

# Application Note

## Basler Offers Retrofit Solution To Aging Amplidyne-Type Excitation System

**As capacity of generating units increased through the 1940s, turbine generator set manufacturers introduced new, “continuously-acting” voltage regulator/ excitation systems that dramatically improved the response of generators during system disturbances.**

Prior to the 1940s’ design, the noncontinuous-acting rheostat-type regulator system had been supplied on most generators through the late 1930s.

The new continuously-acting “dynamic amplification” systems – known by trade names such as “Amplidyne”, “mag a stat” or “Regulex” – were capable of automatically changing the generator excitation either positively or negatively in response to disturbances, which significantly improved both generator response and system stability over the manual operation previously utilized. They represented “state-of-the-art” excitation systems into the decade of the 1960s, with many such systems still in service.

Today, high maintenance costs and the diminishing availability of parts have made it difficult for owners to keep older equipment in reliable service. The purpose of this Application Note is to outline the solid-state voltage regulator and exciter system solutions available from Basler Electric to help owners assure continued long life for the aging generation system.



Figure 1: Continuous acting excitations systems, like the Amplidyne, were installed in generation plants between the 1940s and the 1960s.

### How It Works

Typical of these systems is the Amplidyne exciter/ regulator system shown in Figures 3 and 5. At the heart of the Amplidyne system was a variable output rotating dc supply whose field was controlled by a voltage regulator. The voltage regulator could increase or decrease the Amplidyne generator output in response to changes in generator terminal voltage to control an exciter field connected in series with a variable rheostat.

Figure 2 shows the Amplidyne and rheostat.

Depending upon the age of the machine, the Amplidyne could have been configured to control a single exciter field (see Figure 5) or with two split exciter fields (see Figure 3).

The Amplidyne eliminated the need for the pilot exciter normally used to provide excitation to the rotating exciter via the large rheostat. Unlike older systems, however, the Amplidyne could reverse its output to provide both a positive or negative output to the exciter to speed system response.

The Amplidyne was powered by a three phase ac motor that received its source voltage from the station auxiliary bus. The generator output was designed to be controlled either by a rheostatic element or automatically, via the Amplidyne, combined with a voltage regulator.

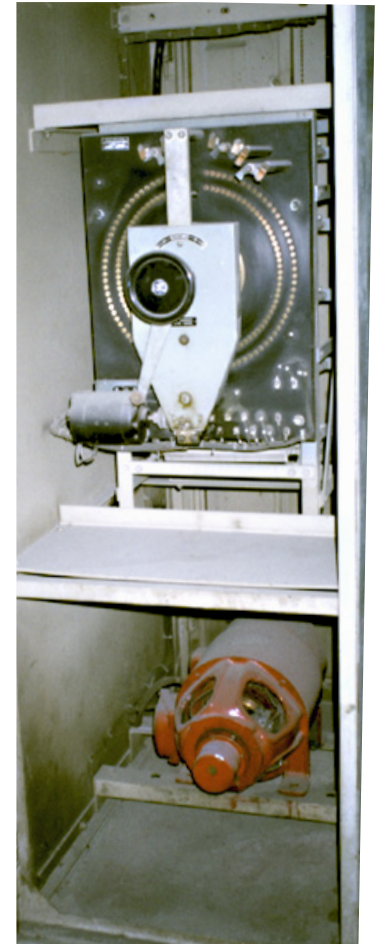


Figure 2: An Amplidyne mounted below a motor-operated rheostat.

In manual, the exciter armature would provide the exciter field current, via a large wirewound rheostat to provide voltage control of the machine voltage.

In automatic control, the rheostat element established only the nominal setpoint of the generator at rated load. The voltage regulator controlled the Amplidyne output via the control field winding. (See Figure 3.) Depending upon the sensed generator voltage, the voltage regulator would vary its output, which caused the Amplidyne to buck or boost against the exciter field current.

