control of blade pitch angle
2. Servomotor actuation of the blade movement
3. Over travel limit switches
4. Small HMI connected to a SIEMENS PLC
5. UPS inside to simulate power failure behavior
6. Blade representation inside the slewing ring
7. Faults can be triggered through the HMI
8. Wind turbine emulation similar to the Nacelle
9. Can be connected to the Nacelle for conjoined operation or used alone



Hydraulic Pitch Hub

1. To teach hydraulic control of blade pitch angle
2. Hydraulic actuation of the blade movement
3. Custom-made hydraulic unit
4. Hand pump in case of power failure
5. Small HMI connected to a SIEMENS PLC
6. Blade representation inside the slewing ring
7. Faults can be triggered through the HMI
8. Wind turbine emulation similar to the Nacelle
9. Can be connected to the Nacelle for conjoined operation or used alone



Solar/Wind Training System



Outline

- Overview
 - Design
 - Overview
 - Topics covered
- Options

Design



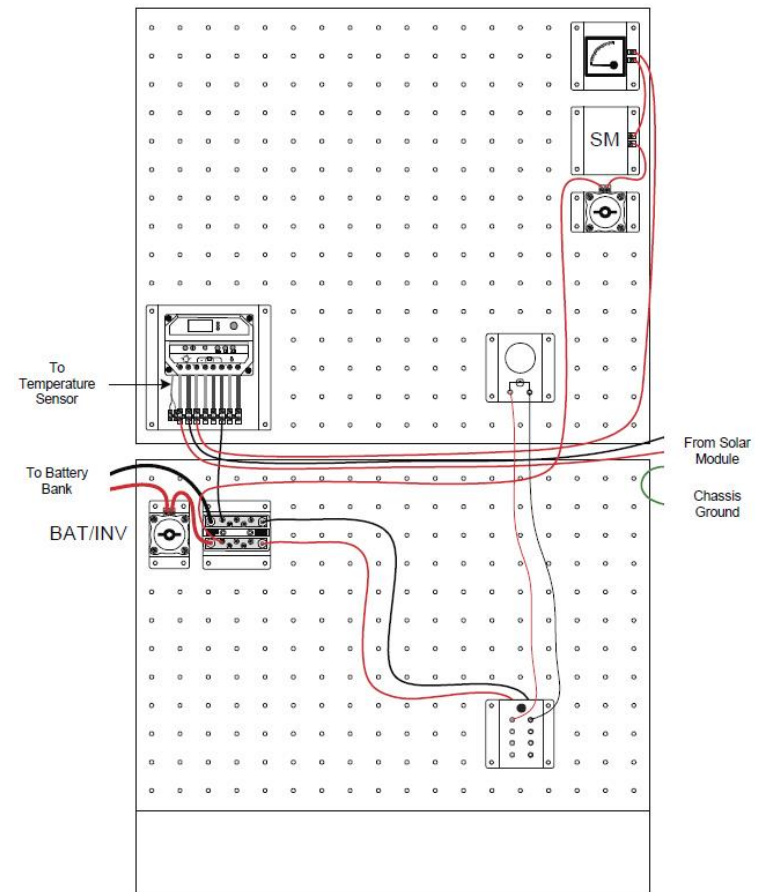
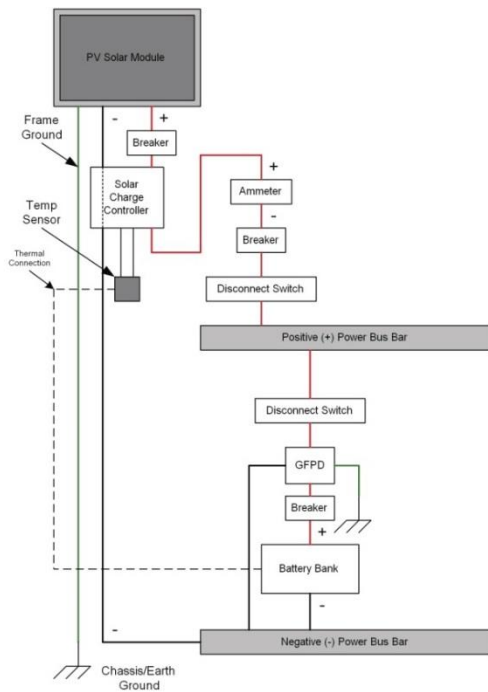
- The Solar/Wind Energy Training System forms a complete hybrid energy training system
- It is a modular program that covers the history, fundamentals, installation, operation, maintenance, and servicing of alternative energy systems
- It is designed for hands-on training

