

# Application Note

## Basler Electric Offers Digital Solutions to Retrofit the Obsolete GFA-4 Indirect-acting Voltage Regulator

**As power systems, generator size and load diversity grew, the necessity for automatic voltage regulation to replace manual voltage control became evident.**

General Electric addressed the issue in the 1920s by developing the GFA-4, an electromechanical type of automatic voltage regulator that interfaced with a motorized field rheostat. During the decades of the 1920-40s, General Electric provided many a-c generators and synchronous condensers with the GFA-4, commonly called automatic voltage regulator, for hydro and steam turbine applications. (See Figure 1)

This Application Note explains the fundamental operation of the GFA-4 automatic voltage regulator and provides Basler Electric’s recommended solutions for replacing this obsolete excitation system.

### How It Works

The complete GFA-4 excitation system consists of the main control element, a motor-operated field rheostat, a relay panel with high-speed contactors, voltage adjusting rheostats, and a cutout switch to enable manual control. See Figure 2 for typical interconnection diagram. The main control element utilizes a polyphase torque motor that receives its voltage input through ganged voltage adjusting rheostats connected to transformers for sensing generator voltage. This effectively makes the regulator sensitive to the average three-phase generator voltage. The torque motor’s shaft connects to a spring-balanced lever that operates pairs of “notching” and “accelerating” spring contacts. A separate slow speed motor rotates a “notching” star-shaped wheel and an “accelerating” smooth wheel that complete electrical circuits with the previously mentioned spring contacts when circumstances dictate.

Under steady state conditions, both pairs of contacts remain out of engagement. Upon a small generator voltage deviation, the torque motor and lever assembly forces the “notching” contacts to temporarily make contact with the star-shaped wheel. The intermittent

completion of this electrical circuit causes the motorized field rheostat to jog in the appropriate raise or lower direction, producing the proper excitation current change.

The purpose of the intermittent jogging of the field rheostat is to avoid over-travel and subsequent hunting. If there is a large generator voltage decrease, such as what may be encountered during motor starting or a system fault, the “raise” notching contact makes increased engagement with the star-wheel, driving the field rheostat to the required position more rapidly.