When the generator voltage was normal, the Amplidyne voltage output was zero, hence no buck or boosting action was required. If, however, the generator output voltage would rise, the voltage regulator would detect the rise and cause the Amplidyne to change its output voltage in an action commonly referred to as “bucking”. This resulted in a new exciter field current that was less than the nominal field current. The lower field current resulted in a decrease in generator terminal voltage. Alternatively, should the

generator terminal voltage decrease, the voltage regulator increased its output to the control field, causing a “boost” action from the Amplidyne to increase the exciter field current and restore the generator voltage back to normal. The Amplidyne voltage regulator included an underexcitation limiter to ensure sufficient reactive power for the megawatts being exported into the system. It also included a maximum excitation limiter to limit prolonged field forcing currents that could cause excess rotor heating.

The early Amplidyne used an NA101 voltage regulator, while the NA143 was used with Amplidyne of the 1950s through 1960s.

Figure 4 shows a cabinet with field switches and the Amplidyne voltage regulator.

For small generators, the rotating exciter was completely eliminated and instead, the Amplidyne supplied excitation directly into the main field.

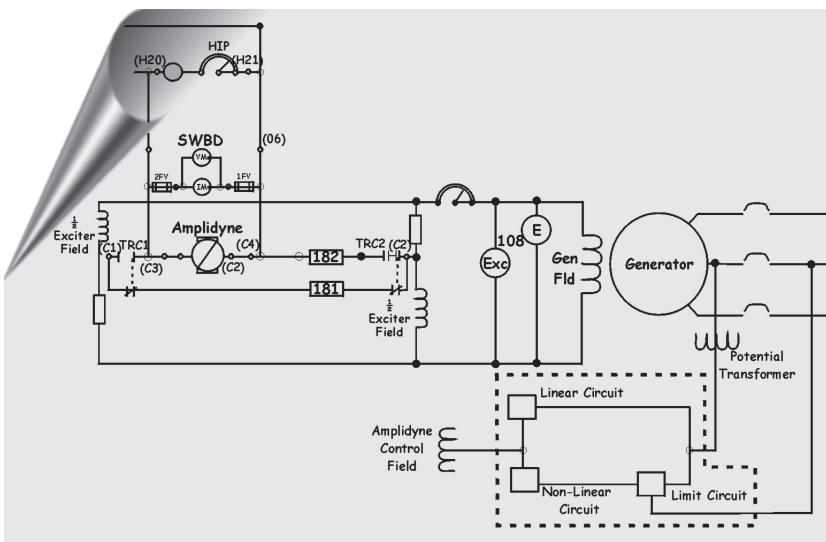


Figure 3: Another typical scheme for the Amplidyne system was to control two split exciter fields.



Figure 4: A system with field switches and an Amplidyne voltage regulator

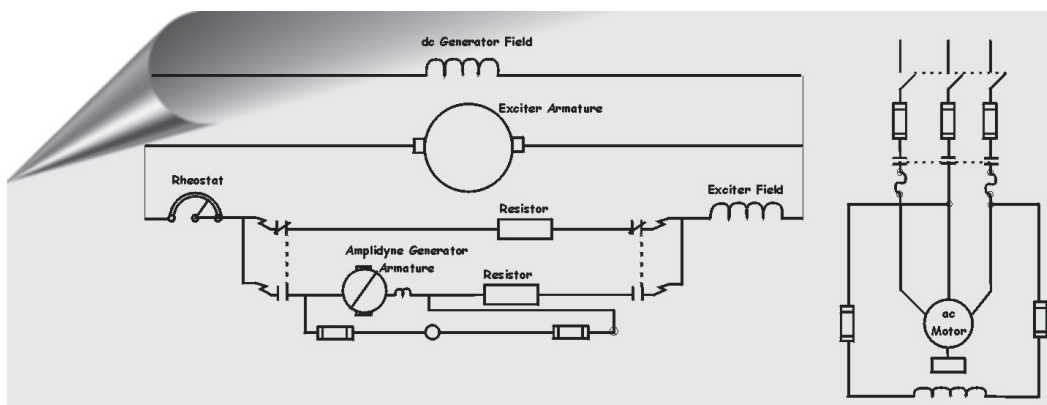


Figure 5: The Amplidyne system controls a single exciter field in series with a variable rheostat.