Overview

- Students will learn how to manage all the interdependent components required generate electricity from
 - The sun
 - The wind
 - Both together

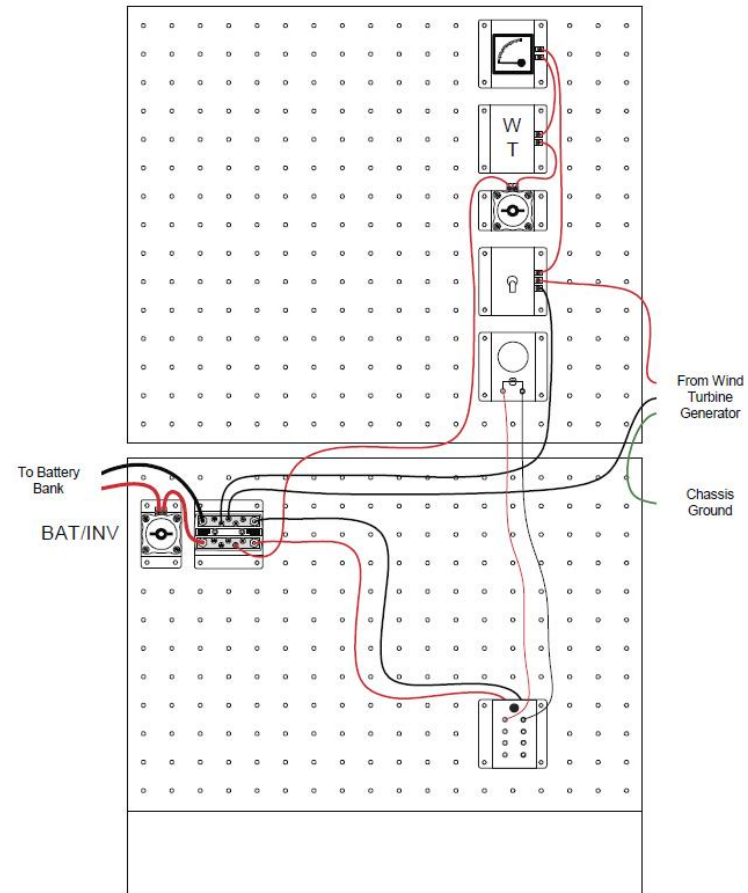
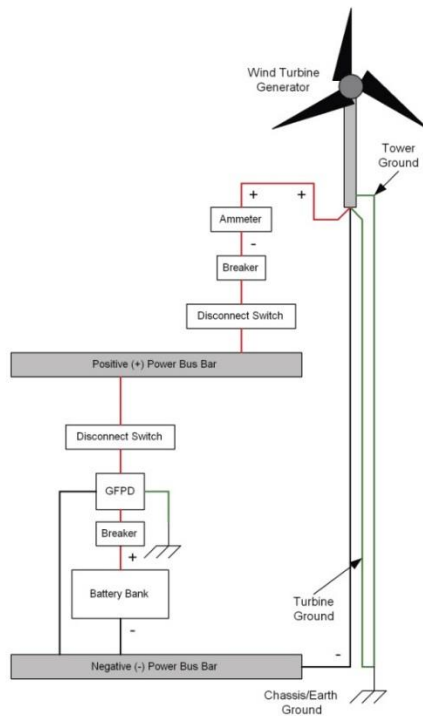
Overview