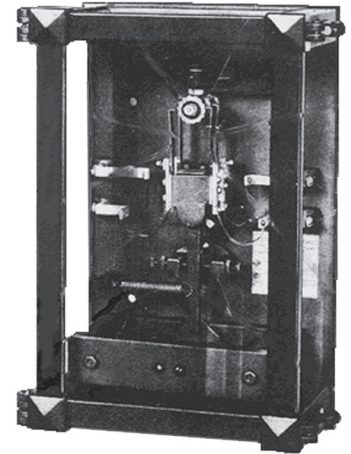


Figure 1: "GFA-4" Indirect-Acting Generator Voltage Regulator

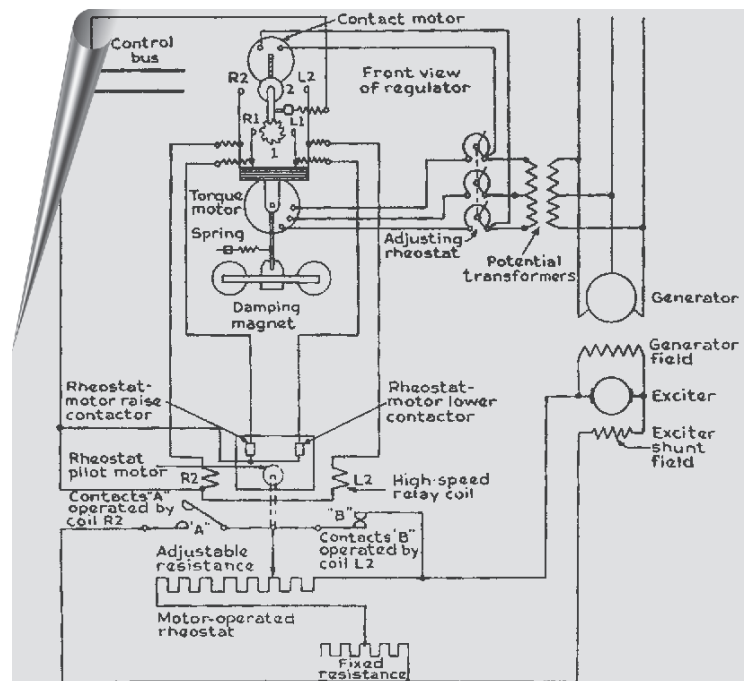


Figure 2: Typical interconnection diagram of GFA-4 regulator

If the increased force on the notching contacts causes continuous engagement, the accelerating contacts also become engaged, causing a high-speed contactor to short out all of the field rheostat resistance to apply full field current. During high voltage excursions a “lower” accelerating contact engages a high-speed contactor and cuts in all field resistance to minimize excitation current.

Wheatstone bridge field rheostats were used for all systems where a pilot exciter supplies power to the main exciter shunt field (See Figure 3). This configuration provided the benefit of wide range excitation control that was particularly advantageous for synchronous condenser and hydro-turbine applications. A particular concern of hydro-turbine applications is to protect from excessive generator overvoltage caused by overspeeding during a full load rejection. The Wheatstone bridge rheostat could drive the excitation voltage to zero or even slightly negative, helping to minimize the overvoltage.

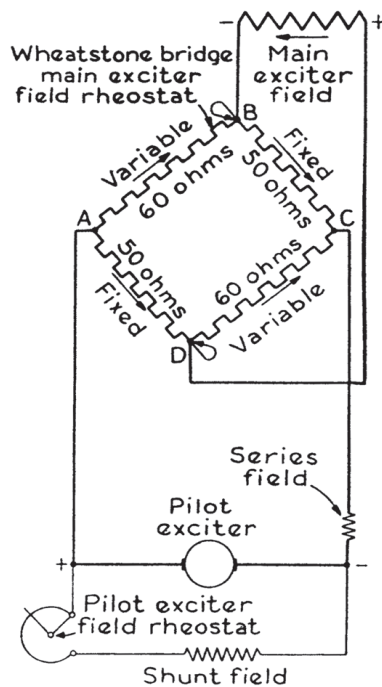


Figure 3: Wheatstone Bridge Rheostat

Maintaining the GFA-4 has become difficult because of the age of the equipment and obsolescence of parts. Concerns include the end of usable life of the motors and other mechanical devices, including the pilot and main exciter, and maintenance problems typical of commutator deterioration.

## The Solution

Basler Electric has two possible solutions for retrofitting the obsolete GFA-4 regulating system:

1. The GFA-4 regulator, field rheostat, pilot exciter and main exciter are replaced with a solid state, static excitation system working directly into the main generator field using a DECS-450 static excitation system.
2. The GFA-4 regulator, field rheostat and pilot exciter are replaced with a voltage regulator connected into the main exciter field using a SGC-250N excitation system.

## Static Exciter Solution

*(Eliminates the Rotating Main and Pilot Exciters)*

From a maintenance and generator performance perspective, a static exciter with the DECS-450 digital excitation control system provides the favored solution (See Figure 4).



Figure 4: DECS-450 prepackaged excitation system offers high efficiency and minimal maintenance costs for main field applications.

By controlling the main field current directly, faster voltage recovery is realized, and first swing transient stability is improved to aid power transfer and relay coordination after a fault. The use of power semiconductors for power control in the main field in lieu of the rotary exciter increases the system operating efficiency and eliminates maintenance associated with commutators and brushes. For hydro-turbine applications, the negative field forcing capability of a 6 thyristor rectifier bridge is ideal for minimizing overvoltage caused by overspeed from full load rejection.

