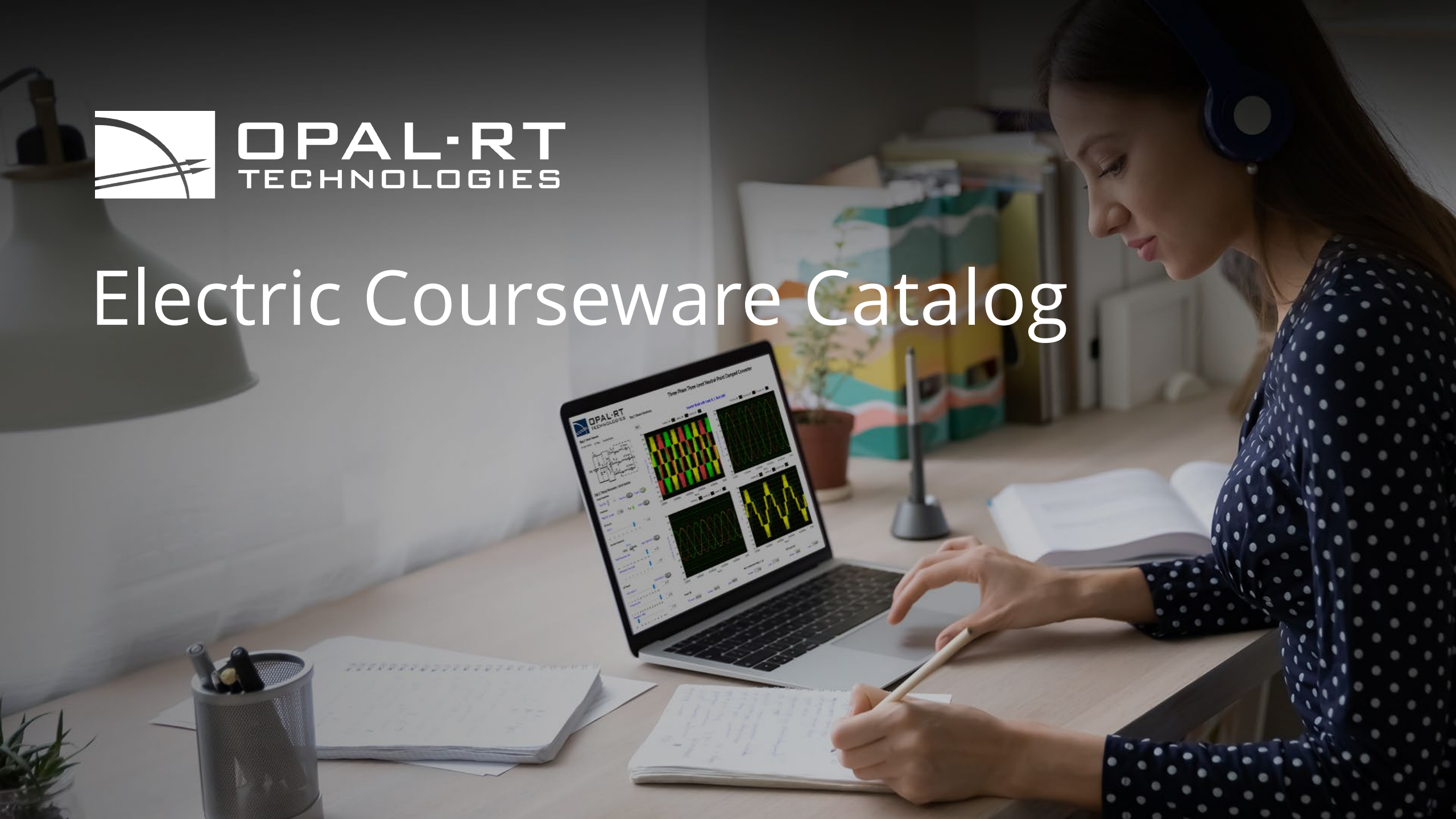
OPAL-RT TECHNOLOGIES

# Electric Courseware Catalog



# COURSEWARE CONTENT

- Power Electronics, since 2014
- Electric Machines, since 2017
- Renewable Energy, since 2021
- Fundamentals of Electrical Engineering, since 2022
- Motor Drives, since 2022

# POWER ELECTRONICS



| Topic | Suggested Lab Sessions |
|---|---|
| Choppers: DC / DC | Boost Chopper |
| | Buck Chopper |
| | Buck-Boost Chopper |
| Rectifiers: AC / DC | Single-phase Diode-based Rectifier |
| | Three-phase Diode-based Rectifier |
| | Three-phase Thyristor-based Rectifier |
| Two-level Inverters: DC / AC | Single-phase IGBT-based Inverter |
| | Three-phase Two-level IGBT-based Inverter |
| Three-level Converter: DC / AC & AC / DC | Three-phase Three-level IGBT-based NPC in Inverter and Rectifier Mode |

# POWER ELECTRONICS

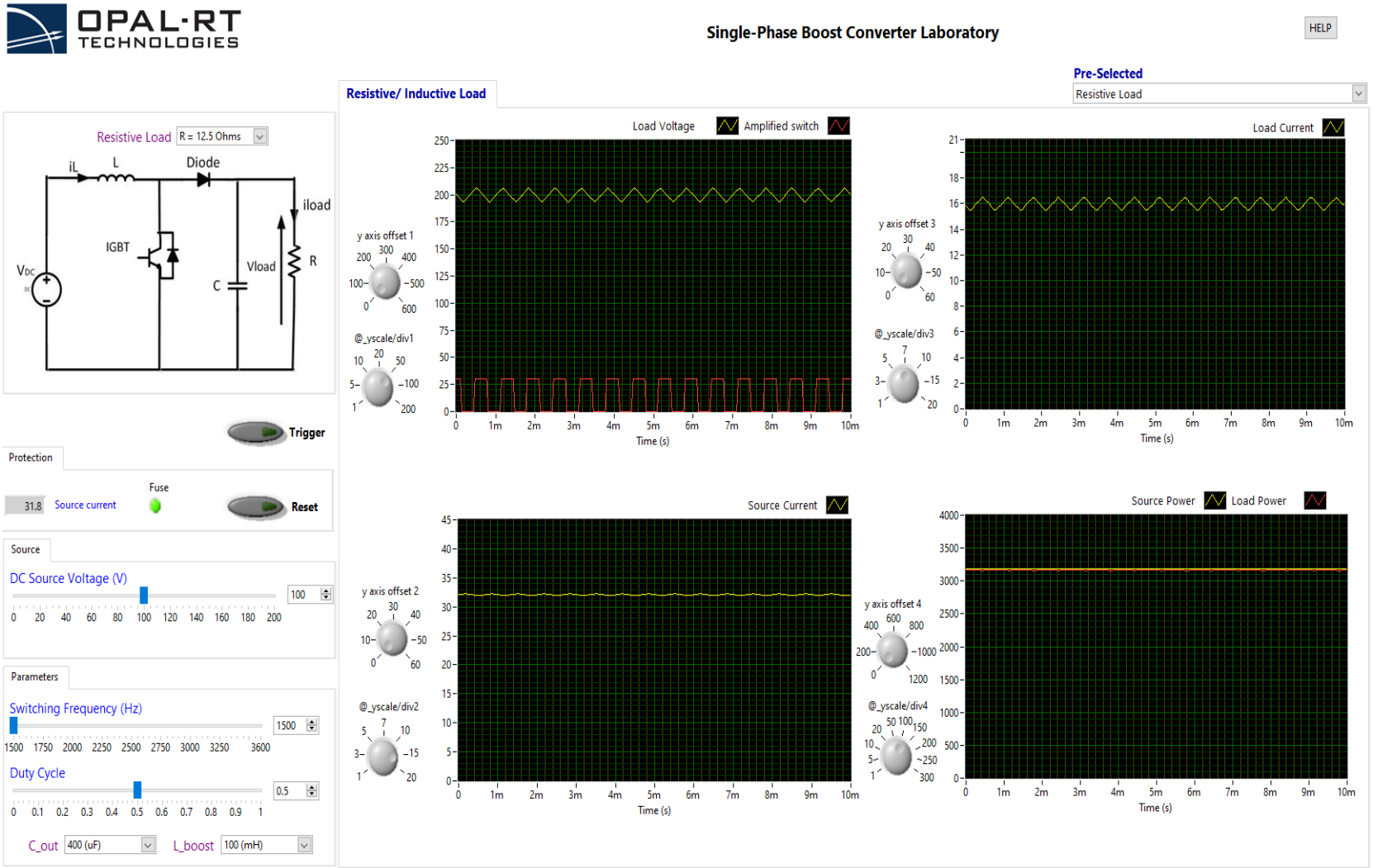
**Power Electronics**
Electric Machines
Renewable Energy
Fundamentals Elec. Eng.
Motor Drives

**Choppers**
Rectifiers
Two-level Inverters
Three-level Converters

OPAL-RT TECHNOLOGIES

## Features

- Scope:
  Trigger, Memory,
  y-scale & y-offset
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Varying DC Source Voltage
- Varying Switching Frequency
- Varying Duty Cycle
- Varying converter passive element:
  capacitor and inductor
- Loads:
  Resistive & Inductive



# POWER ELECTRONICS

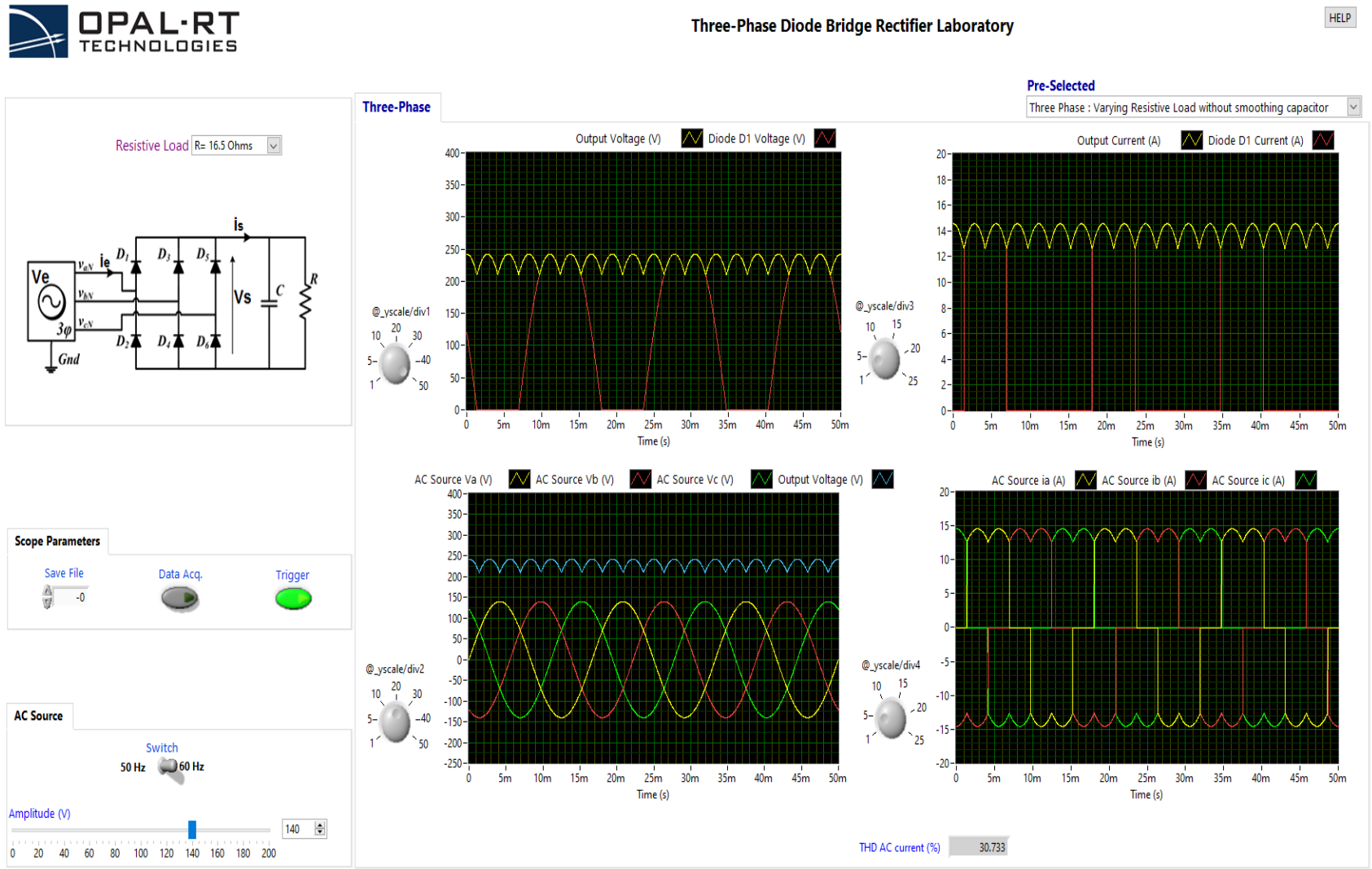
**Power Electronics**
Electric Machines
Renewable Energy
Fundamentals Elec. Eng.
Motor Drives

Choppers
**Rectifiers**
Two-level Inverters
Three-level Converters

OPAL-RT TECHNOLOGIES

## Features

- Scope:
  Trigger, Memory, y-scale & y-offset
- Varying AC Source Voltage
- Selecting AC Source Frequency: 50Hz/60 Hz
- Loads:
  Resistive, Inductive & Capacitive
- Harmonic Analysis:
  Online & Offline



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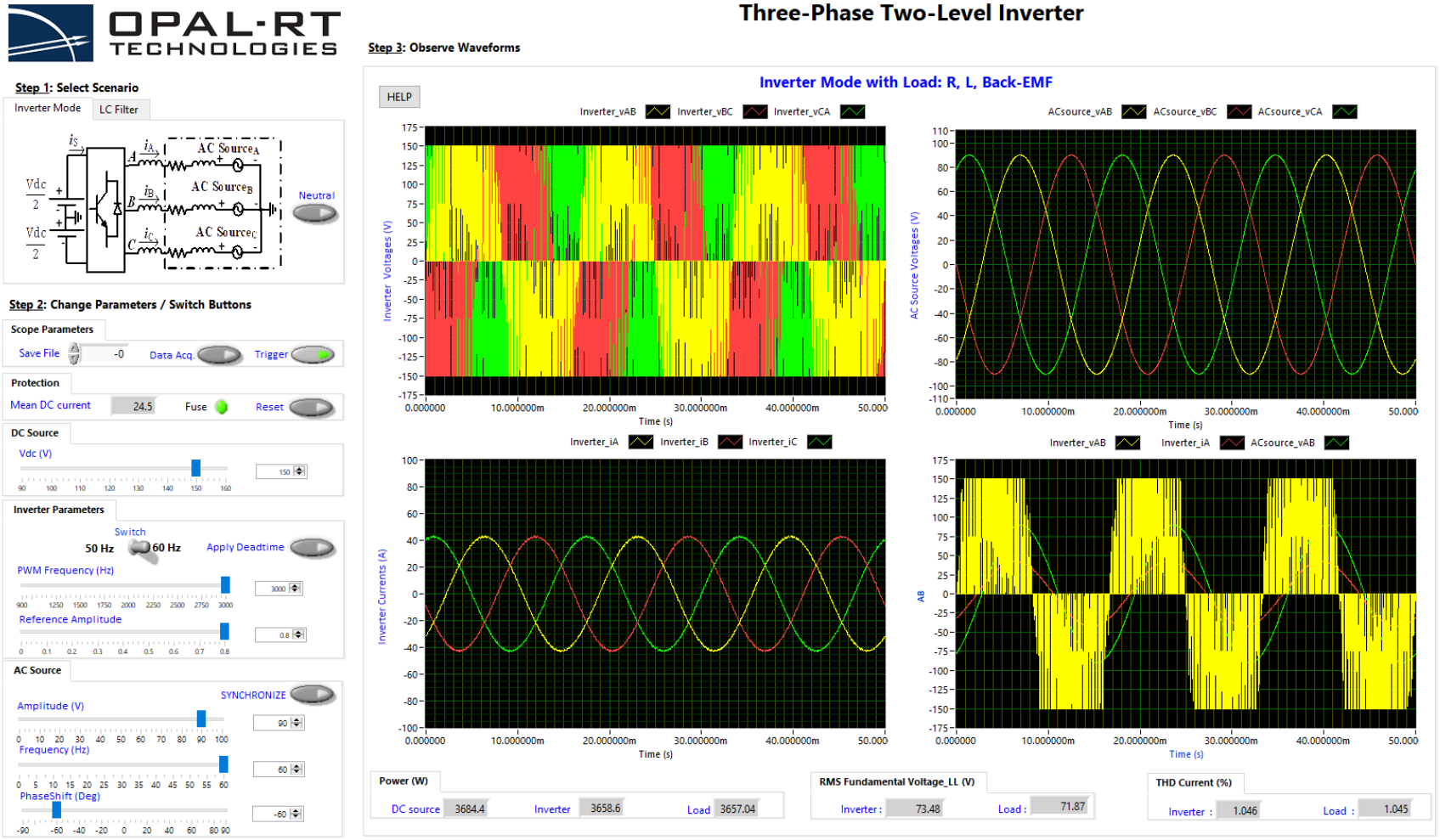
Three-level Converters

## Features

- Scope:
  Trigger, Memory,
  y-scale & y-offset
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Varying DC Source
  Voltage
- Varying PWM Frequency
  & Reference Amplitude
  (Modulation)
- Applying Dead-Time
- Selecting Reference:
  Frequency: 50/60 Hz
- Varying AC Source:
  Amplitude, Frequency
  & Phase-shift
- LC-Filter
- Load Neutral:
  Connect / Disconnect
- Harmonic Analysis:
  Online & Offline
- Power & Fundamental
  Computation:
  Source, Inverter & Load