From the sun



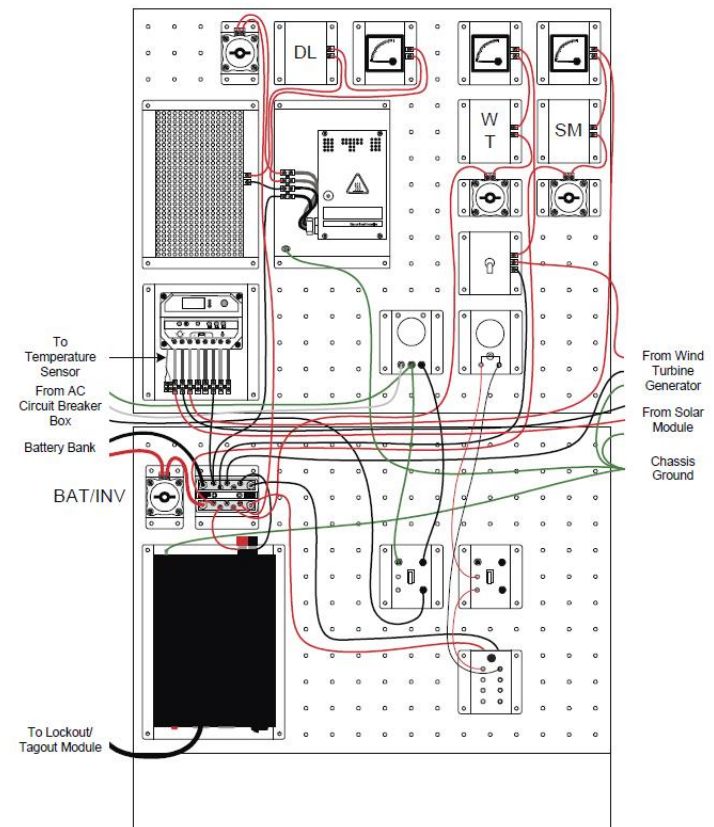
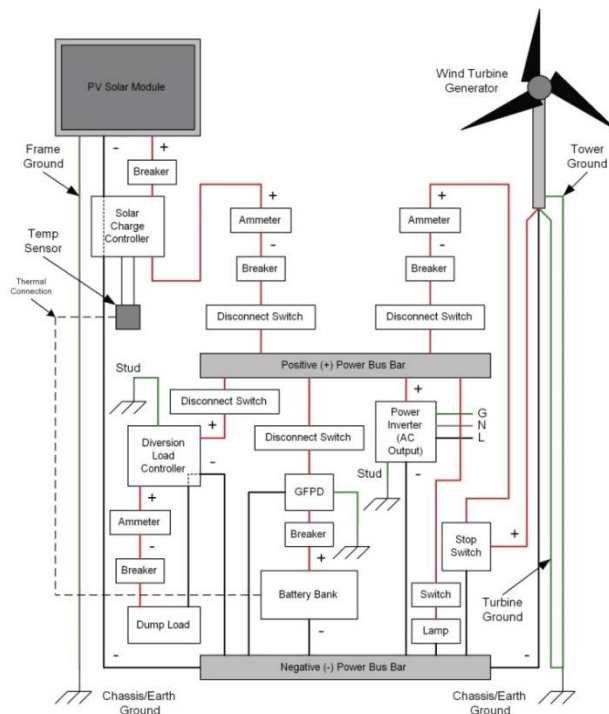
Overview

From the wind



Overview

From the sun and the wind



Topics covered

Energy Fundamentals (86514-20)

- Sources of Energy, Power and Work, Measurements and Units

Trainer Familiarization and Safety (86515-20)

- Trainer Components, Safety Practices, Lockout/Tagout Procedure, Proper Grounding ,Equipment Protection

Solar Module (86516-20)

- Siting, Photovoltaic Module, Charge Controller, Loading, Battery Bank

Topics covered

Wind Turbine (86517-20)

- Siting, Turbine Generator, Stop Switch, Loading, Battery Bank

Solar/Wind Systems (86518-20)

- Diversion Load and Controller, DC-to-AC Inverter, Power Consumption, Power Efficiency, Power Transmission and Distribution, On/Off Grid Operation, Hybrid Generator, Troubleshooting

Going Green (86519-20)

- Solar Energy History, Wind Energy History, Solar/Wind Energy Careers

Options

Networked Data Acquisition

Remote monitoring system that allows power and energy levels from the 46120 to be monitored from a wide area network (WAN) or a local area network (LAN). For monitoring of