The static exciter (See Figure 6 for typical interconnection diagram.) contains a power transformer and power rectifiers sized to provide the rated load excitation requirements to the main field of the generator. A DECS-450 Digital Excitation Control System provides multiple features including:

- 0.1% regulation accuracy
- Standby Manual Mode (Field Current Regulation)
- VAR/PF Control, Excitation Limiters, remote set point adjusters, and excitation protection
- Auto tracking of non-active operating modes for bumpless transfer

The excitation system uses positive and negative field forcing to speed generator voltage recovery. A crowbar circuit consisting of two SCRs connected in antiparallel with a series discharge resistor provides a path to discharge the field energy and eliminates the need for a dc field breaker.

The DECS-450 digital excitation system setup and control is user friendly with Windows® based BESTCOMSPiUS® software, common to Basler product family. See Figure 5 and Figure 10.

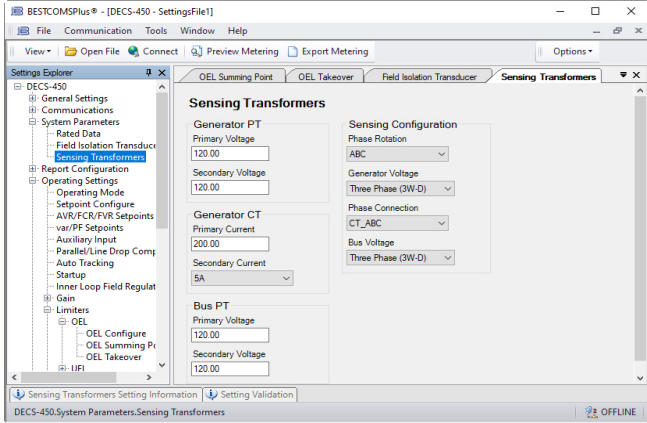


Figure 5: Basler's User-Friendly BESTCOMSPiUS software provides screens to aid with calibration, setup, and operation.

The system also adapts easily to power plant automation by accepting control signals from contact inputs or through Modbus® communication protocol.

For further details on the DECS-450, refer to the product bulletin available at [www.basler.com](http://www.basler.com).

## Voltage Regulator System

*(Eliminates the GFA-4, Pilot Exciter, and Field Rheostat)*

For systems where the main rotating exciter is in good condition and only the GFA-4 or pilot exciter has operational problems, the more appealing solution may be to retain the main exciter and utilize a digital excitation system to control the main exciter shunt field. (See Figure 6 for typical interconnection diagram.)

Basler recommends using a prepackaged digital excitation control system such as the SGC-250N to simplify installation (see Figures 7 and 8). All SGC-250N components are mounted and wired on a pan chassis and completely tested as a system at the factory. Basler's BESTCOMSPiUS® communication software is also used for ease of setup and commissioning. The SGC-250N incorporates many of the features of the DECS-450 such as excitation limiters, Var/PF control, back-up manual mode, and remote set point control. See Features table below.

Where redundancy is required, in the event of an unlikely failure, the SGC-250N will automatically transfer to a redundant backup DECS-250N regulator to maintain power system integrity.

For details on the DECS-250N, refer to the product bulletin available at [www.basler.com](http://www.basler.com).