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## Features

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  Trigger, Memory,
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- Nameplate & Ratings
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  & Reference Amplitude
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  Computation:
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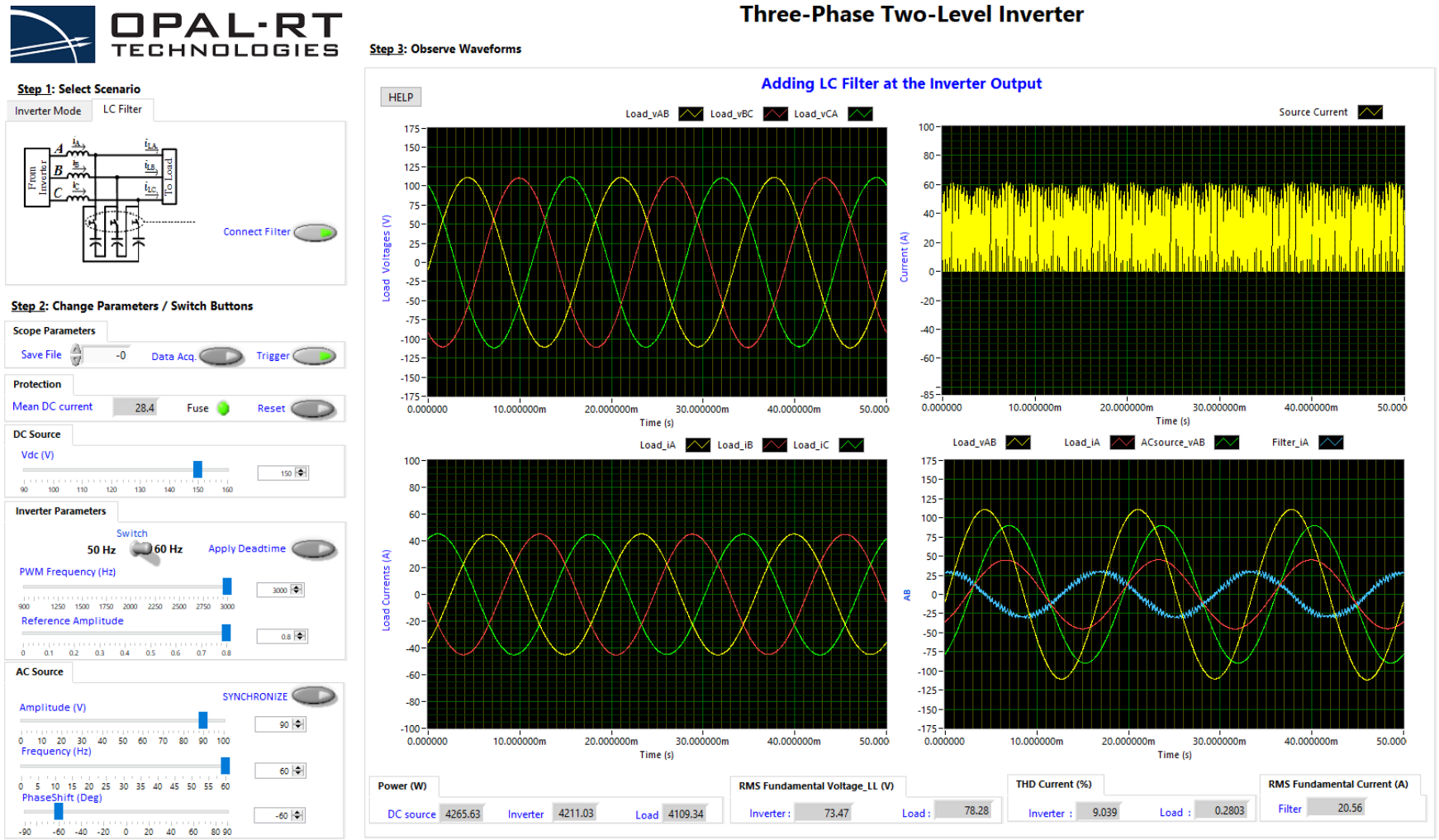
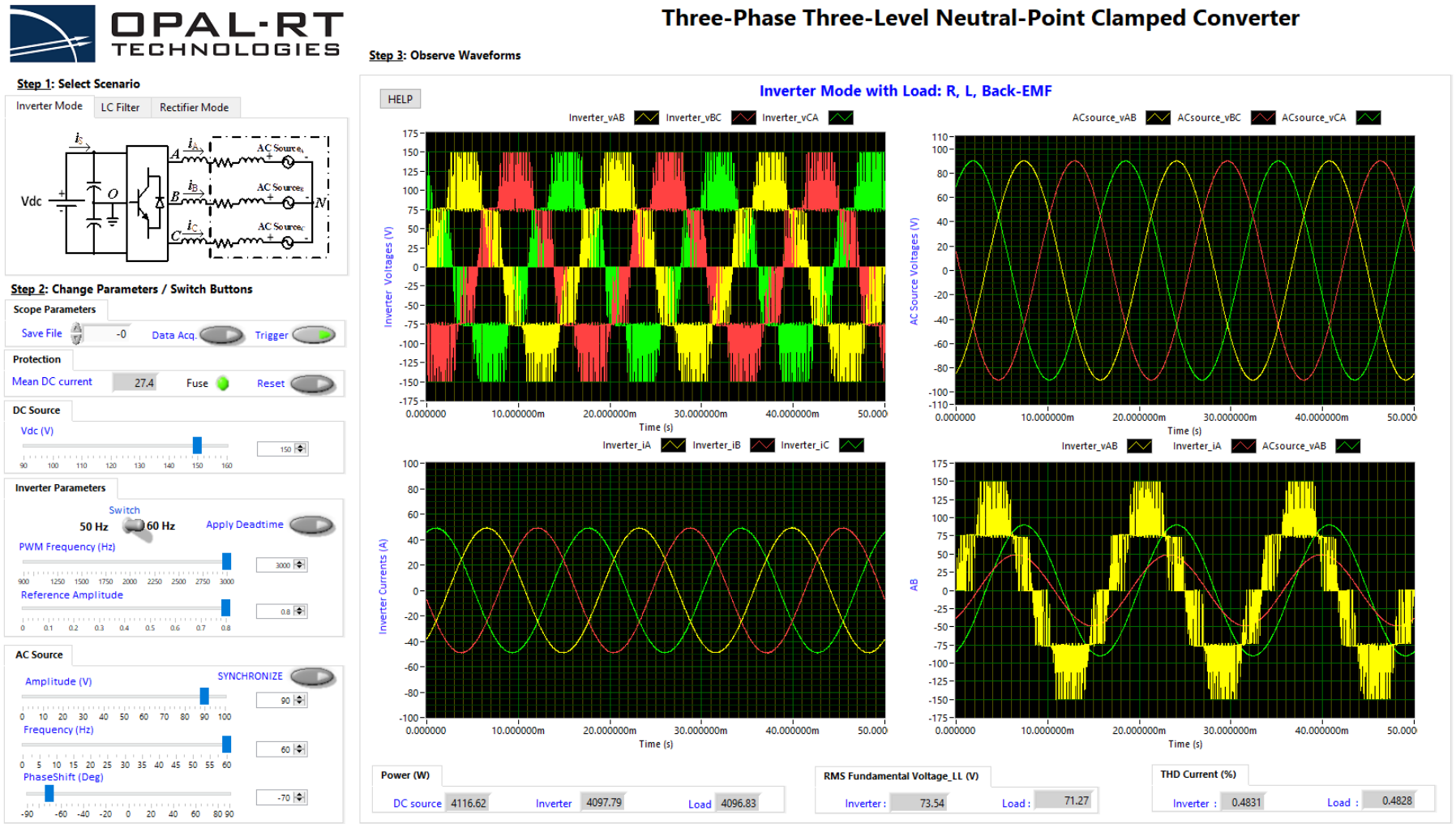


# POWER ELECTRONICS

## Features

- Scope:
  Trigger, Memory,
  y-scale & y-offset
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Varying DC Source
  Voltage
- Varying PWM Frequency
  & Reference Amplitude
  (Modulation)
- Applying Dead-Time
- Selecting Reference:
  Frequency: 50/60 Hz
- Varying AC Source:
  Amplitude, Frequency
  & Phase-shift
- LC-Filter
- Harmonic Analysis:
  Online & Offline
- Power & Fundamental
  Computation:
  Source, Inverter & Load
- Mode: Inverter & Rectifier



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Motor Drives

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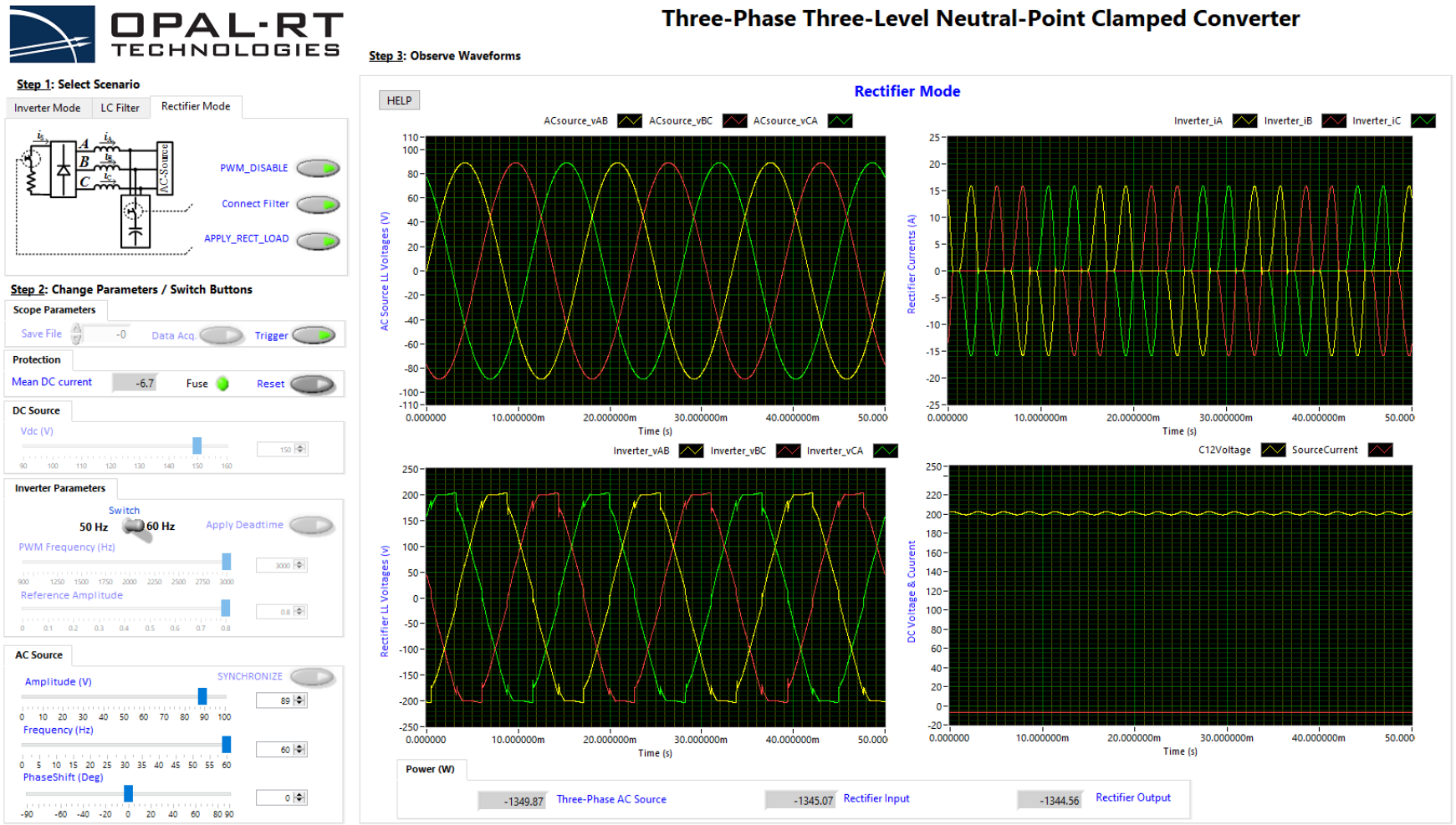
OPAL-RT TECHNOLOGIES

## Features

- Scope:
  Trigger, Memory,
  y-scale & y-offset
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Varying DC Source
  Voltage
- Varying PWM Frequency
  & Reference Amplitude
  (Modulation)
- Applying Dead-Time
- Selecting Reference:
  Frequency: 50/60 Hz
- Varying AC Source:
  Amplitude, Frequency
  & Phase-shift
- LC-Filter
- Harmonic Analysis:
  Online & Offline
- Power & Fundamental
  Computation:
  Source, Inverter & Load
- Mode: Inverter & Rectifier



# ELECTRIC MACHINES



OPAL-RT TECHNOLOGIES

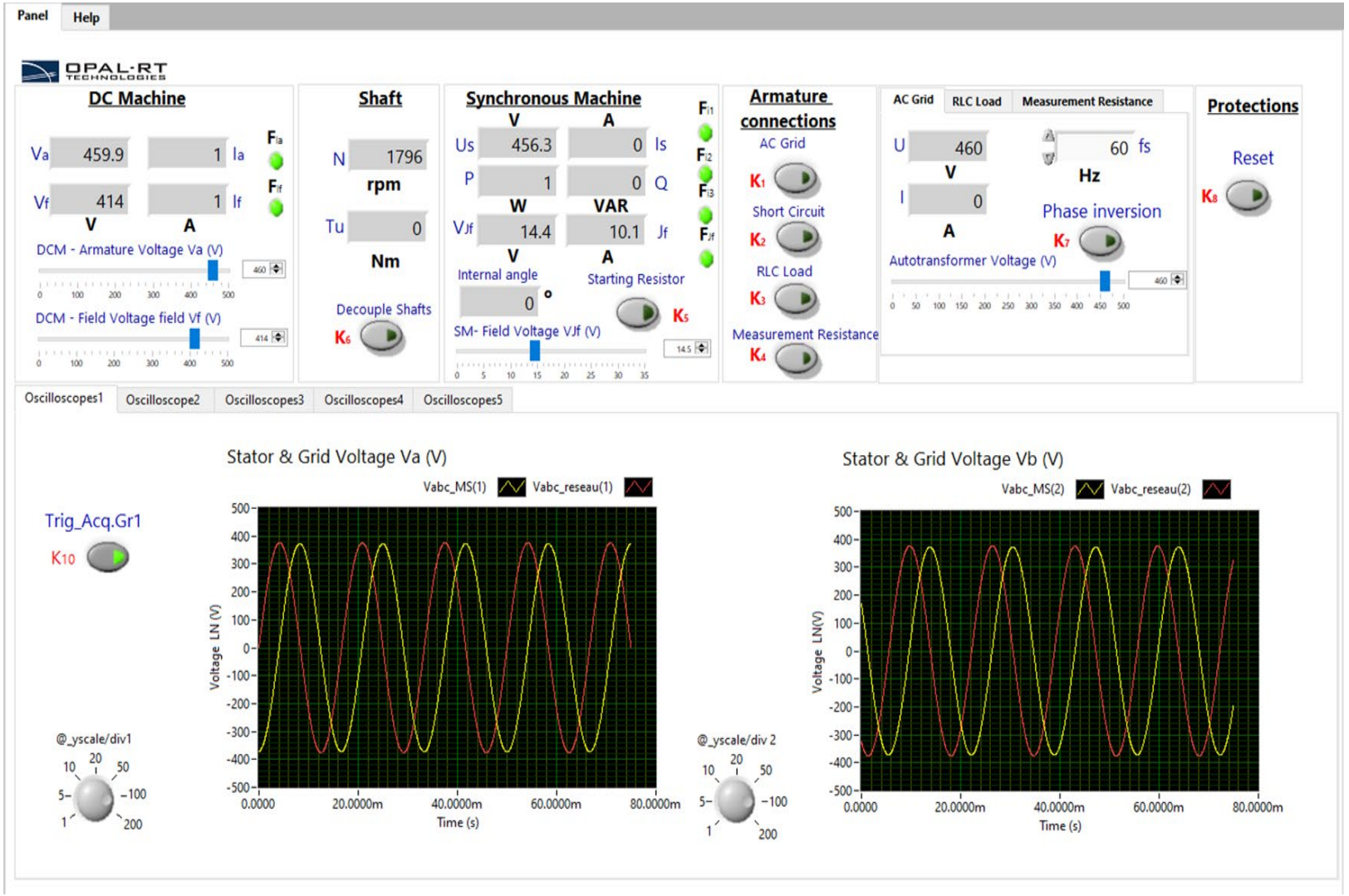
| Topic | Suggested Lab Sessions |
|---|---|
| Synchronous Machine | Parameters Identification |
| | Generator Mode Feeding Passive Load |
| | Generator Mode Connected to Grid |
| | Motor Mode |
| | Faults and Recovery |
| Asynchronous Machine | Transformer and Frequency Converter |
| | Parameters Identification |
| | Speed Control with Variable Voltage |
| | Speed Control with Variable Resistance |
| | Speed Control with Three-phase Inverter |