## Excitation System Options: Static Exciter or Voltage Regulator

There are two possible solutions for upgrading the Amplidyne excitation system:

1. The Amplidyne and the rotating exciter can be replaced with a static exciter that works directly into the main generator field using a DECS-450 excitation system. See Figure 6.
2. The use of the Amplidyne can be eliminated and instead, a new voltage regulator system can be provided. The new system works directly into the exciter field using a DECS-250N (Negative Field forcing) for fields 20 Adc and below, while the DECS-450 works for fields greater than 20 Adc. See Figure 7.

## Static Exciter Solution (Eliminate Rotating Exciter)

The best solution involves the replacement of the rotating exciter for a static exciter connected into the generator's main field. The static exciter provides multiple benefits. These include improved transient voltage response, steady state stability performance, and with the benefit of high operating efficiency that reduces waste heat losses. Additionally, it virtually eliminates system maintenance and improves excitation system reliability.

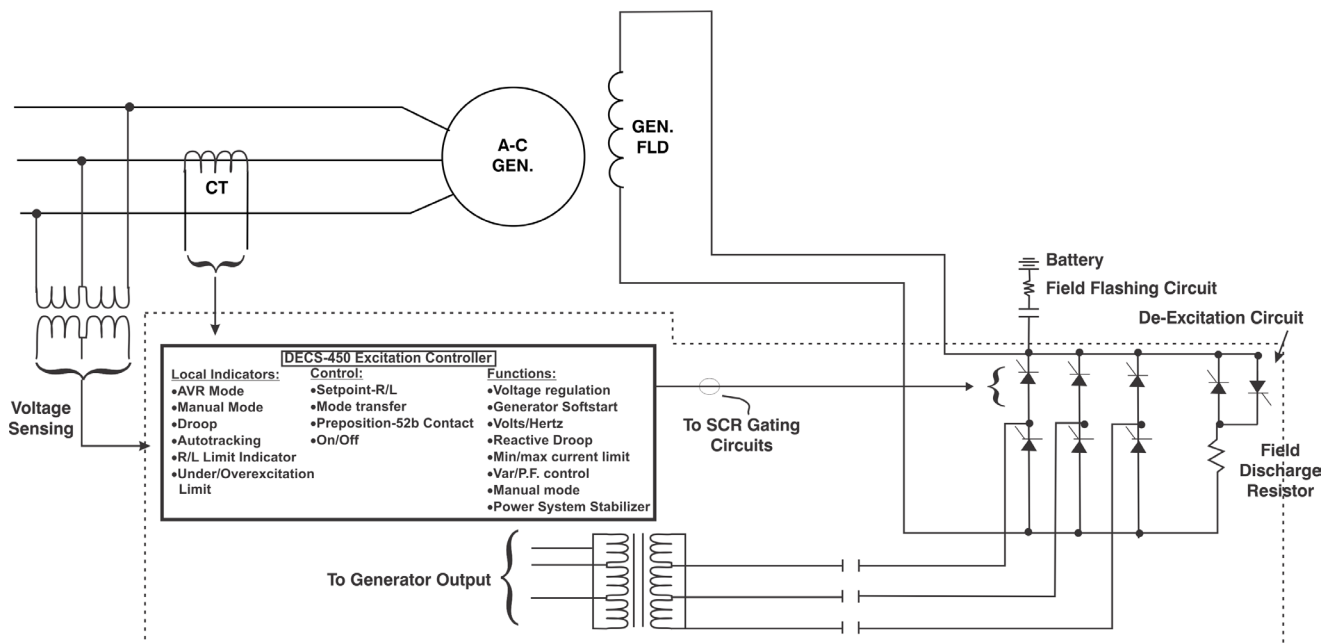


Figure 6: The replacement of the Amplidyne and rotating exciter for a modern static exciter interfacing to the main field.