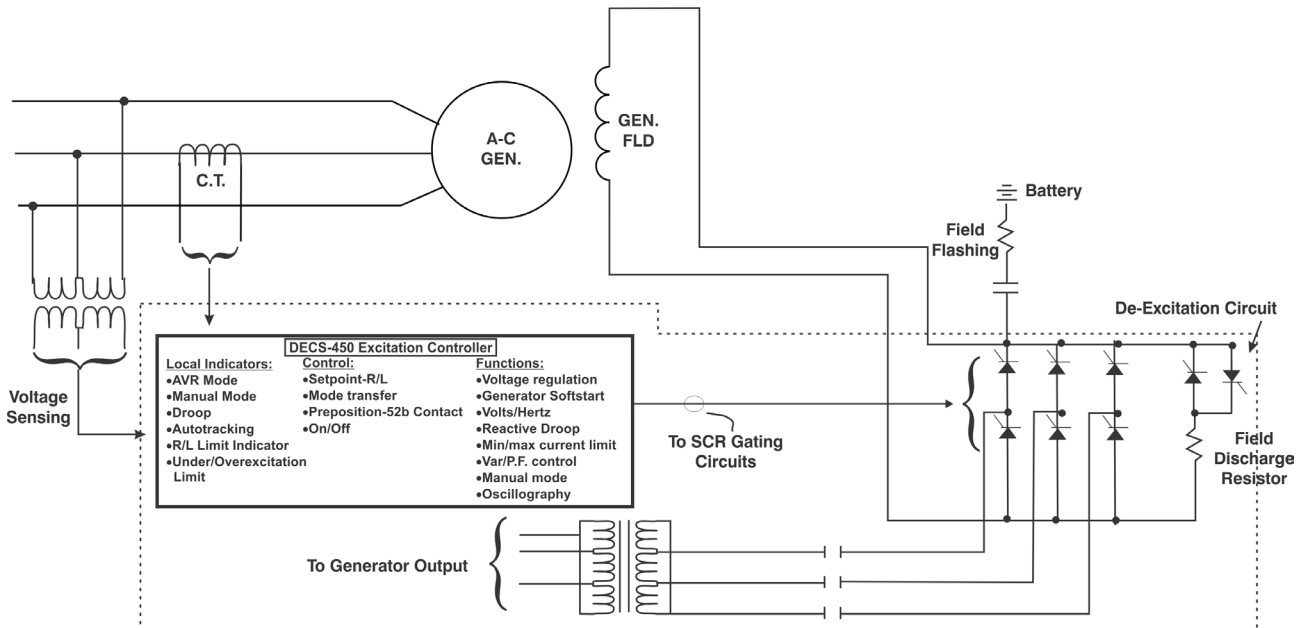
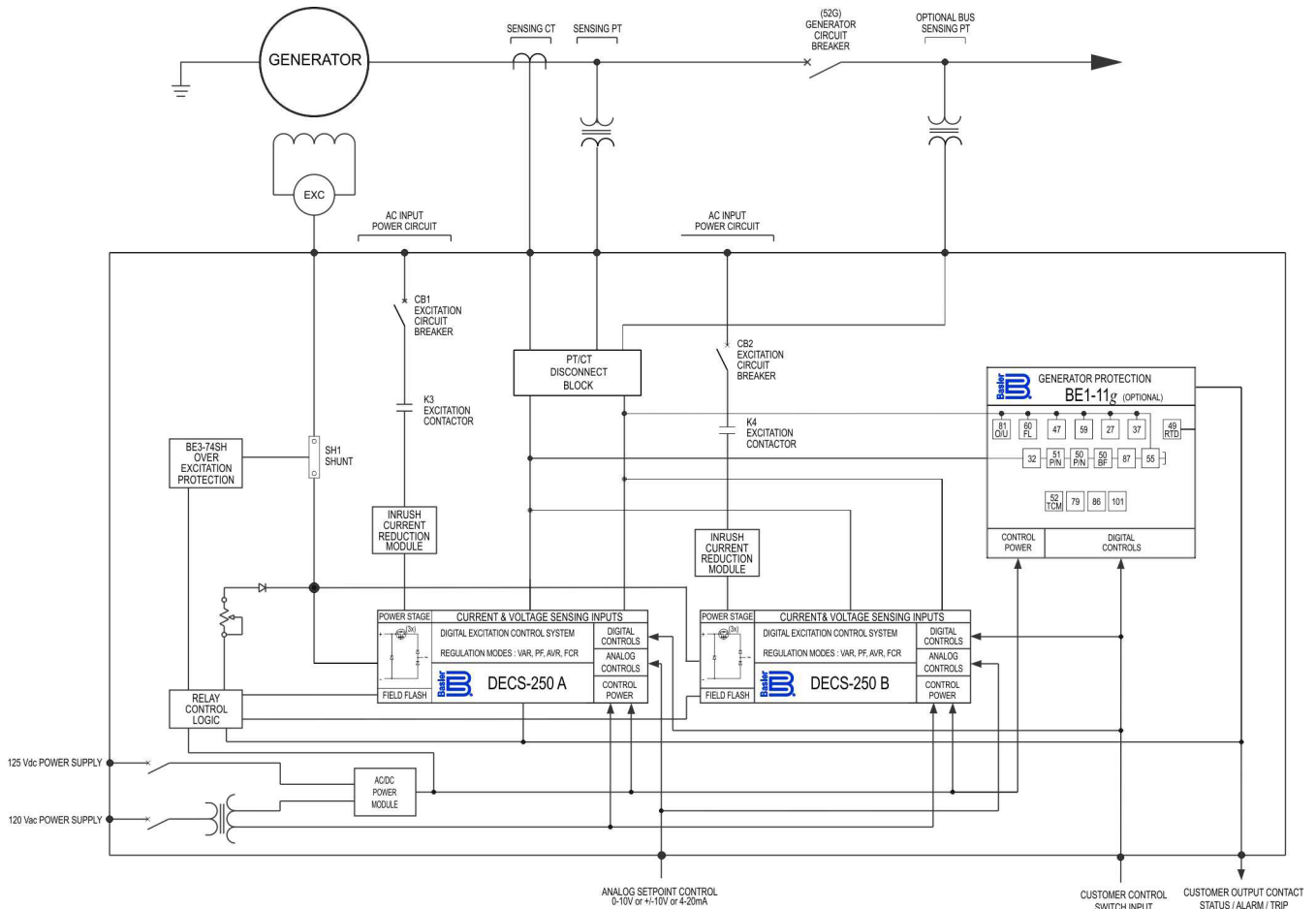