# ELECTRIC MACHINES



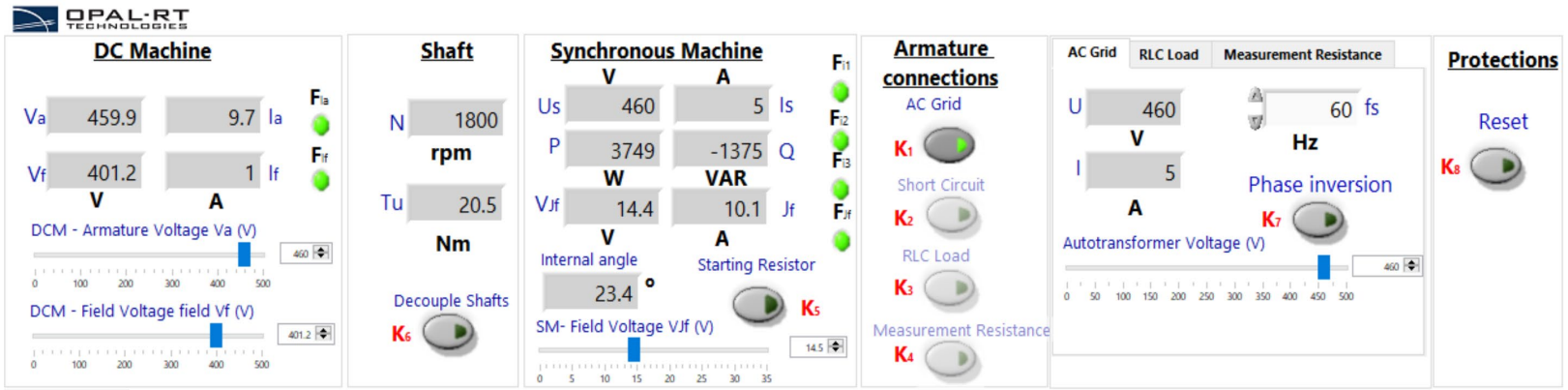
## Features

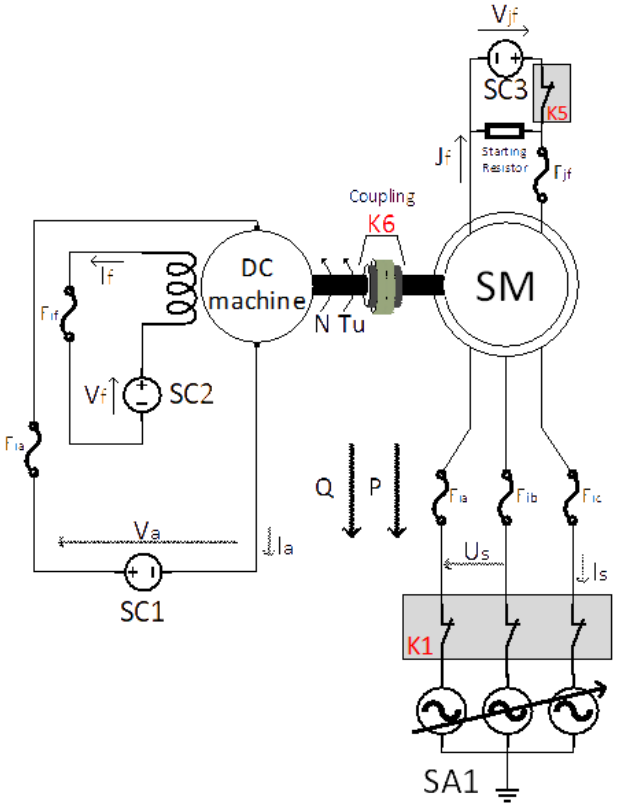
- Scope:
  Trigger, Memory,
  y-scale & y-offset
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Parameters Identification
- Operation Mode:
  Generator & Motor
- Connection to Grid:
  Synchronization & Loss of Synchronism
- V-Curves
- Passive & Active Loads
- Faults Tests:
  Short-circuit Currents & Recovery Voltages
- Selecting Frequency: 50/60 Hz
- Power Computation



# ELECTRIC MACHINES

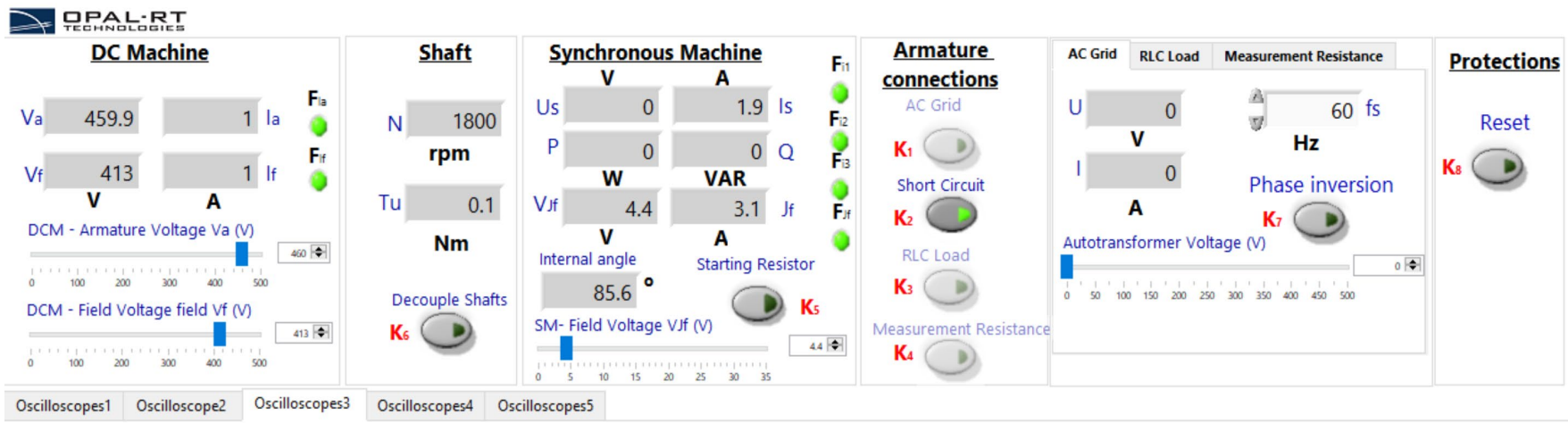
## Connection to Grid: Power Exchange, Internal angle limits, Motor & Generator Mode

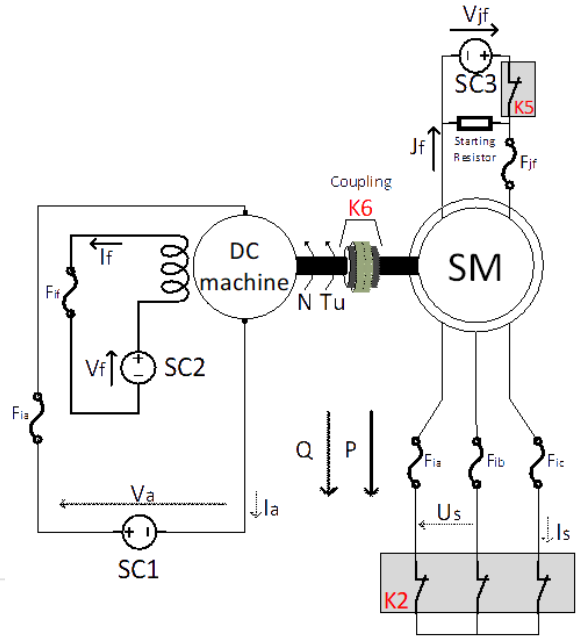


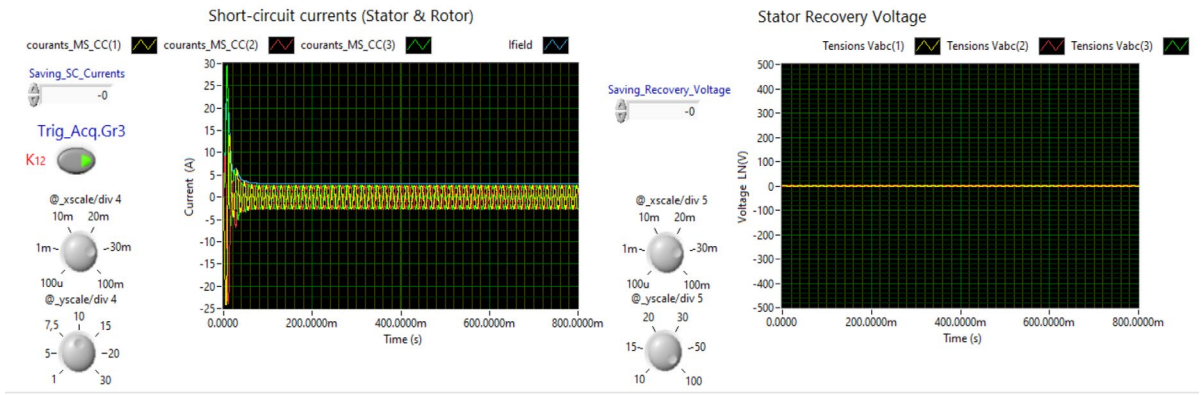



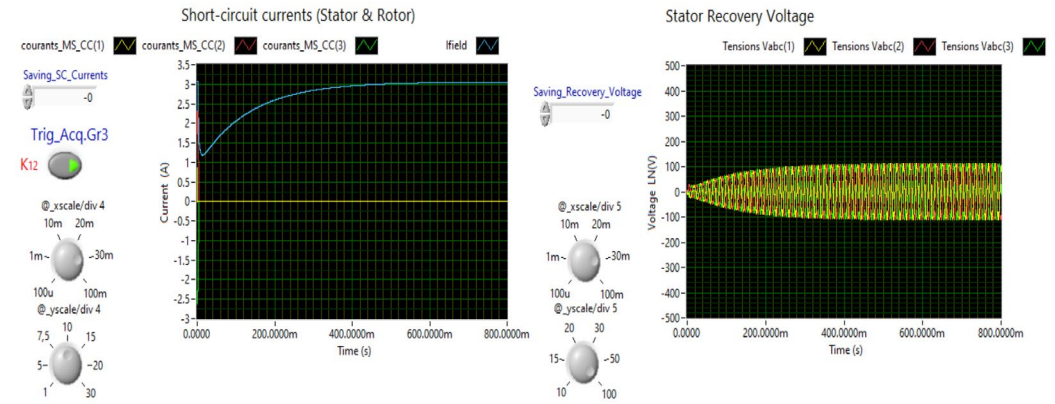
# ELECTRIC MACHINES

## Faults Tests: Short-circuit Currents & Recovery Voltages



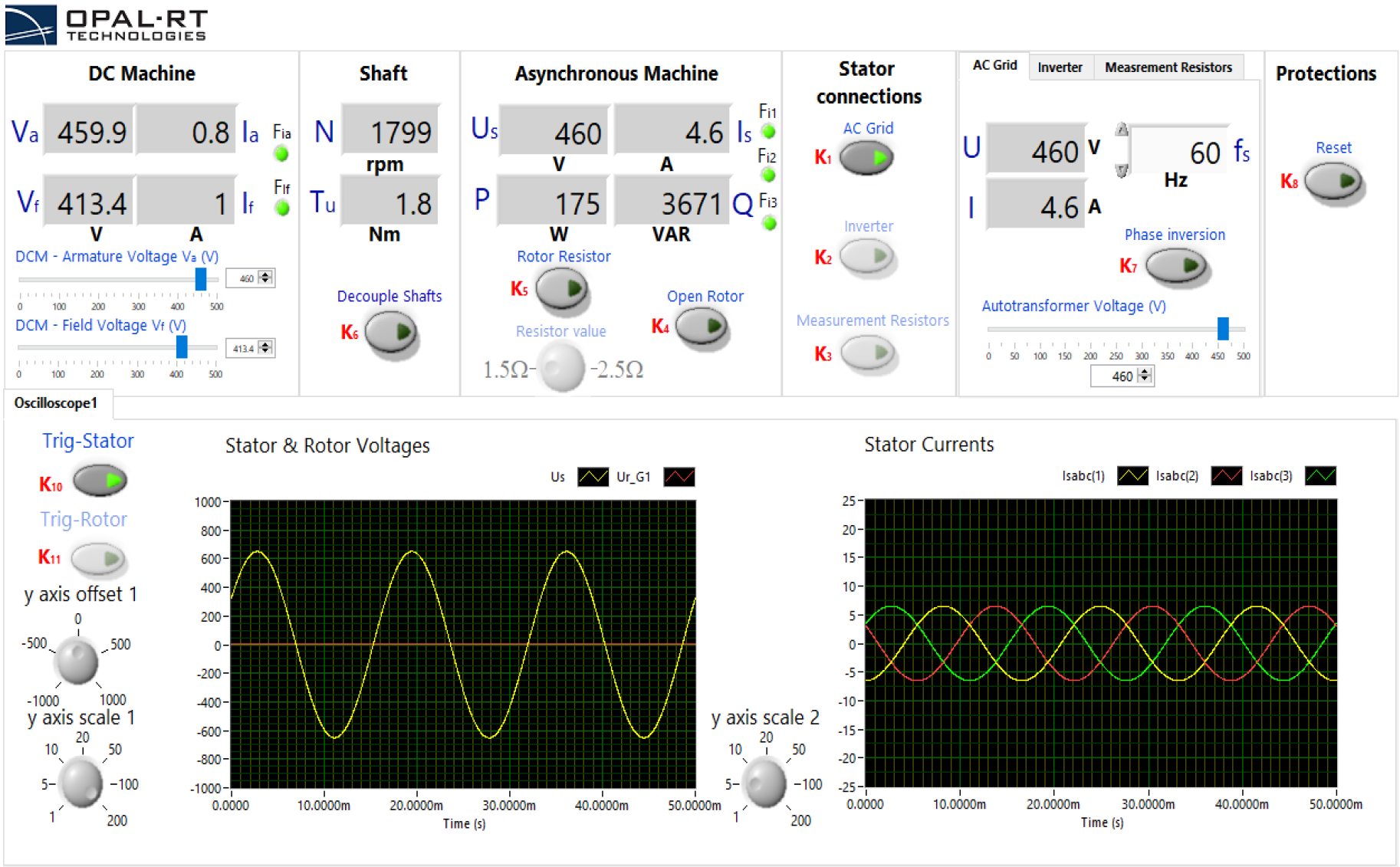



# ELECTRIC MACHINES



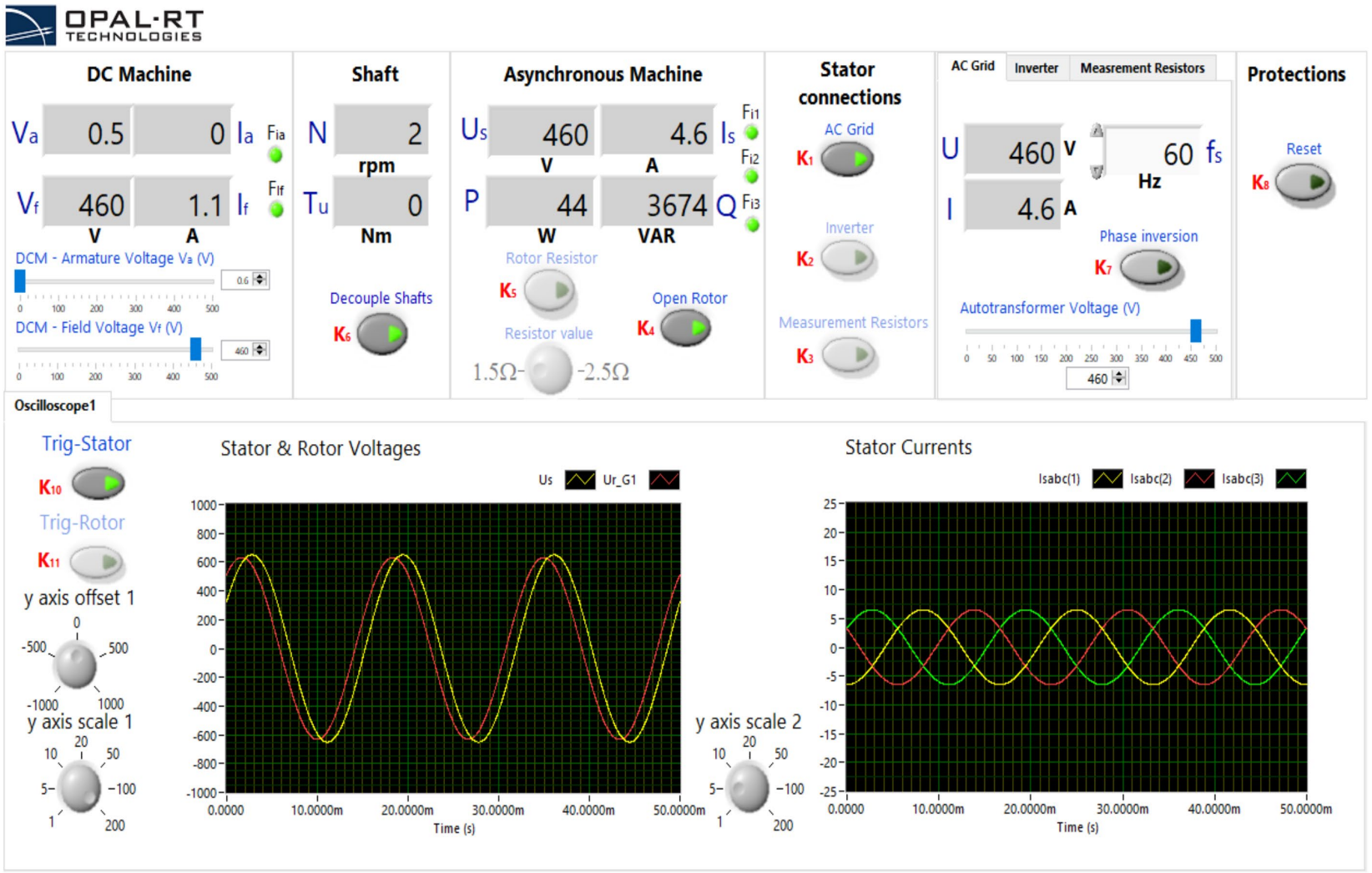
## Features

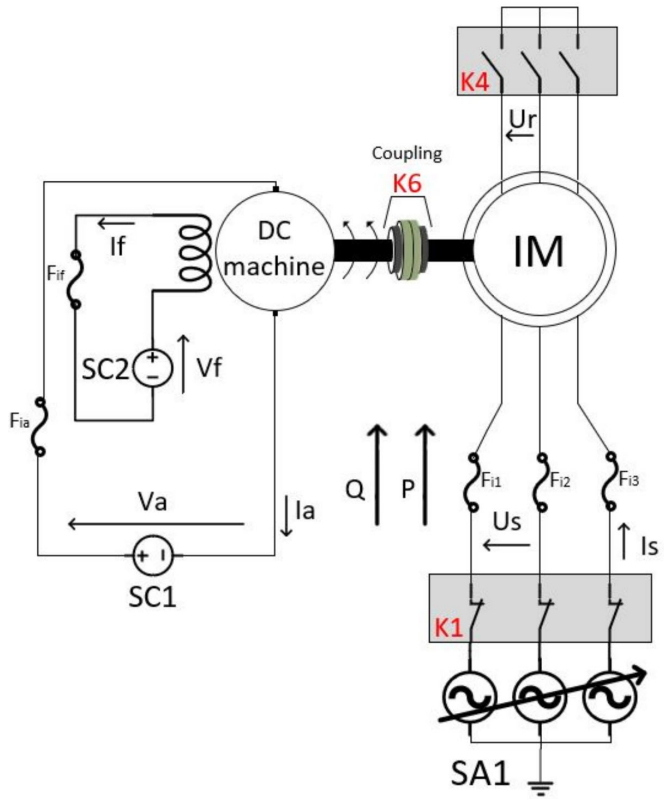
- Scope:
  Trigger, Memory,
  y-scale & y-offset
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Parameters
  Identification
- Transformer &
  Frequency Converter
- Motor Mode
- Speed Control with:
  Variable Resistor,
  Variable Voltage &
  Three-phase Inverter
- Selecting Frequency:
  50/60 Hz
- Power Computation