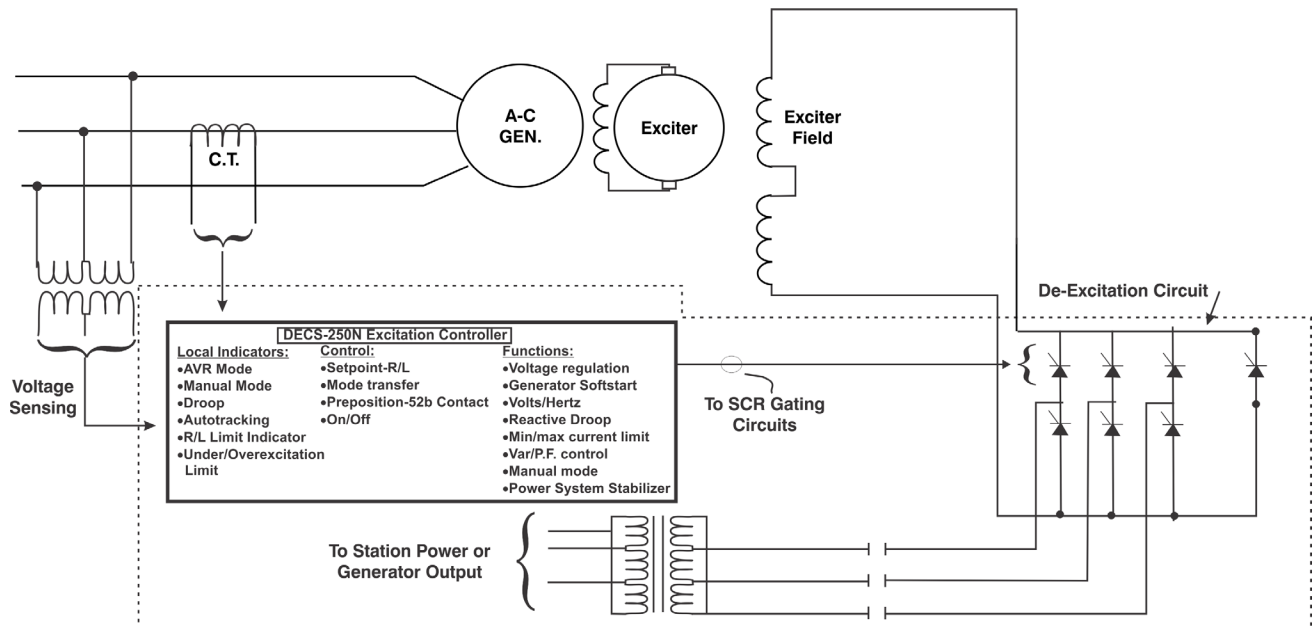


Figure 7: New DECS-250N voltage regulator interface with rotating exciter field.

The static exciter contains a power rectifier bridge and power potential transformer sized to meet the full load field requirements of the generator.

Figure 6 highlights the interface of the static exciter to the main field. The static exciter power bridge provides dc into the field. The excitation system is equipped with both positive and negative field forcing to improve generator voltage recovery time. A field discharge resistor accompanied by a solid state field discharge circuit eliminates the need for the dc field breaker. SCRs are connected in anti-parallel across the field with a series discharge resistor to provide an alternate energy path to discharge the field energy. The excitation system output ratings are selected based upon the generator full load field excitation requirements.

### Voltage Regulator System (Eliminates Rheostat and Amplidyne)

For some systems, where the rotating exciter is in good condition and only the Amplidyne excitation system has operational problems, an alternative solution may be to retain the rotating exciter and utilize only the exciter shunt field. The new excitation system will eliminate the need for the Amplidyne, the rheostat, and the existing voltage regulator system. Figure 7 illustrates the changes involved with a new DECS-250N voltage regulator excitation system.

Like the full static exciter solution, a DECS-250N excitation system is used that provides 0.2% voltage regulation, dc field current regulator, var/PF control, excitation limiters, volts/Hertz limiting, autotracking, and follower circuits for ensuring bumpless transfer between modes, plus additional features to provide a complete and automatic control system to regulate the generator output.

Positive and negative field forcing from the power converter bridge, combined with a tuned stability network provides extremely fast response to system disturbances.

Power for the excitation system can be derived from the station power source, however; reliability of the source must be considered. Loss of the power source under load will result in loss of excitation to the machine and subsequent pole slip.

Although most of these systems derive power from the station bus, the new excitation system also may derive its power from the generator output, as shown in Figure 7. The power potential transformer primary voltage matches the generator output while the secondary voltage matches

the ac voltage required to provide the continuous and forcing requirements of the field.

In addition, the rated load excitation requirement of the exciter field needs to be obtained in order to properly select the excitation system power ratings.