Figure 6: The replacement of the GFA-4 and rotary exciter for a static exciter interfacing to the main field



**Figure 7: Prepackaged Basler SGC-250 systems replace exciter field rheostat and voltage regulator**



**Figure 8: SGC-250 Prepackaged Basler Excitation Control System**

## DECS-250N and DECS-450 Features

- UL Recognized, CSA Qualified, CE Compliant
- Oscillography - 1,200 points, 6 programmable parameters, holds up to 6 records
- Meets ANSI C37.90.1 for Surge Withstand and Fast Transient
- Meets RFI (Radio Frequency Interference)
- Meets Conducted and Radiated Noise per IEC 60255-22-6 (Conducted) & 60255-22-3 (Radiated)
- Field current or field voltage regulator for standby mode and NERC testing
- Operating Temperature Range -40° to 60°C
- Voltage Regulation - 0.1% Accuracy for the DECS-450 and 0.2% Accuracy for the DECS-250N
- DECS-250N can be used for systems whose fields do not exceed 20 Adc continuous, DECS-450 for all systems greater than 20 Adc continuous
- Var/Power Factor Controller
- Automatic Nulling - Nulling between operating modes and redundant DECS
- Selectable Underfrequency or Volts/Hertz Ratio Limiter
- Minimum Excitation Limiter - Flexible 5 point map on real/ reactive power axis or Internal generated UEL curve
- Maximum Excitation Limiter
- Var Limiter
- Stator Current Limiter
- Dual PID Setting Groups - Allows for programmed changes in PID gain settings for use with Power System Stabilizer or alternate transmission systems
- Auto Tuning of the Voltage Regulator PID gains
- Auto Voltage Matching - Automatically matches generator voltage to bus voltage
- Auto Synchronizing (Device 25A) option
- Autotracking for bumpless transfer between Automatic Voltage Regulator (AVR), manual control, and Redundant Controller when included
- 3 Preposition Set points - Programmable for AVR, Manual, Var/PF Controller
- Reactive Droop or Line Drop Compensation, Network Reactive line sharing via Ethernet communications for multiple machine on a single bus
- Loss of Voltage Sensing - Transfers to manual control automatically due to loss of voltage sensing at the voltage regulator
- Sequence of events - stores 2,047 records
- Real time chart recorder, data logging including oscillography and sequence of event information for data capture up to six channels
- Built-in Dynamic Analyzer for measuring frequency response of generator and excitation system using Signal Generator
- Protection
  - Generator Overvoltage
  - Generator Undervoltage
  - Loss of Voltage Sensing
  - Field Overvoltage with Dual Settings Groups
  - Field Overcurrent with Dual Settings
  - Generator Overfrequency
  - Generator Underfrequency
  - Generator Reverse Power
  - Generator Loss of Excitation
  - Synch Check when 25A is disabled
  - Exciter Diode Monitor for Brushless
- Exciters
  - Generator Below 10Hz
  - Volts per Hertz: coordinates with the V/Hz limiter function
  - Loss of Field Isolation Transducer
  - Control Power Input Failure
  - Crowbar Activated
  - Field Over Temperature
  - Watchdog Timer: monitors the microprocessors and provides a trip contact if a microprocessor fault occurs
- Redundant Controller
- Field overvoltage, generator over/undervoltage, field overcurrent, and loss of field protections have dual set points selectable via programmable logic
- HMI Metering, Operating Screen - Metering, Control, Annunciation
- IRIG-B Time Synchronization stamp
- Generator Field Temperature Monitoring (Static Exciter)
- 5 Analog Transducers Outputs
- Optional Built-in Power System Stabilizer, Type 2A/2B/2C, Integral of Accelerating Power
- Phase Plot Compensator for Power System Stabilizer assisted tuning
- 6 SCR Bridge Rectifier
- RS-485
- Ethernet over Modbus® TCP
- BESTCOMSPPlus® common operating software to Basler Electric product family
- BESTlogic™Plus programmable logic
- Expandable Inputs and Outputs via remote modules