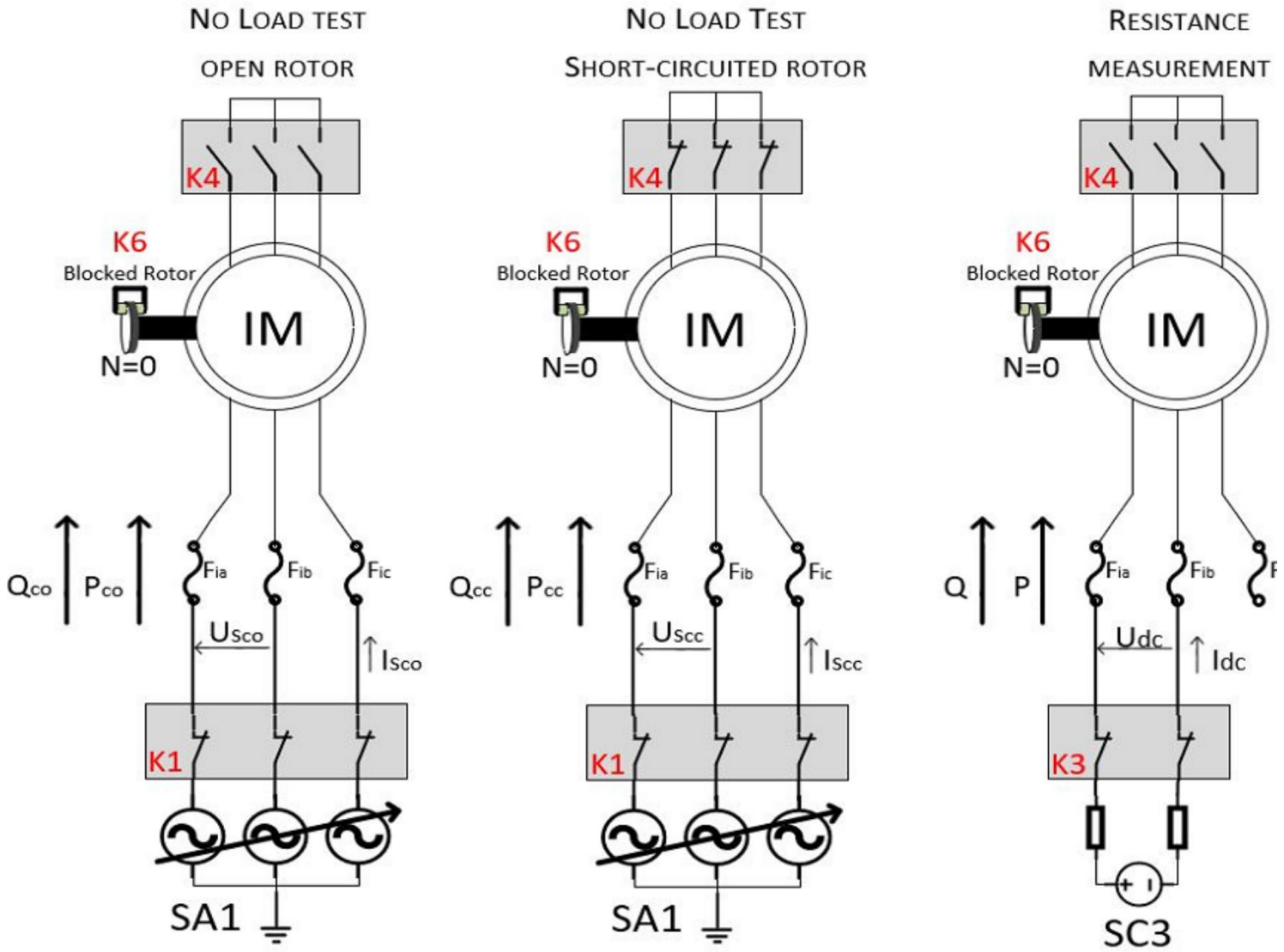
# ELECTRIC MACHINES

## Transformer & Frequency Converter

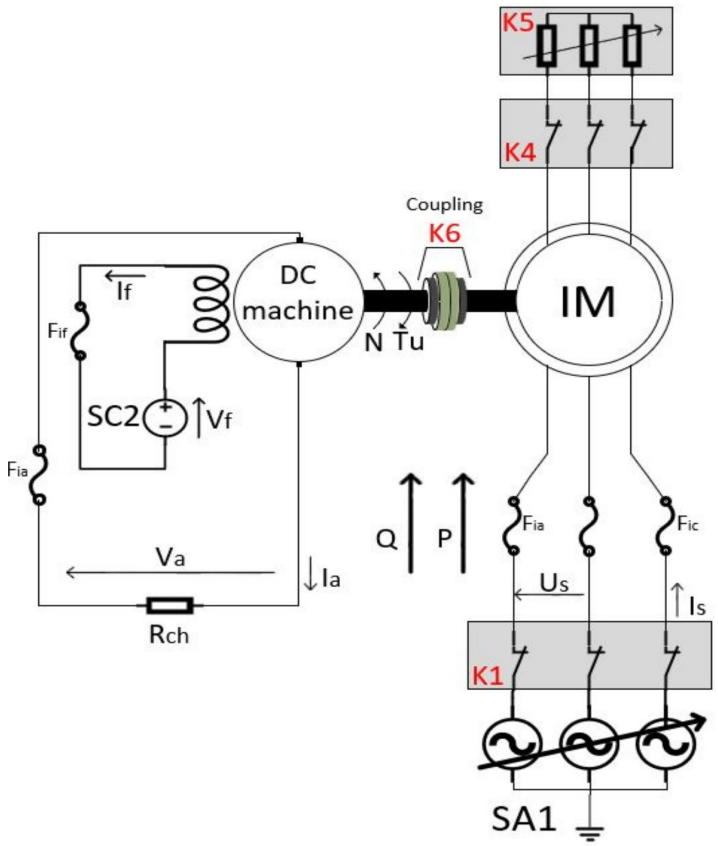


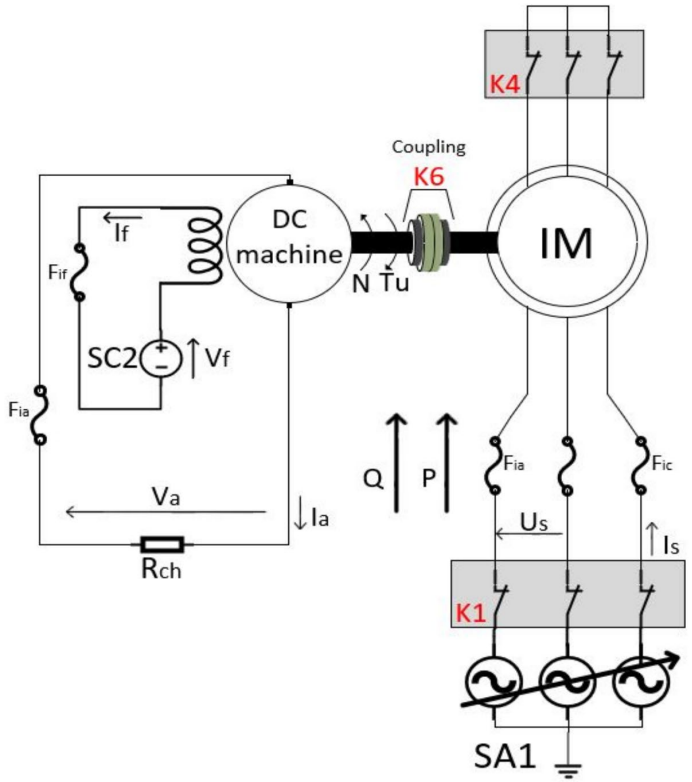



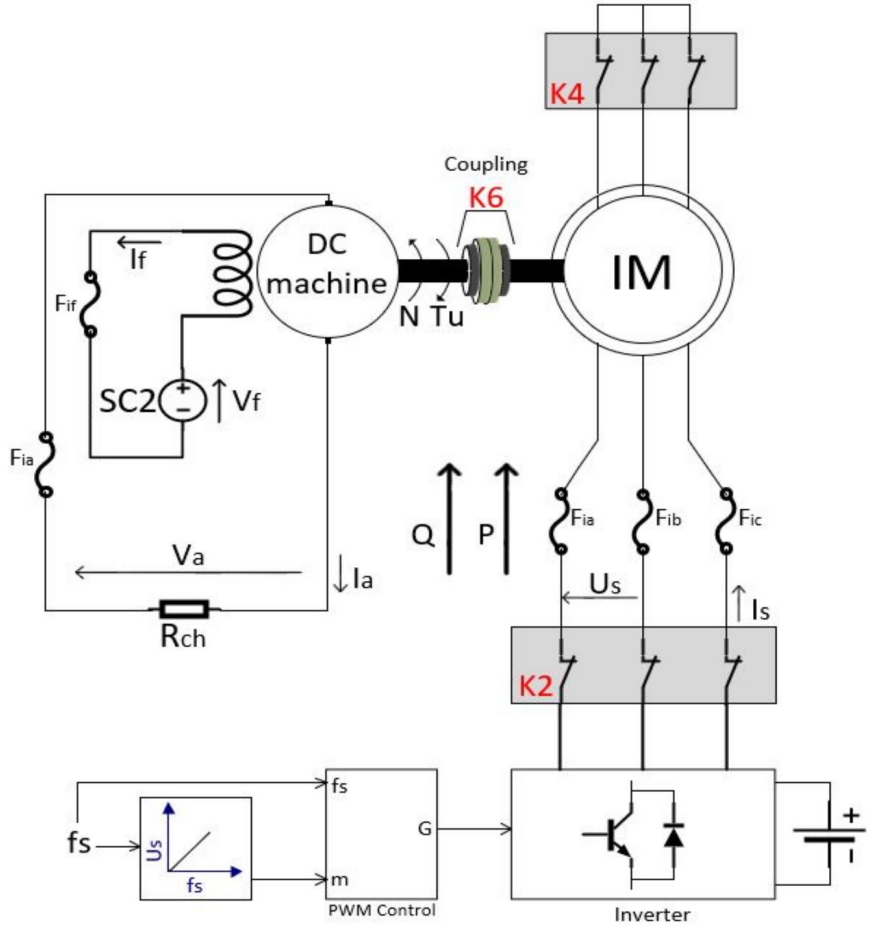
## Parameters Identification



# Speed Control: Variable Voltage, Variable Resistor & Three-Phase Inverter



# RENEWABLE ENERGY

Power Electronics
Electric Machines
**Renewable Energy**
Fundamentals Elec. Eng.
Motor Drives

Battery Energy Storage
Photovoltaic Generation
Wind Turbine Generation
Microgrid

OPAL-RT TECHNOLOGIES

| Topic | Suggested Lab Sessions |
|---|---|
| Battery Energy Storage | Grid Connected & Islanded |
| | PV & PQ Modes |
| | Interactive Help |
| Photovoltaic Generation System | Curtail & MPPT |
| | Setpoints: Irradiance, P & Q |
| | Interactive Help |
| Wind Turbine Generation System | Rotor & Grid Sides Controllers: Back-to-Back Converter |
| | Setpoints: Wind speed, Id & Iq |
| | Interactive Help |
| Micro Grid | All items cited above |
| | Power Flow Computation |
| | Microgrid Controller |
| | Load: Critical, Partially/Fully Sheddable. Demand Response. 24-hour Profile |
| | Interactive Help |

# RENEWABLE ENERGY

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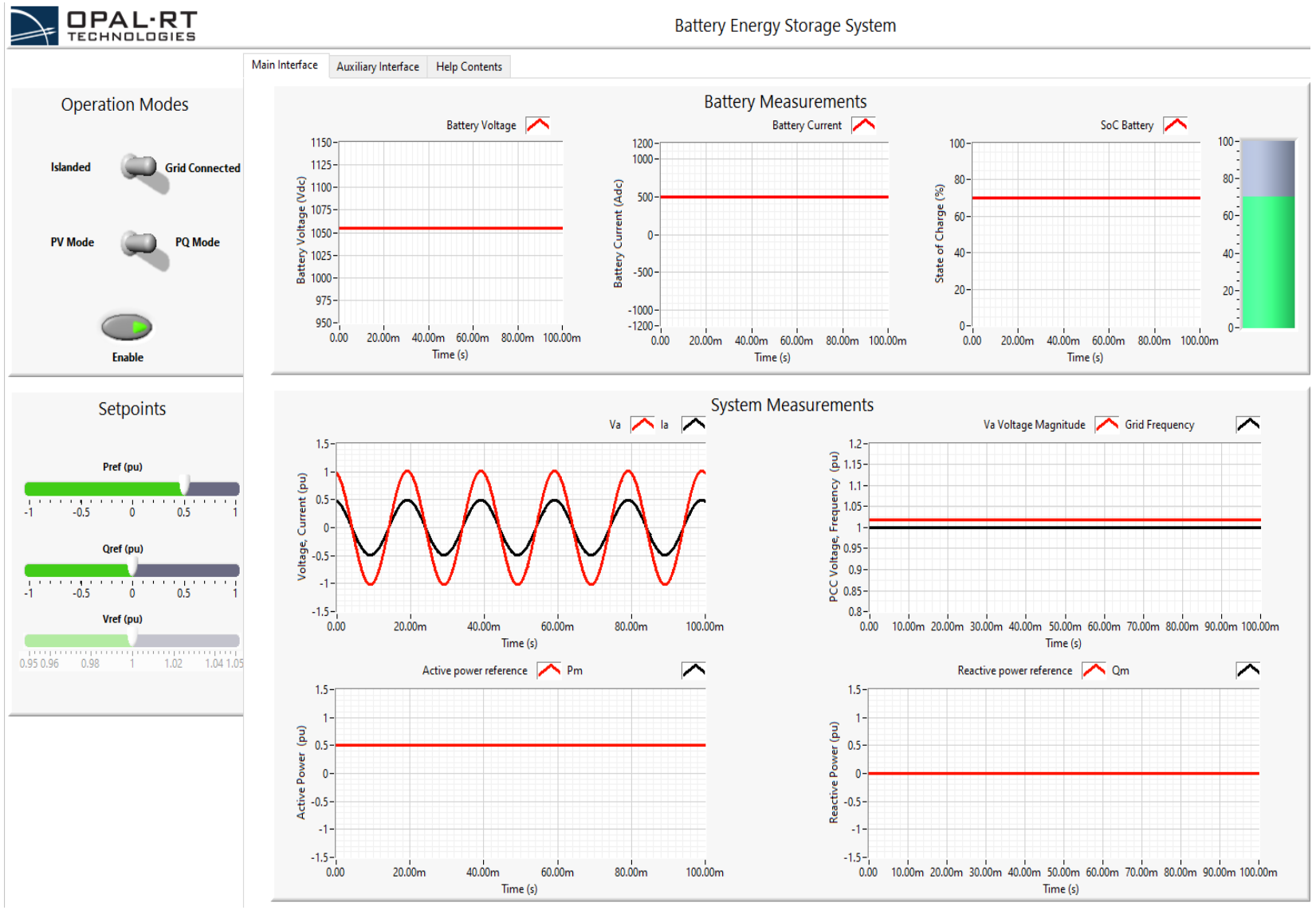
**Battery Energy Storage**
Photovoltaic Generation
Wind Turbine Generation
Microgrid

OPAL-RT TECHNOLOGIES

## Features

- Scopes for waveforms' display
- Varying active power reference
- Varying reactive power reference
- Varying voltage reference
- "PQ" and "PV" modes of operation
- Grid following, operation mode when connected to grid
- Grid forming, islanding operation mode
- Power flow computation
- Interactive Help with live displays of currents, voltages, and power flow