- | | |
|--|--|
| <ul style="list-style-type: none"> • AC Load Voltage • AC Load Current • DC Load Current • Wind Turbine Current • Solar Module Voltage • Solar Module Current • Battery Bank / Wind Turbine / DC Load Voltage • Battery Bank Current (negative = charging) • Solar Irradiance • Wind Speed • Total Power Consumed • Total Energy Generated | <ul style="list-style-type: none"> • Total Energy Generated (long term) • Total Energy Consumed (long term) • Energy Cost Savings • CO2 Emissions Avoided • Energy Cost Savings (long term) • CO2 Emissions Avoided (long term) • CO2 Emissions Offset (for driving) • CO2 Emissions Sequestered (by planting) • Server Access Time |
|--|--|



Temperature sensor Add-on

- For measuring solar module or ambient air temperatures; but either the anemometer or pyrometer input must be used instead to provide each thermometer function. Up to two temperature probes may be added.

Options

Additional Solar Panel

Outdoor Wind Option A

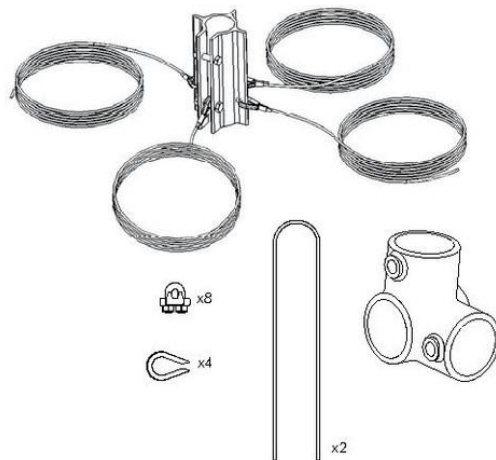
- Wind Turbine kit for outdoor use consisting of the same wind turbine as the 46120-G and an EZ Tower with mast



Options

Outdoor Wind Option B

- Wind Turbine kit for outdoor uses consisting of the same wind turbine as the 46120-G and a Guyed Tower (requires pipe)



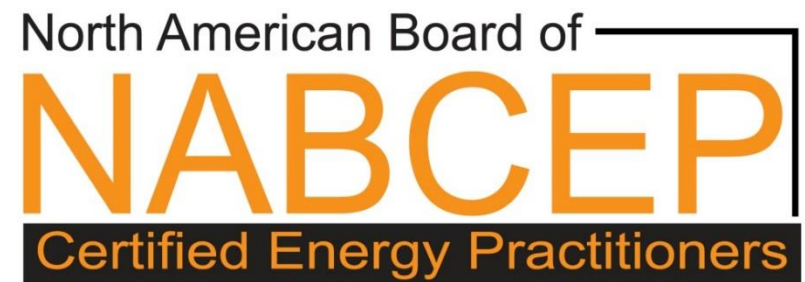
Competitive Advantages

- ETA-certified training for Photovoltaic Installer and Small Wind Turbine Installer



Competitive Advantages

- Festo Solar/Wind Energy Training System covers the majority of objectives of the NABCEP certification with written and hands-on exercises (Entry Level Exam). See dealer access for details.



Competitive Advantage



Identification on wires; allows students to save time

Commercial-grade components

Push-lock fixture allows quick and easy component placement and removal

Many configurations possible

Can be connected with outdoor components (see options)

Components – W&S

Components for both Solar and Wind Energy

- Mobile Workstation*
 - Compact and practical
- Multimeter
- Battery Bank
- Battery Junction Box*
- AC Outlets
- Ammeters
 - To measure current from:
 - SM: Solar Module
 - WT: Wind Turbine
 - DL: Dump Load
- DC Power distribution Panel
- Disconnect switches horizontal and vertical*



Components – W&S

- Diversion load controller*
 - Diverts excess energy to a dump load when battery voltage is too high
- Dump Load
 - Resistive element; excess power from source is dumped to this load.
- DC Circuit Breaker
- AC/DC Wall Switch
- Lockout/Tagout Module
- Power Usage Monitor*
 - Voltage, current, active and apparent power, frequency, power factor, power consumption



Components – W&S

- kWh Meters with AC Circuit Breaker Box*
 - (UL/CSA approved version, 66059-A)
- DC Lamp Socket
- Connection Cables Kit*
 - Identified for speedy connections
- Accessories