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

The DECS-250/N 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 ( $\tau_e$ ) (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

A Phase Plot Compensator 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 8. When the red and blue curves align in the Phase Lag graph below, proper compensation has been achieved and test validation is then required.

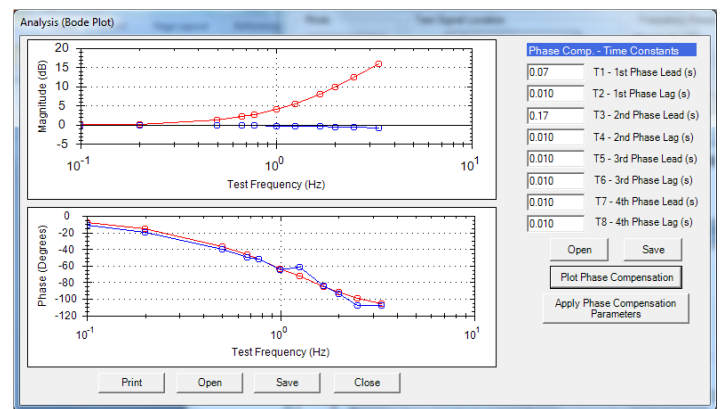


Figure 8: Frequency Response Results using Built-in Dynamic Analyzer

## 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

## BESTspace™

The DECS-450 offers a setup commissioning tool in BESTCOMSPPlus 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 BESTCOMSPPlus is opened. Valuable time saved during setup speeds the commissioning preparation time for startup. See Figure 9.

## Solutions are available

Solutions are available today to retrofit the Amplidyne, creating a new excitation system that will improve performance and offer years of additional service for existing generator systems. See Figure 10.

## 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: New DECS-250 and DECS-450 regulator/excitation packages eliminate the Amplidyne, rheostat, and obsolete voltage regulator.

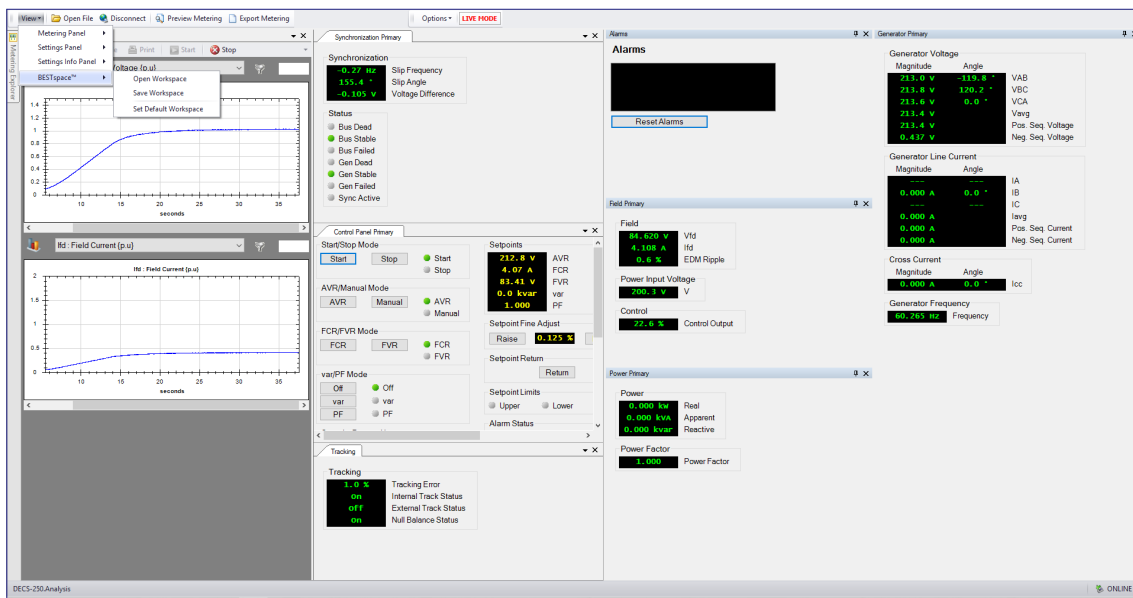


Figure 9: BESTspace