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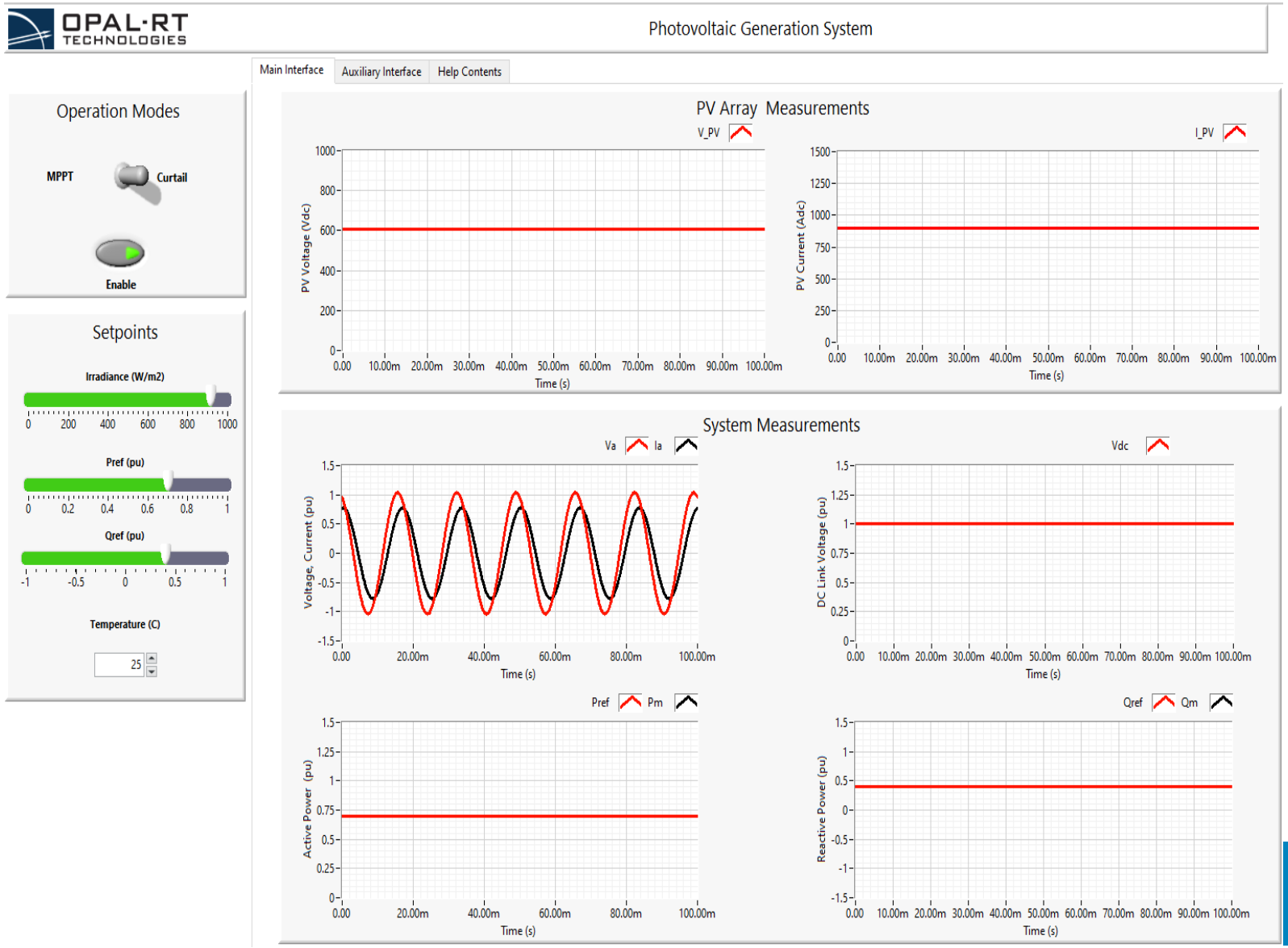
Microgrid

OPAL-RT TECHNOLOGIES

## Features

- Scopes for waveforms' display
- Varying solar irradiance
- Varying active power reference
- Varying reactive power reference
- Varying temperature
- Curtail operation mode
- Maximum power point tracking (MPPT) operation mode
- Power flow computation
- Interactive Help with live displays of currents, voltages, and power flow



# RENEWABLE ENERGY

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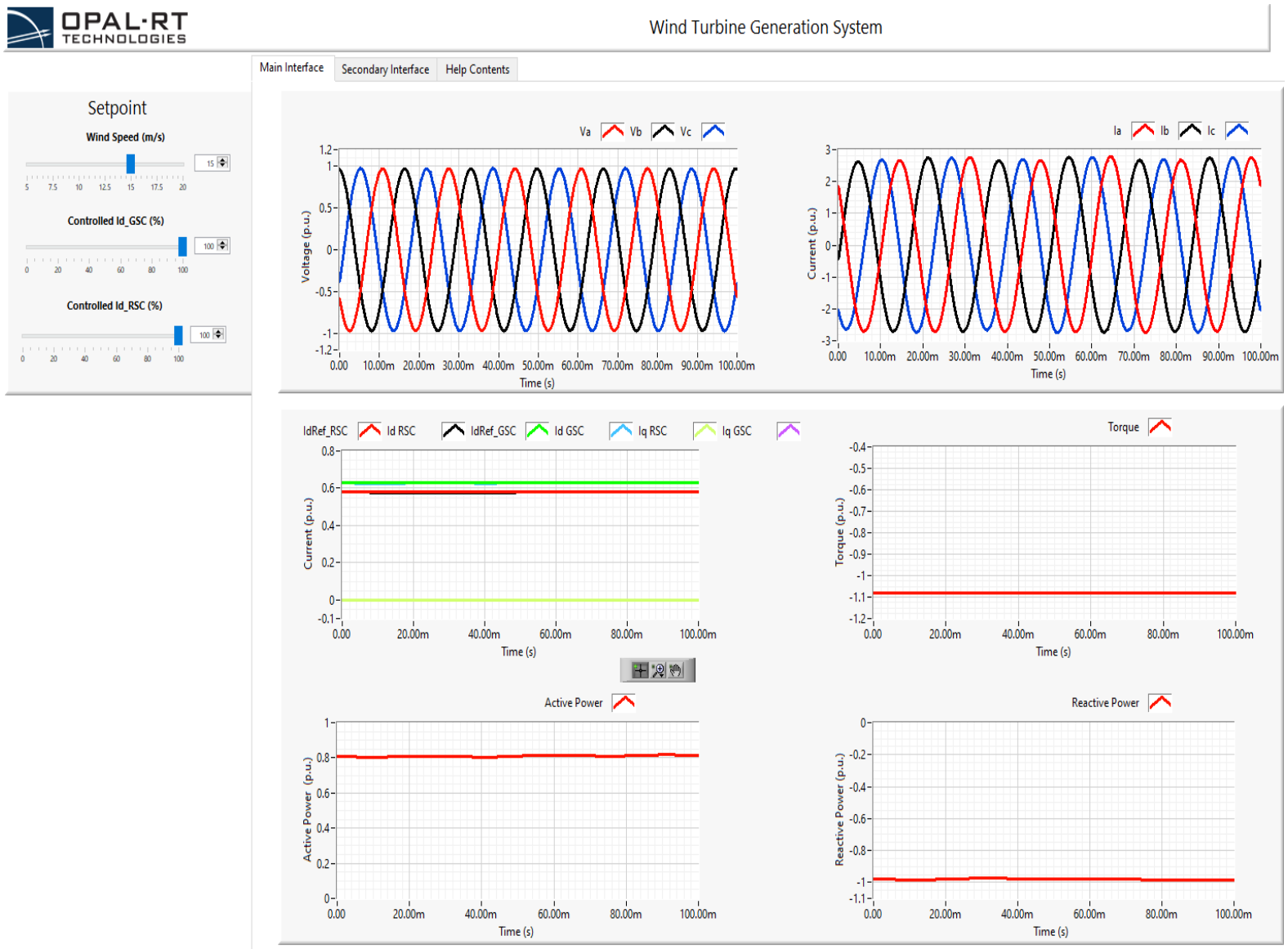
Photovoltaic Generation
**Wind Turbine Generation**
Microgrid

OPAL-RT TECHNOLOGIES

## Features

- Scopes for waveforms' display
- Varying wind speed
- Type 3 Wind Turbine
- Doubly-Fed Induction Generator (DFIG) with rotor and grid sides controllers
- Back-to-back converters
- Varying reference current Power flow computation
- Interactive Help with live displays of currents, voltages, and power flow



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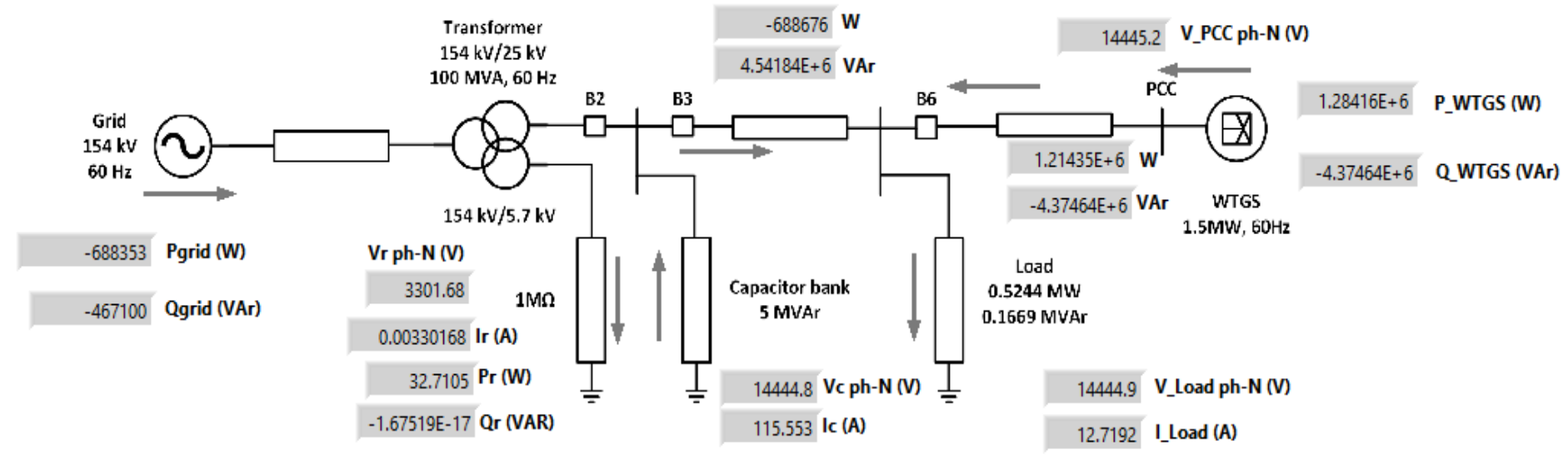


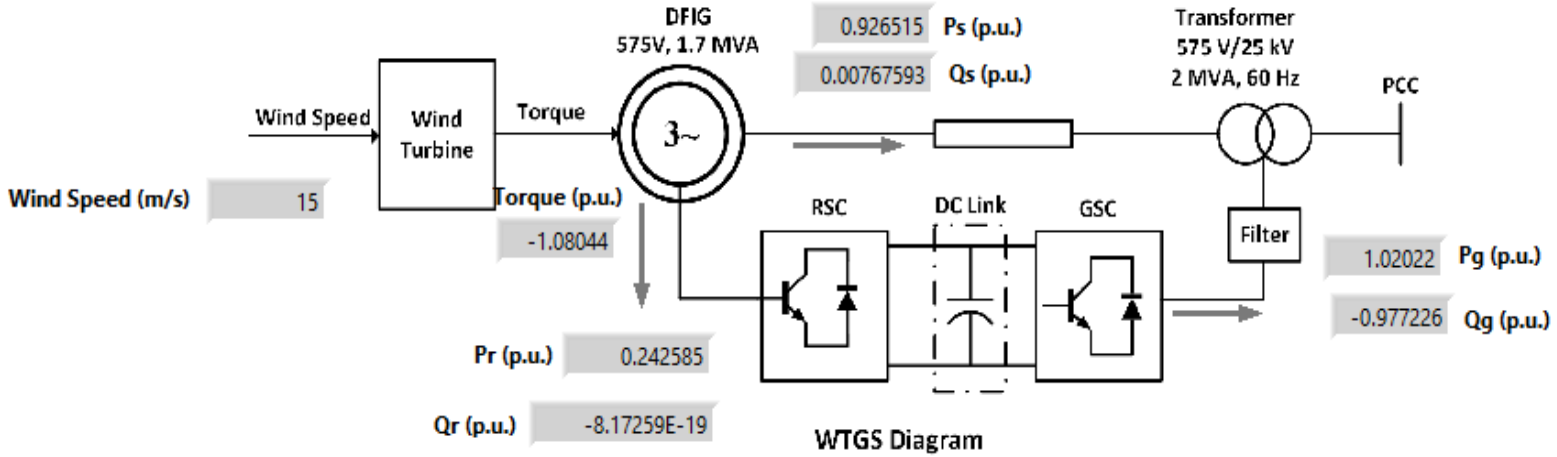


WTGS Diagram

**Notes**: 1-The Vabc and Iabc signals shown in the main interface are measured at the low side voltage of the transformer right before the Point of Common Coupling (PCC).

2- The active and reactive powers shown in the main interface are computed at the PCC.

3- Iq references are set at zero.

4- Controlled Id_GSC is the ratio of Id reference over the Id nominal for the grid side controller. Similar definition applies for the controlled Id_RSC.

RSC: Rotor Side Converter

GSC: Grid Side Converter

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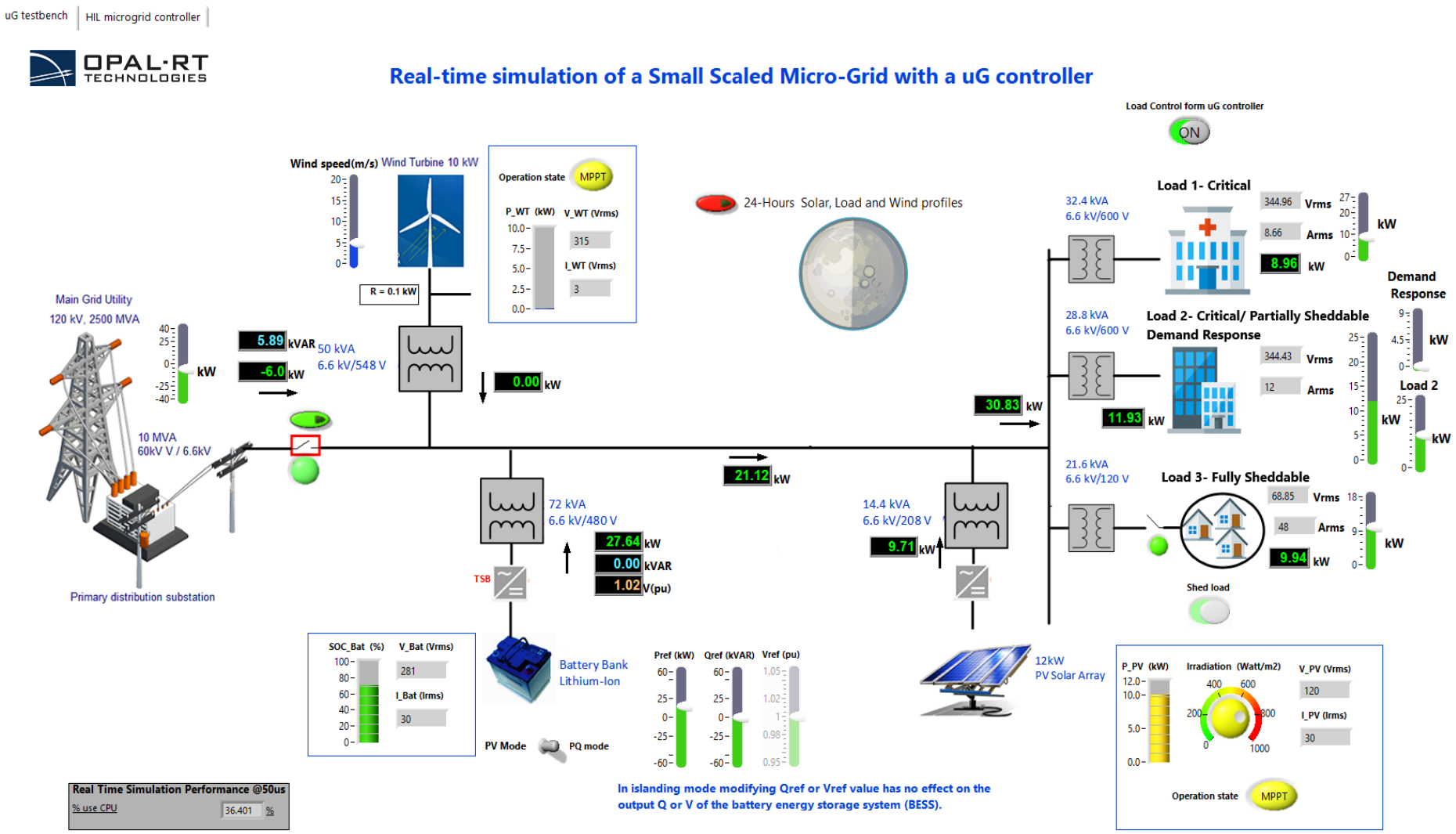
OPAL-RT TECHNOLOGIES

**Features of Microgrid Model**

- Varying solar irradiance
- Varying wind speed
- Varying reactive power reference
- Varying load demand
- Varying voltage reference
- Maximum power point tracking (MPPT) operation mode
- Microgrid (uG) controller
- Varying Demand response
- Load shedding
- Power flow computation
- Two operation modes: connected to grid and islanding
- Acquisition panels for waveform's display of the wind turbine, PVGS and BESS
- 24-hours load, wind speed and solar irradiance profiles to automatically change varying parameters
- Real scope feature: y-scale divisions



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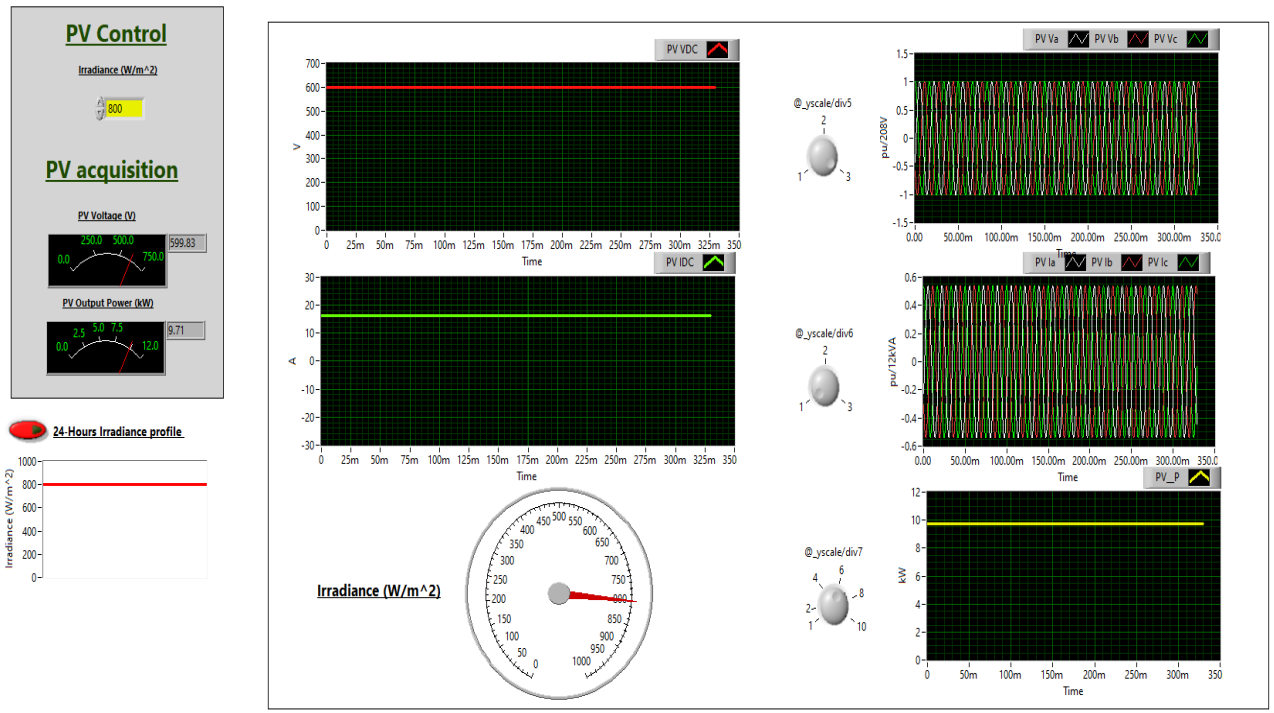