Components – W&S

- AC Circuit Breaker Box
- Power Bus Bar
- Power Inverter with Remote Control
 - 12 V DC in
 - 120 V AC out
 - Up to 1000 Watts



Components - Wind

Components for Wind Energy

- DC Motor Controller
- Wind Turbine Generator



Components - Solar

Components for Solar Energy

- Photovoltaic (PV) Module
- Solar Array Junction Box
- Solar Charge Controller
 - Controls and conditions battery charging
- Sun Simulator
 - Easily removable for outdoor use
- Stop switch
 - Ensure that the battery bank output is never shorted



EDS Solar Thermal Energy



Design

- EDS Solar Thermal Energy Training System is a solar hot water heating system. Students will be able to install system components and observe pressures, temperatures, and flow rates.
- Students will set up various realistic operating environments, such as radiant floor heating, passive and active solar water heating, space heating, and hot water heat exchangers.
- It is designed for hands-on training.



Overview

- Only one configuration available.
- Front
 - Students will complete all the piping connections.
- Back
 - One square meter, flat-plate solar collector and 1000 W light.



Left Side

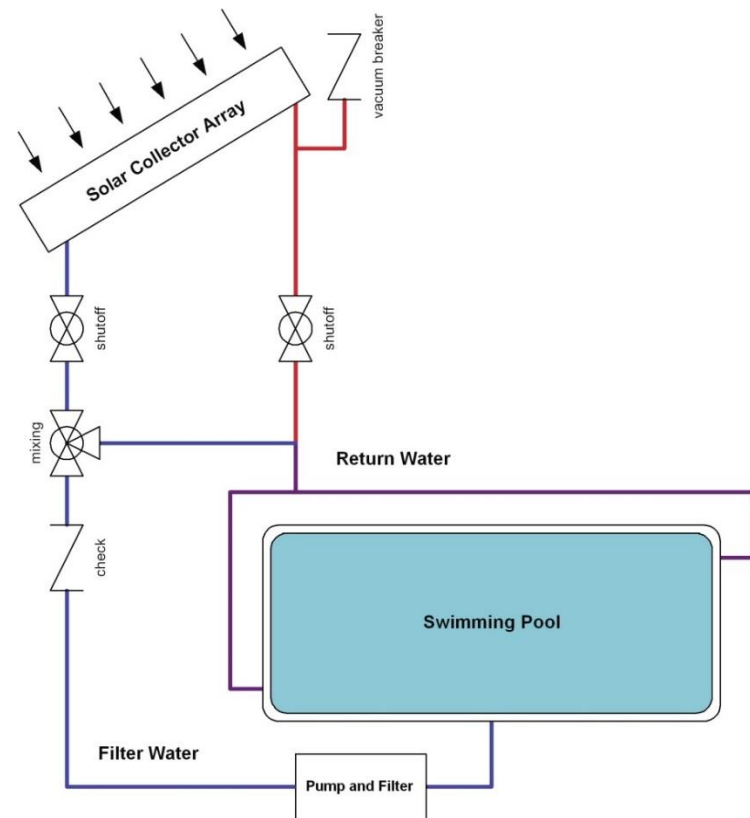
- Storage tank connection
- Pipe storage

Right Side

- All electrical devices securely fixed to a panel on the right side of the trainer.

Overview

Students build various solar thermal systems, from the very basic swimming pool solar heater to a multiple loop system featuring air and floor applications.