## DECS-250N and DECS-450 Auto Tuning

The DECS-250N and DECS-450 have a feature called PID auto tuning via BESTCOMSPPlus® operating software. Auto tuning is used during commissioning with the generator spinning. After initiation, the auto tuning feature is performed in less than a minute that will determine the PID gains for the generator. It accomplishes this with the spinning machine open circuited by performing number of voltage step changes to the generator output resulting in suggested gains. Additionally, the auto tuning will determine the machine Time Constants of the Exciter (te) (where applicable) and Generator (T'do"), which is

required data for generator modeling. The PID auto tuning process speeds commissioning to enable the generator to become fully operational sooner to the system.

## DECS-250N and DECS-450 Phase Plot Compensator

Additionally, a Phase Plot Compensators is provided with the Dynamic Frequency Analyzer to assist in evaluating the Power System Stabilizer Lead/Lag time filters selected that are derived from the Frequency Response of the generator system. Proper compensation is required for all systems that require a Power System Stabilizer. See Figure 9.

When the red and blue curves align in the Phase Lag graph below, proper compensation is achieved and test validation is then required.

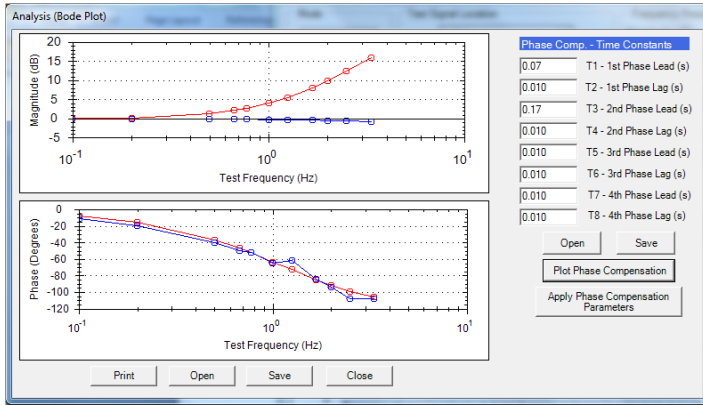


Figure 9: Frequency Response Results using Built-in Dynamic Analyzer

## BESTspace™

The DECS-250N and DECS-450 offer a setup commissioning tool in BESTCOMSP/plus operating software

that allows one to set up preferred monitoring screens from the Metering Explorer. BESTspace allows one to save the file as a "default" and it will come up on the preferred screen every time BESTCOMSP/plus is opened. Valuable time saved during setup speeds the commissioning preparation time for startup. See Figure 10.