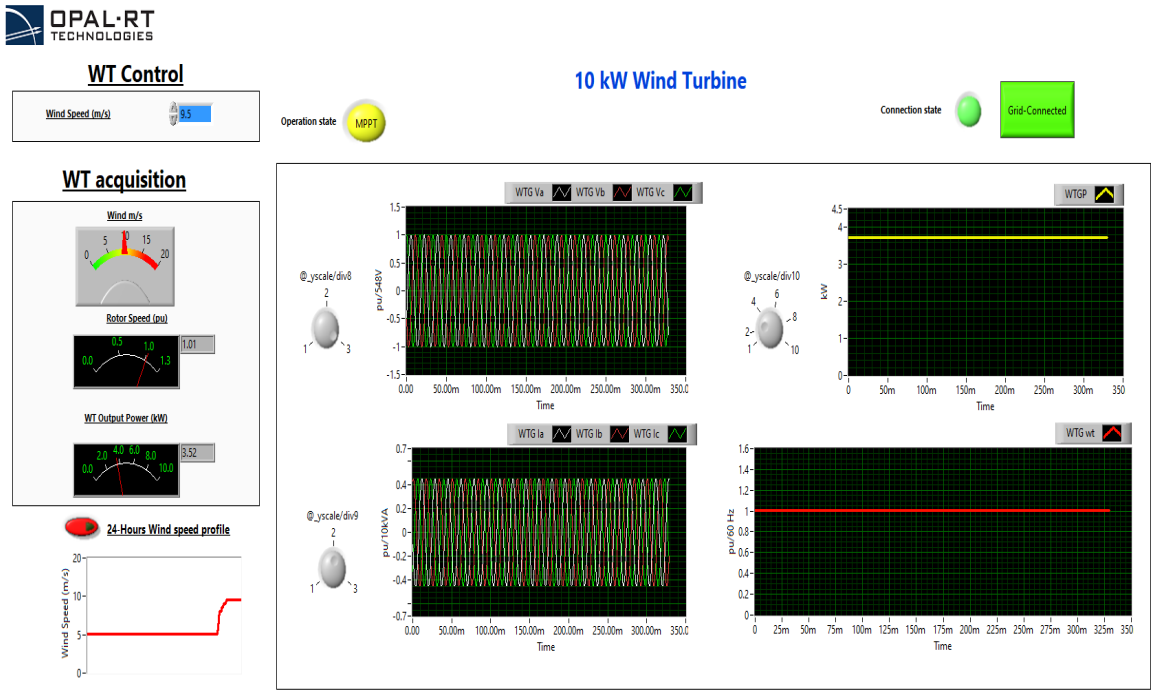

# FUNDAMENTALS ELEC. ENG.

Power Electronics
Electric Machines
Renewable Energy
**Fundamentals Elec. Eng.**
Motor Drives

Measurement Instruments
Electric Circuits
Electrical Engineering
Single-phase Transformer
Three-phase Transformer

OPAL-RT TECHNOLOGIES

| Topic | Suggested Lab Sessions |
|---|---|
| Measurement & Instruments | Scope |
| | RMS, Max, Mean |
| Electric Circuits | Steady-state |
| | Instantaneous, Sinusoidal & Frequency Response |
| | P, Q, Power Factor |
| Electric Engineering | Single-phase |
| | Three-phase: balanced & unbalanced |
| | Power Factor Compensation |
| Single-phase Transformer | Parameters Identification: no-load, short-circuit |
| | Saturation |
| Three-phase Transformer | Parameters Identification: no-load, short-circuit |
| | Saturation |
| | Internal Connection: wye-delta, alpha-numeric code |

# FUNDAMENTALS ELEC. ENG.

Power Electronics
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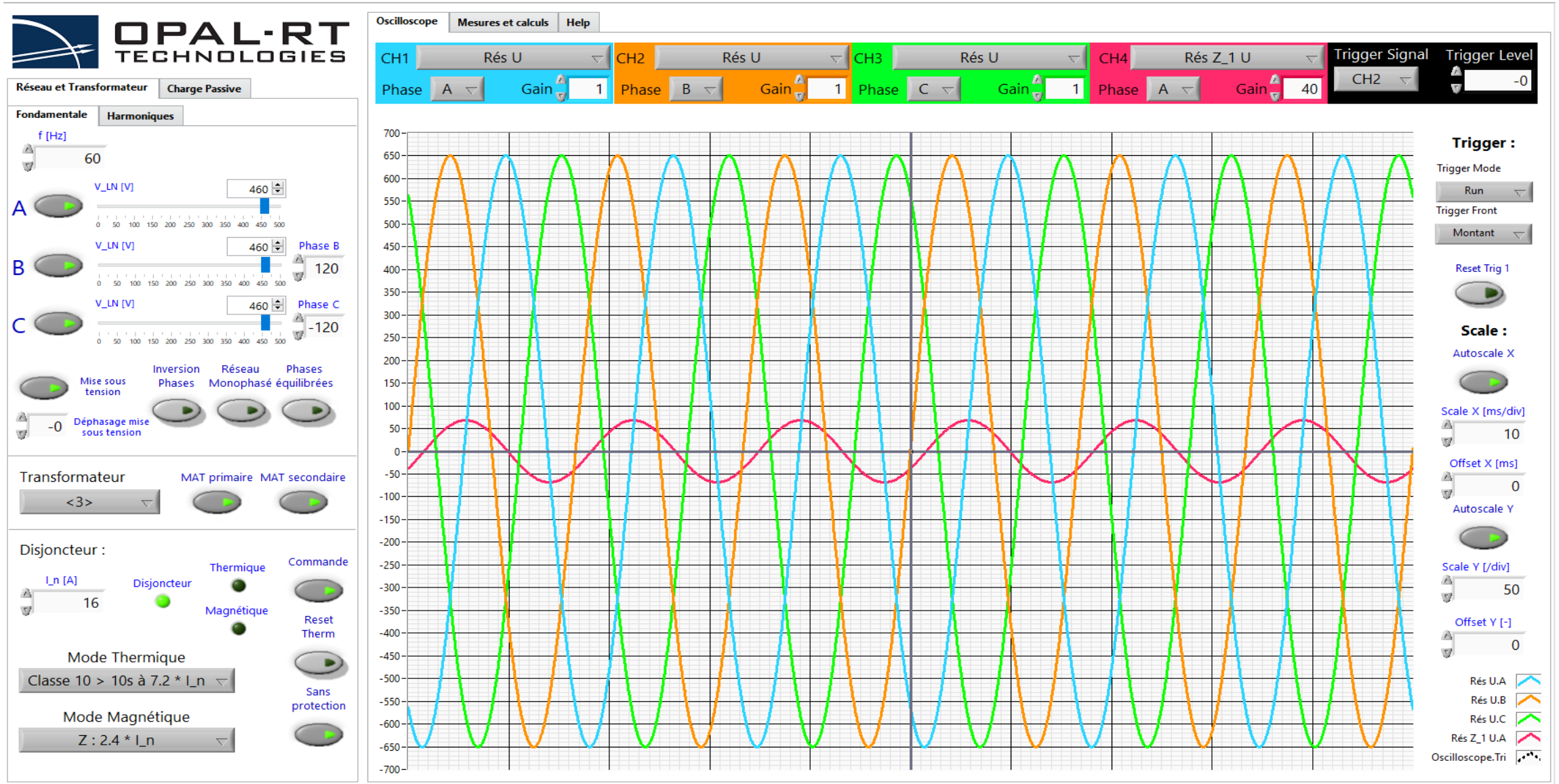
Renewable Energy
**Fundamentals Elec. Eng.**
Motor Drives

**Measurement Instruments**
Electric Circuits
Electrical Engineering
Single-phase Transformer
Three-phase Transformer

OPAL-RT TECHNOLOGIES



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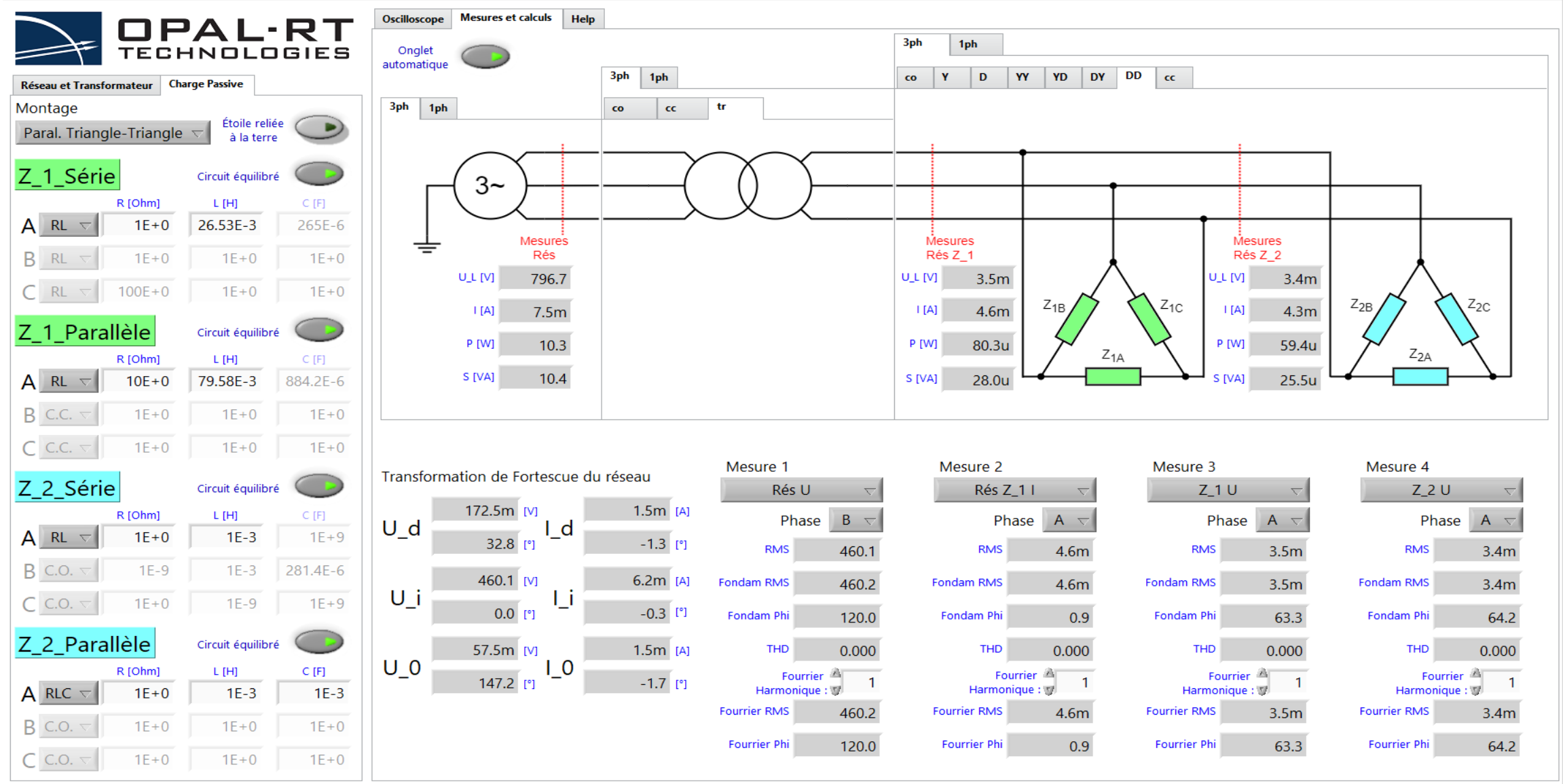
Measurement Instruments
**Electric Circuits**
Electrical Engineering
Single-phase Transformer
Three-phase Transformer

OPAL-RT TECHNOLOGIES



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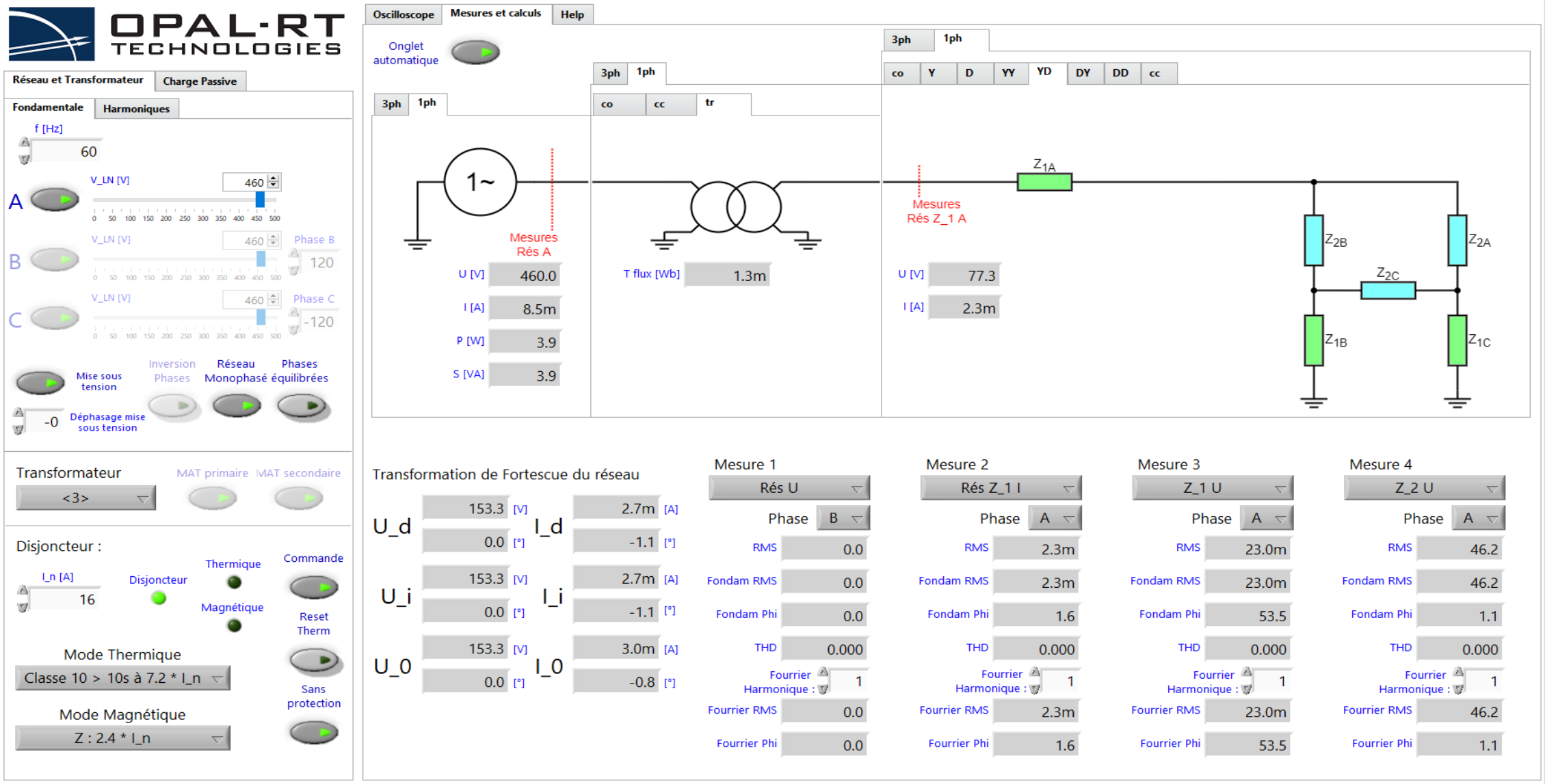
**Electrical Engineering**
Single-phase Transformer
Three-phase Transformer

OPAL-RT TECHNOLOGIES



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Electric Circuits
**Electrical Engineering**
Single-phase Transformer
Three-phase Transformer

OPAL-RT TECHNOLOGIES

ver.1- 31 mars 2022

## Z_1_Série

| R [Ohm] | X_L [Ohm] | X_C [Ohm] |
|---|---|---|
| 1.0 | 10.0 | 2.7m |
| 1.0 | 10.0 | 2.7m |
| 1.0 | 10.0 | 2.7m |