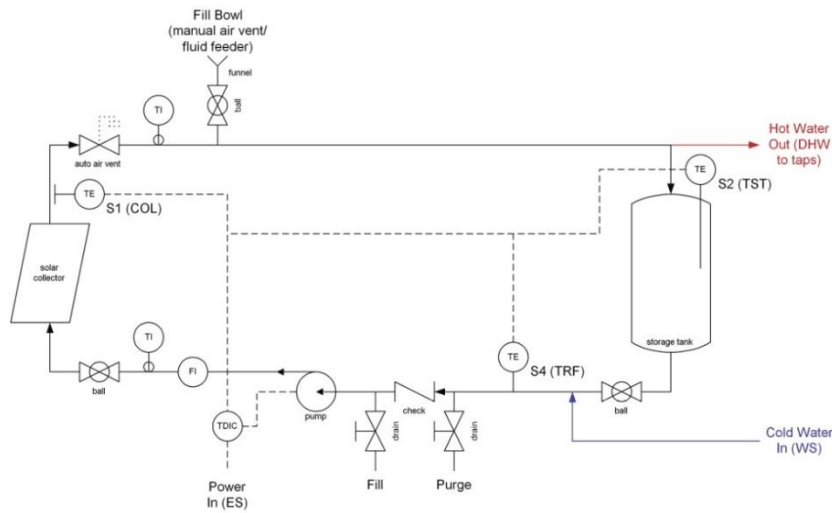


Active, Direct, Open-loop, Draindown, Water-Heating System.

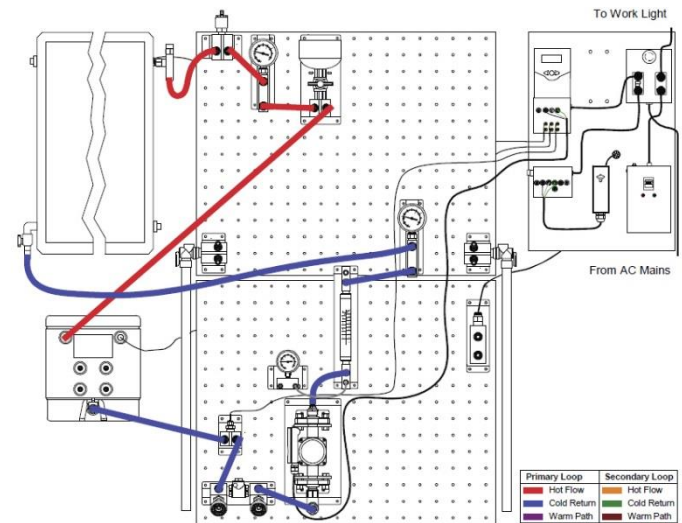
Overview

Example of basic system:

- Open-loop, flooded/recirculation



Open-loop, Flooded/Recirculation System Schematic

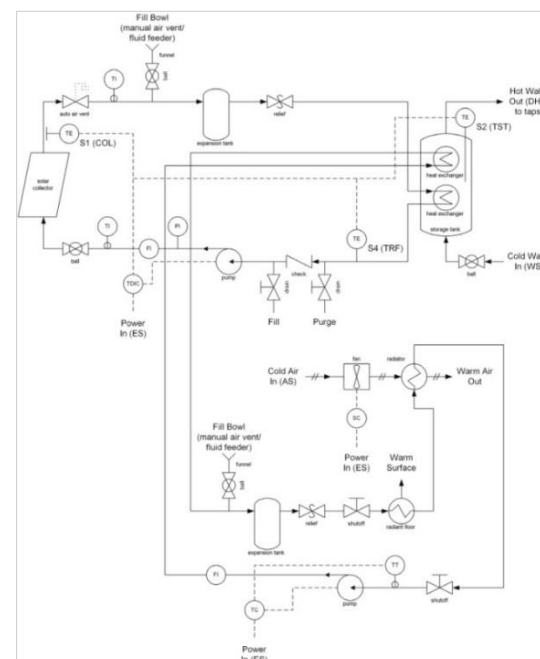
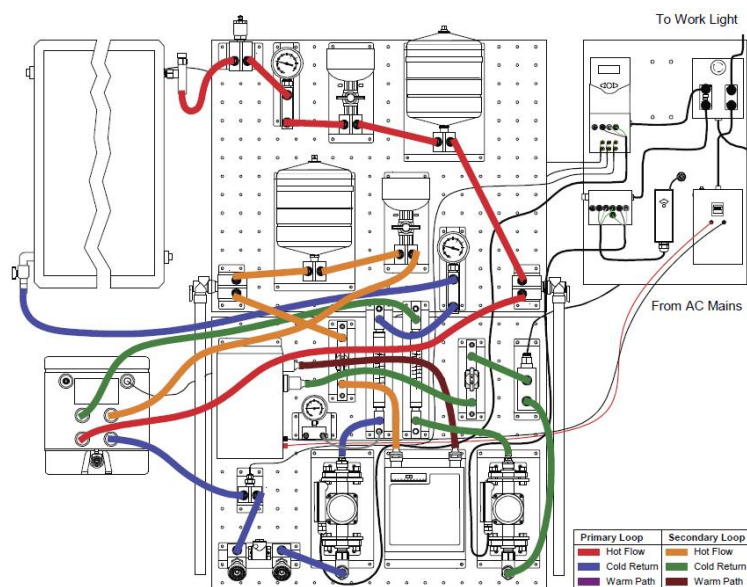


Open-loop, Flooded/Recirculation System Configuration.