## Solutions are Available

Solutions are available to replace obsolete GFA-4 voltage regulators to improve performance and provide years of additional service for existing generator systems.

## For More Information

For more information, call 618.654.2341 to consult with a Basler Excitation System Application Specialist or visit [www.basler.com](http://www.basler.com) to download a DECS-450 or DECS-250N product bulletin.

For technical papers on auto tuning and phase plot compensation visit [www.basler.com](http://www.basler.com).

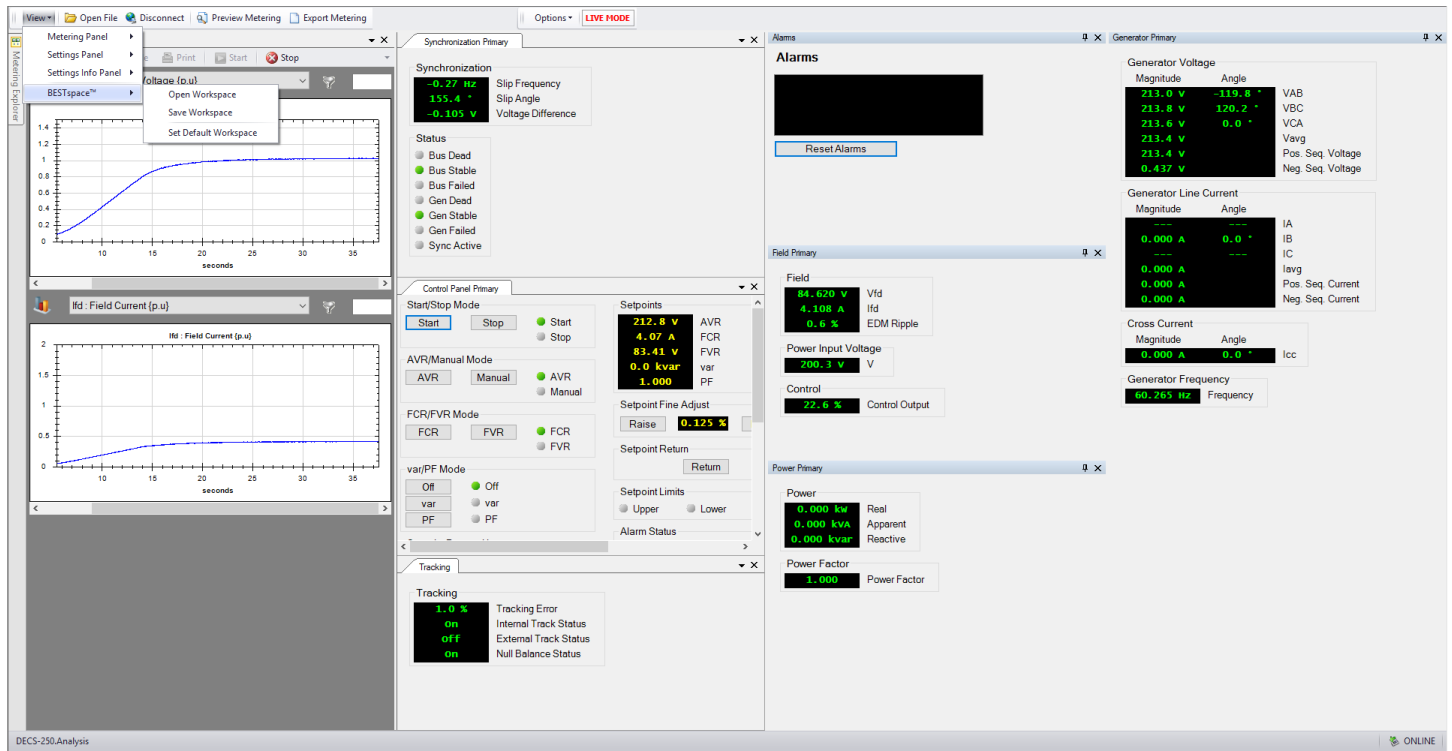


Figure 10: BESTspace