## Z_1_Parallèle

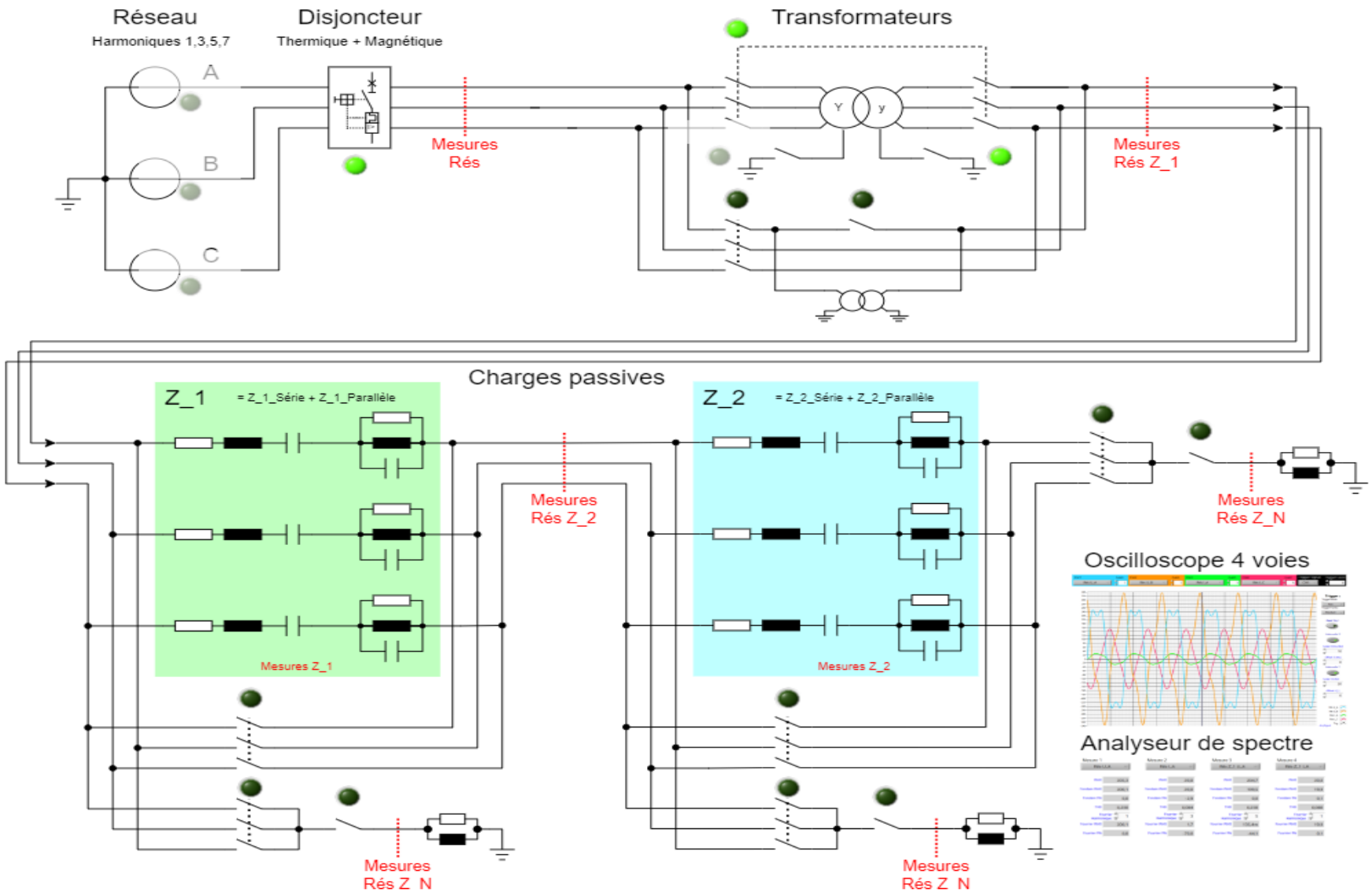
| R [Ohm] | X_L [Ohm] | X_C [Ohm] |
|---|---|---|
| 10.0 | 30.0 | 2.7M |
| 10.0 | 30.0 | 2.7M |
| 10.0 | 30.0 | 2.7M |

## Z_2_Série

| R [Ohm] | X_L [Ohm] | X_C [Ohm] |
|---|---|---|
| 1.0u | 377.0n | 2.7m |
| 1.0u | 377.0n | 2.7m |
| 1.0u | 377.0n | 2.7m |

## Z_2_Parallèle

| R [Ohm] | X_L [Ohm] | X_C [Ohm] |
|---|---|---|
| 1.0u | 377.0 | 2.7M |
| 1.0u | 377.0 | 2.7M |
| 1.0u | 377.0 | 2.7M |



# FUNDAMENTALS ELEC. ENG.

Power Electronics
Electric Machines
Renewable Energy
**Fundamentals Elec. Eng.**
Motor Drives

Measurement Instruments
Electric Circuits
Electrical Engineering
**Single-phase Transformer**
Three-phase Transformer

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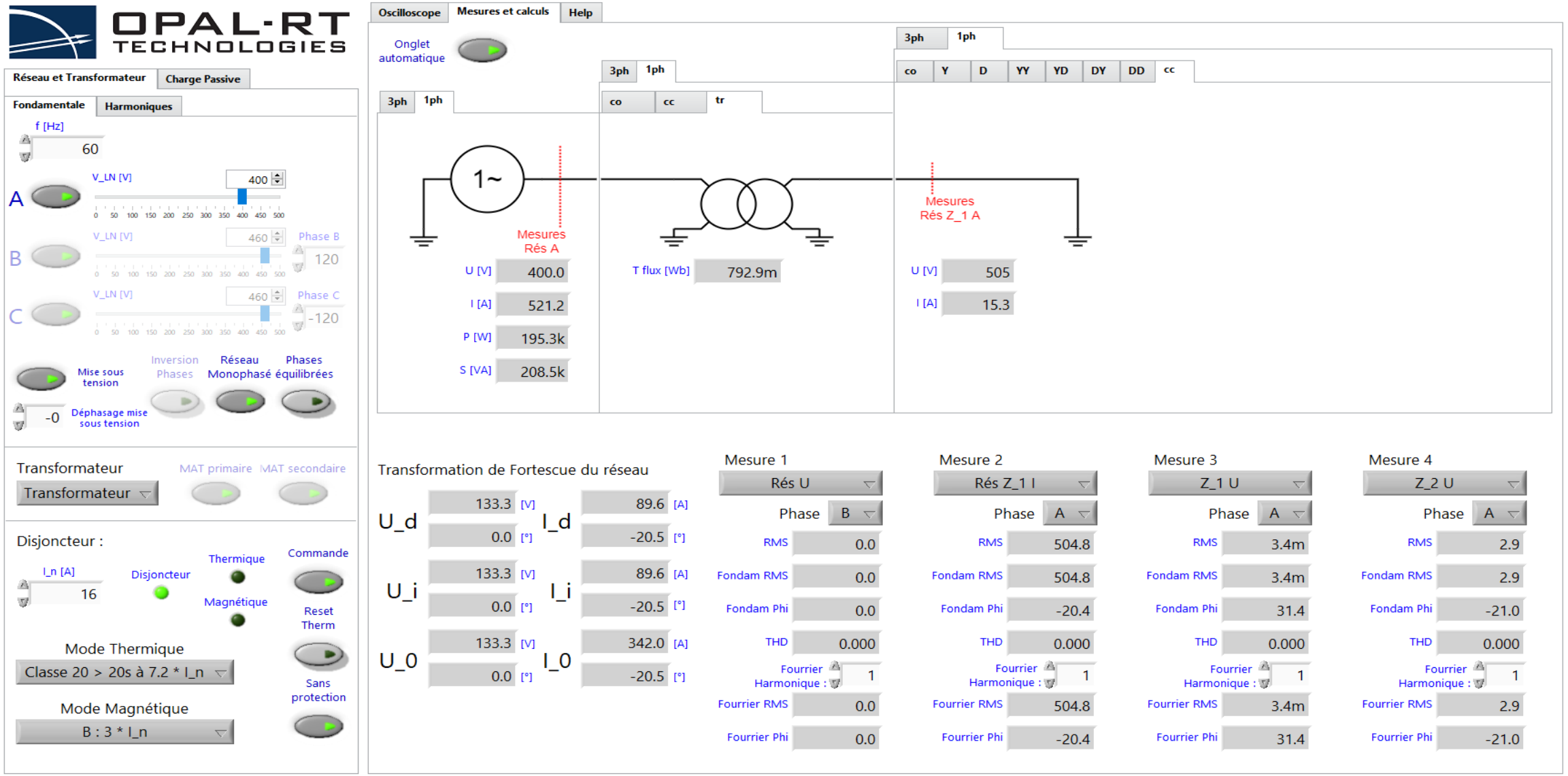

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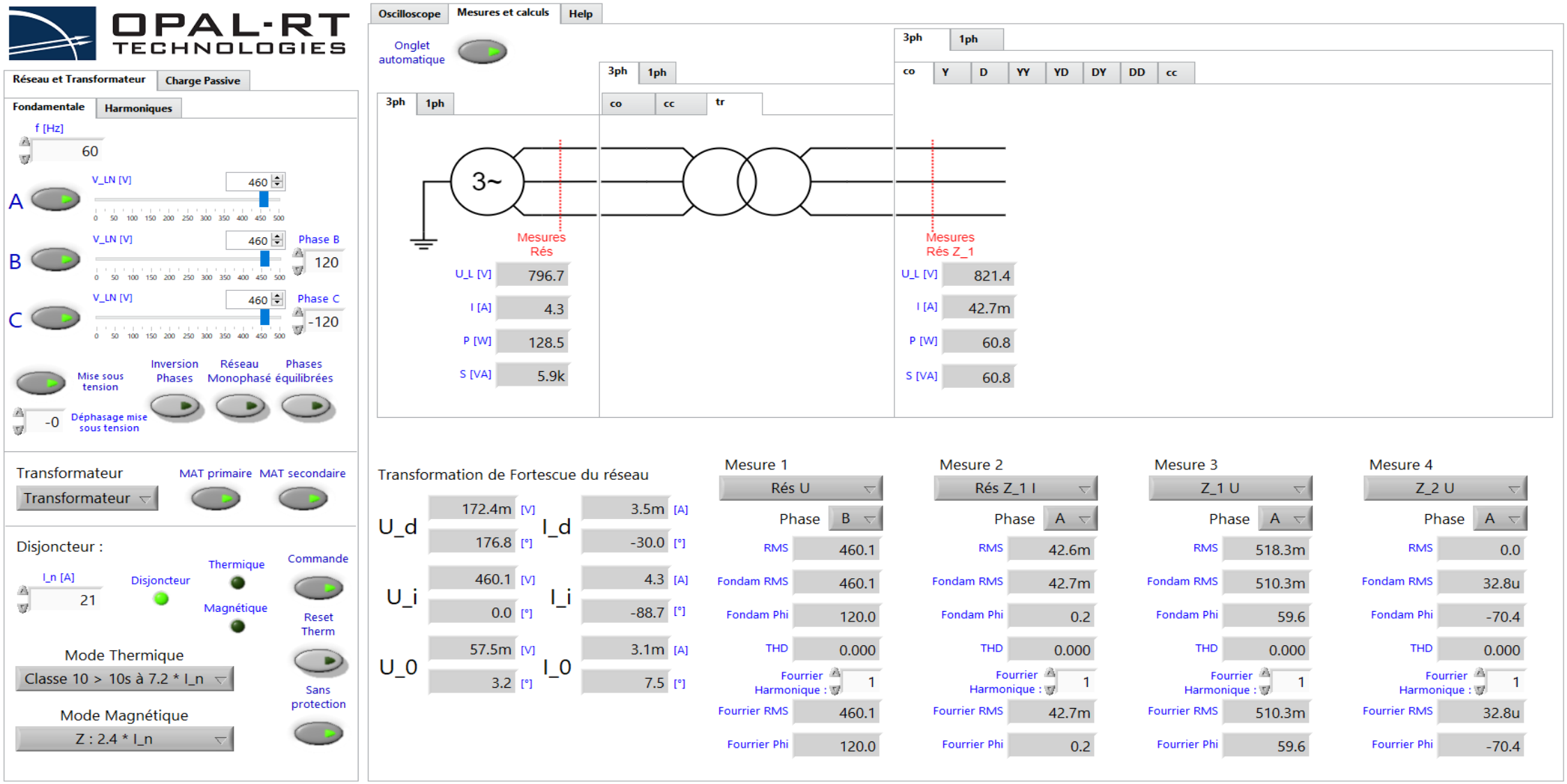

# MOTOR DRIVES

Power Electronics
Electric Machines
Renewable Energy
Fundamentals Elec. Eng.
**Motor Drives**

DC Motor Drive
PMSM Motor Drive
Induction Motor Drive
Doubly-Fed ind. Motor Drive

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| Topic | Suggested Lab Sessions |
|---|---|
| DC Motor Drive | Parameters Identification |
| | Current Control |
| | Speed Control |
| PMSM Motor Drive | Transformations: Clark, Concordia, and Park |
| | Self-Control: Hysteresis and PI Control |
| | Vector Control |
| Induction Motor Drive | V/f Control |
| | Vector Control |
| Doubly-Fed Induction Motor Drive | Rotor Controller |
| | Vector Control |

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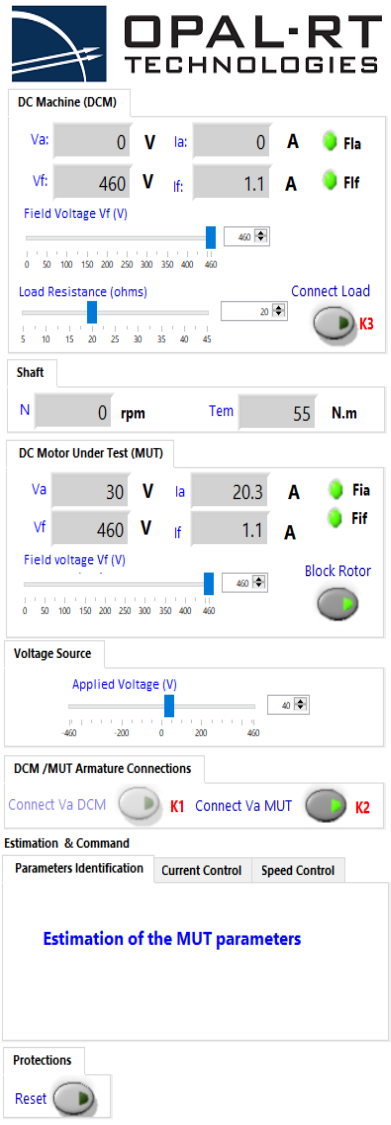
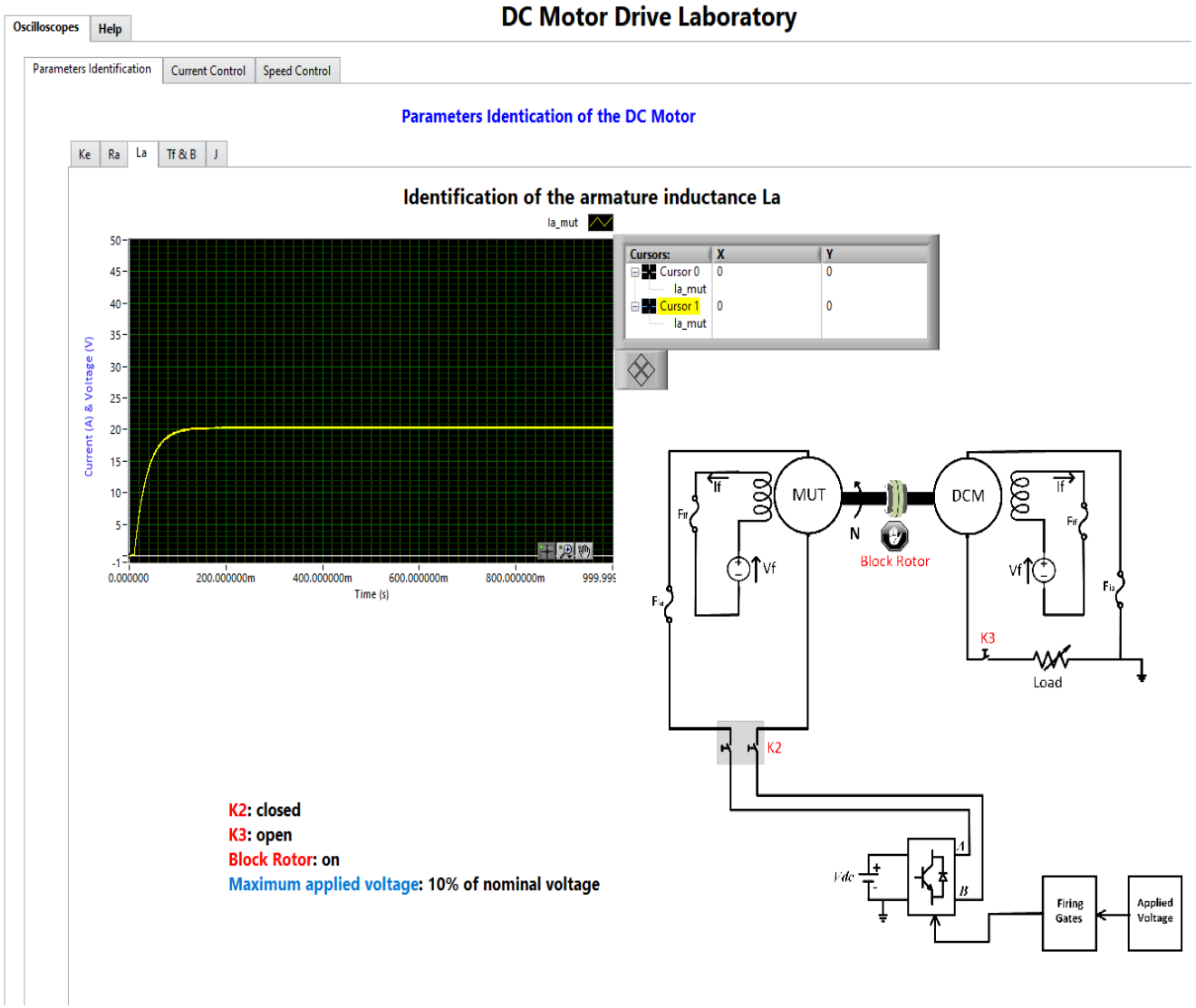
OPAL-RT TECHNOLOGIES

## Features

- Scope:
  Trigger, Cursor, Zoom-In, Zoom-out
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Parameters Identification
- Current Control
- Speed Control
- Varying resistive load
- Varying input voltage
- Varying current and speed references
- Computation of RMS Voltage and Current