Overview

Example of advanced system:

- Closed-loop, Water/Floor/Air-Heating Combination (Storage)



Topics Covered

Introduction

- Thermal Energy Fundamentals
 - Thermal Equilibrium
 - Heat Transfer Modes: Conduction, Convection, And Radiation
 - Potential and Kinetic Energy (E); Work (W)
 - Temperature (T), Pressure (P), And Volume (V)
 - Laminar and Turbulent Flow
 - Thermal Expansion / Contraction
 - Heat $Q = mc\Delta T$
 - Thermal Expansion $\Delta V = \beta \times V_0 \times \Delta T$
- Trainer Familiarization and Safety
- Site Analysis
- System Sizing

Multiple Loops

- Closed-Loop Water Heating
- Closed-Loop Surface Heating
- Closed-Loop Air Heating
- Closed-Loop Drainback
- Closed-Loop Combination Systems

Single Loop

- Solar Heating and Cooling
- Collecting Thermal Energy
- Storing/Exchanging Thermal Energy
- Supplying/Controlling Thermal Energy

Options

Direct Flow Panel (Vacuum Tube Collector)

- Built for the classroom to connect to the EDS Solar Thermo
- Allows comparison with flat type solar collector
- Mechanism for easy drainage



Competitive Advantages

- Quick-connect garden hose connectors
- The combination of a 1000 W lamp and a Solar Collector with an absorption area of 1.00m² makes calculations easier
- Push-lock fixture allows quick and easy component placement and removal
- Commercial-grade components
- Storage tank can be used as reservoir or heat exchanger
- Two types of heat exchangers can be studied
 - Brazed plate
 - Copper coil



Components

Solar Collector

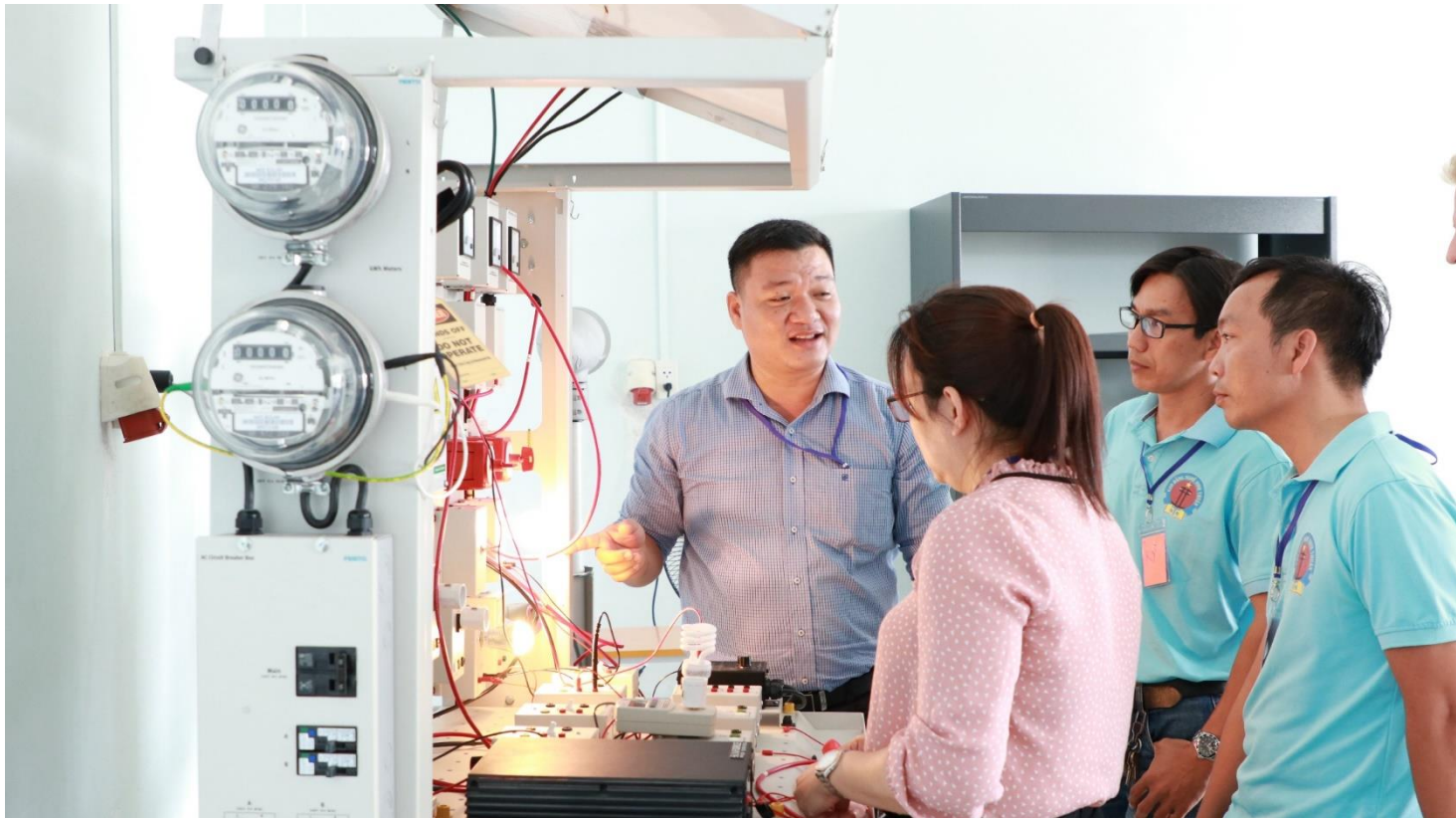
- The aluminum box is thermally-insulated with 50mm thick polyurethane resin insulation
- The absorber has a selective coating rated to 95% absorption
- Glazing is achieved by a 3.2mm thick, low-iron, clear glass panel
- Content volume is 0.75L
- Absorption area of 1.00m², thermal capacity of 3.06kJ



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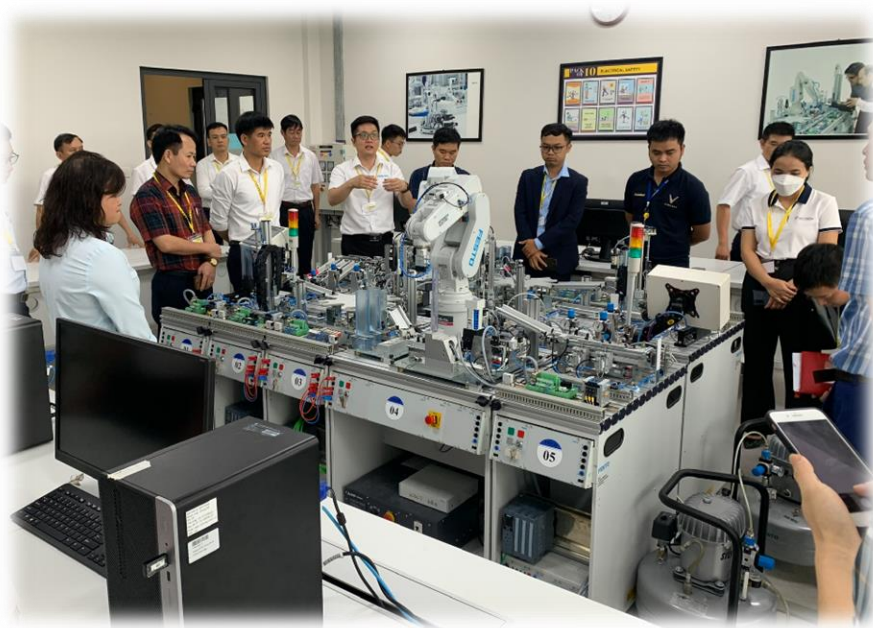
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Any Questions?