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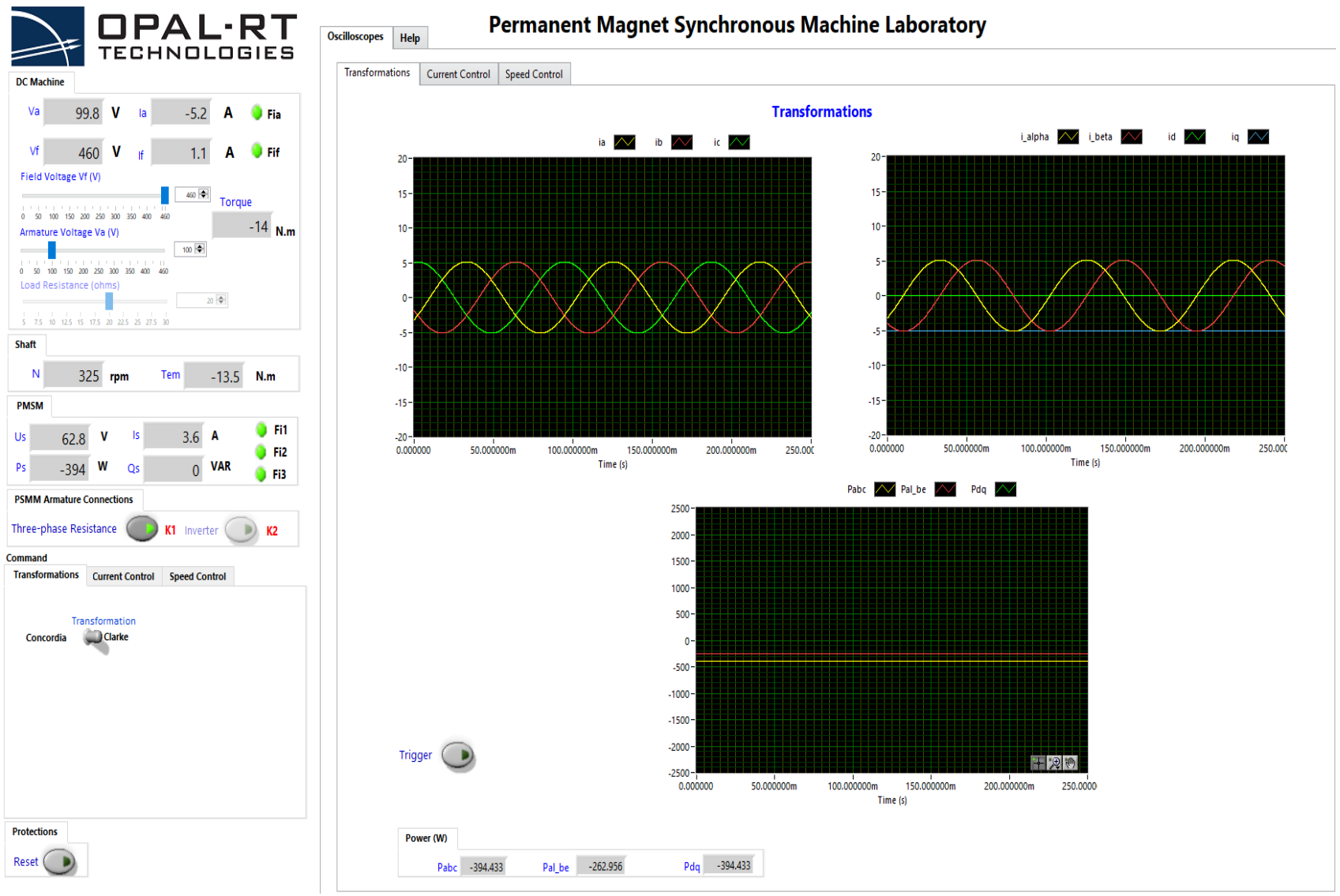
## Features

- Scope:
  Trigger, Cursor, Zoom-In, Zoom-out
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- Parameters Identification
- Self current control
- Vector current control
- Speed control
- Varying resistive load
- Clarke, Concordia and Park transformations
- Varying armature voltage
- Varying current and speed references
- Computation of RMS voltage and current
- Power computation



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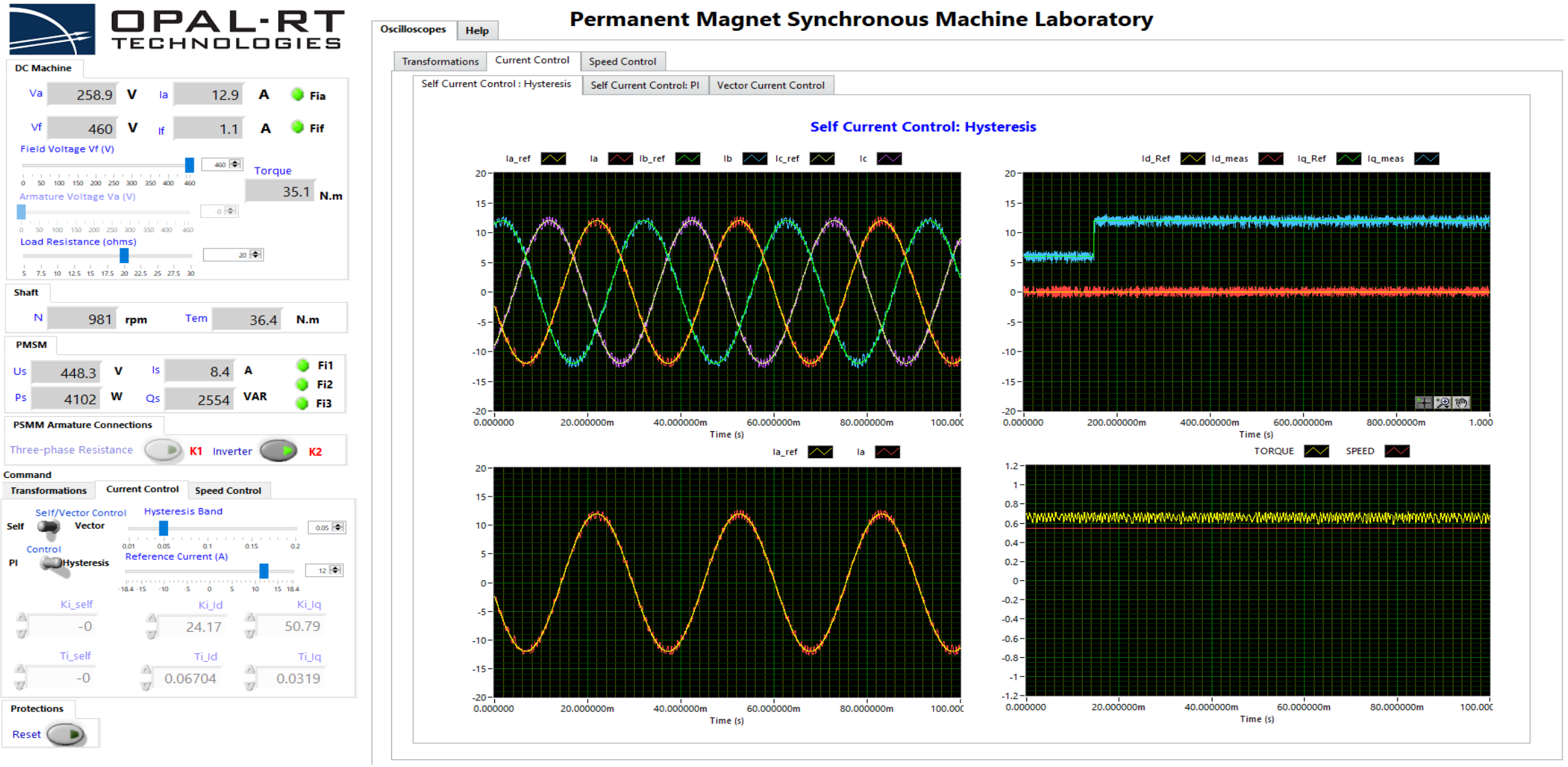

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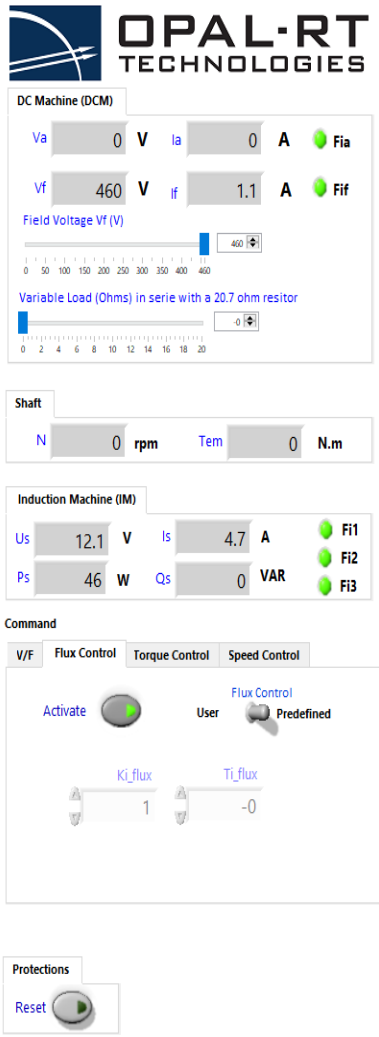
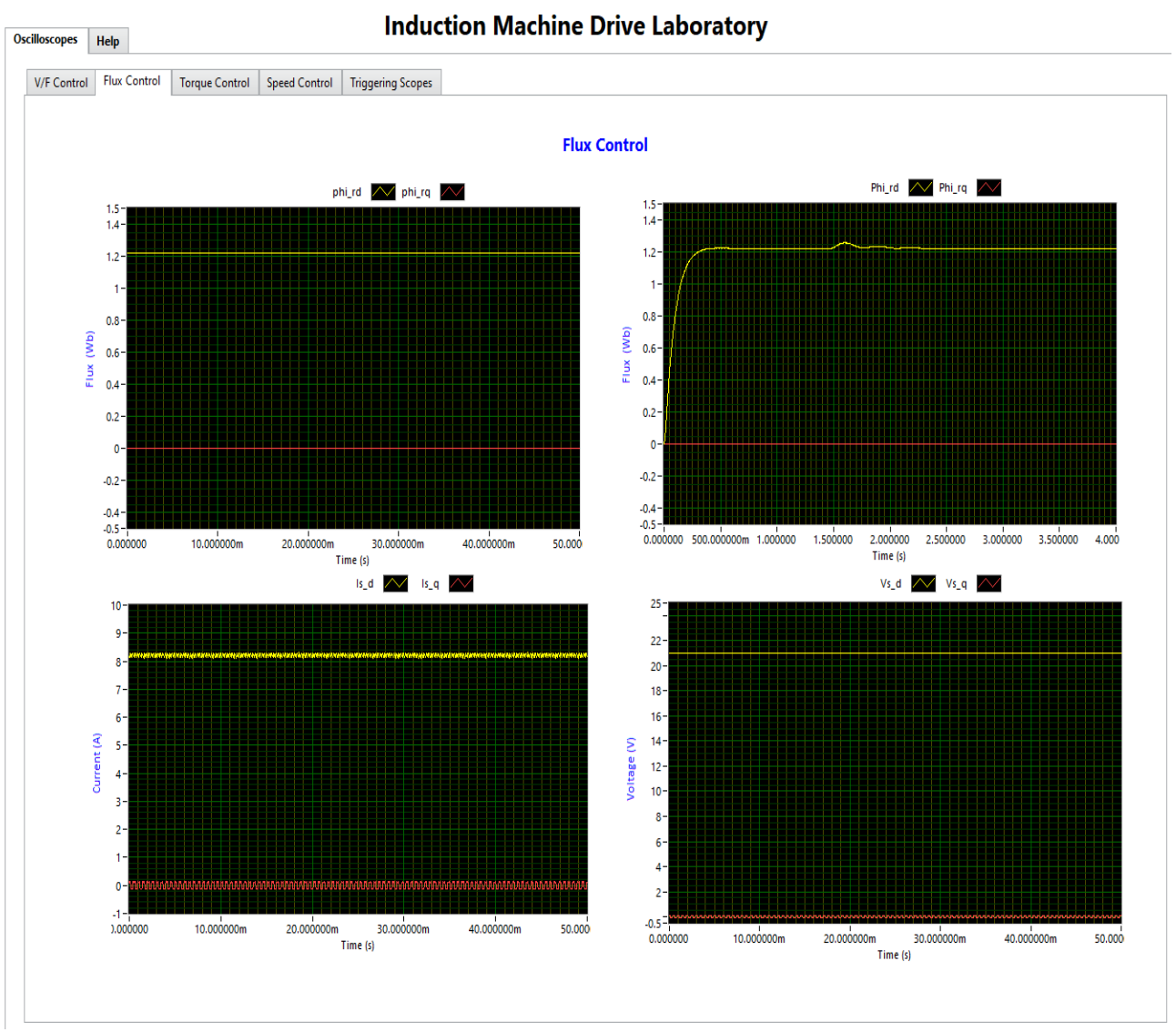
OPAL-RT TECHNOLOGIES

## Features

- Scope:
  Trigger, Cursor, Zoom-In, Zoom-out
- Nameplate & Ratings
- Protection:
  Fuse & Reset
- V/f control
- Flux control
- Torque control
- Speed control
- Varying resistive load
- Varying torque and speed references
- Computation of RMS voltage and current
- Power computation
- User and predefined controls



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## Induction Machine Drive Laboratory

Oscilloscopes | Help

V/F Control | Flux Control | Torque Control | Speed Control | Triggering Scopes

**DC Machine (DCM)**

Va 122.7 V  Ia -5.9 A  Fia

Vf 460 V  If 1.1 A  Fif

Field Voltage Vf (V)

Variable Load (Ohms) in serie with a 20.7 ohm resitor

**Shaft**

N 499 rpm  Tem 15.4 N.m

**Induction Machine (IM)**

Us 146.2 V  Is 5.9 A  Fi1 Fi2 Fi3

Ps 901 W  Qs 1085 VAR

**Command**

V/F | Flux Control | Torque Control | Speed Control

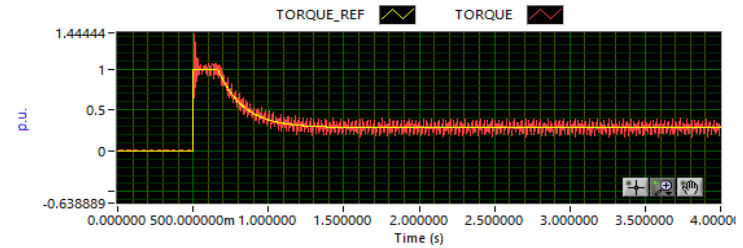
Enable  User  Speed Control: Predefined

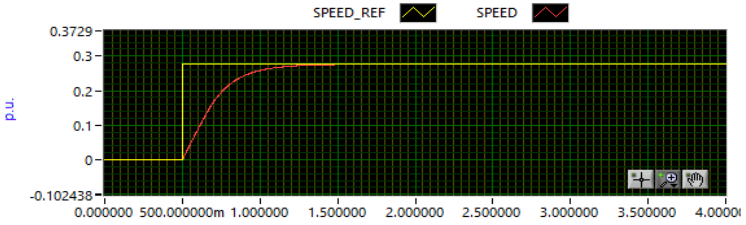
Reference Speed (rpm)

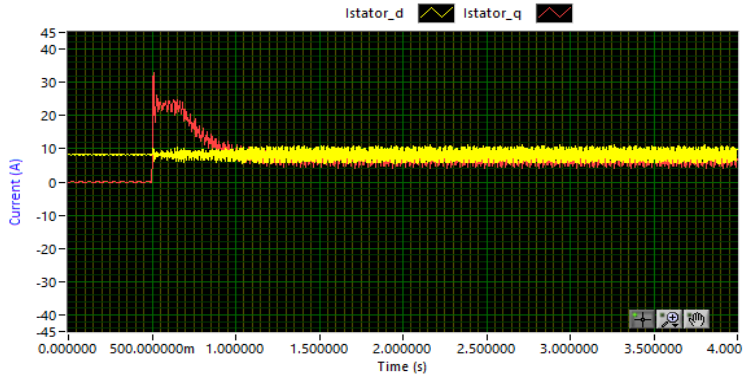
Ki_speed 0.01  Ti_speed -0

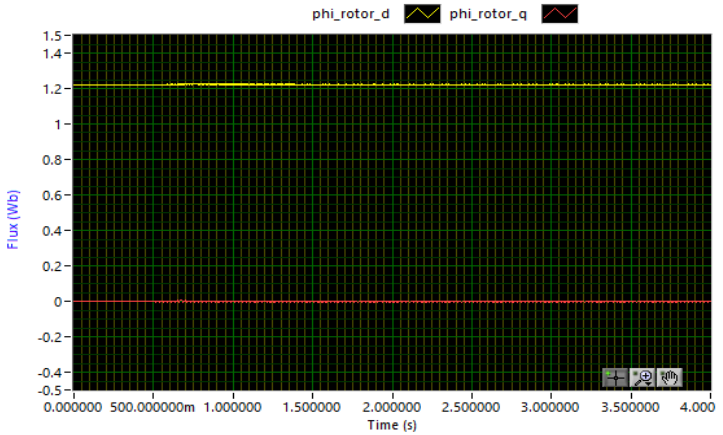
**Protections**

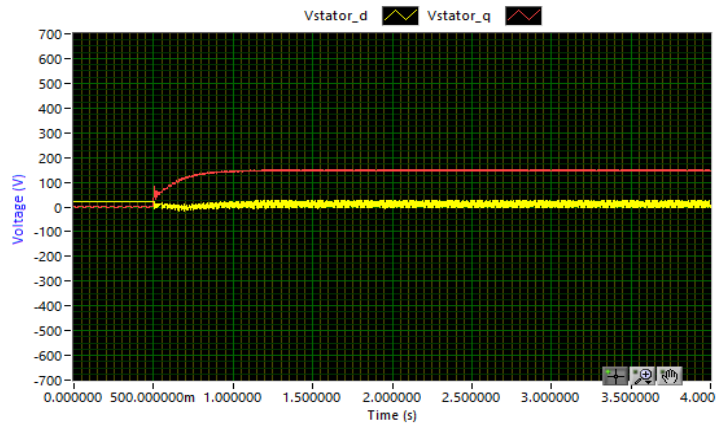
Reset



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