— ANNEX I. SOME CONTROL VARIABLES USED WITH AEL-MPSS MODULAR SMART GRID POWER SYSTEMS —

The AEL-MPSS Modular Power Systems is one of the most advanced and complete modular power systems of the market. In the following pages the most important variables which allow the control of the system both in local and remote through the included SCADA are indicated.

The following are the most important **285 control variables** that make the AEL-MPSS a forefront system able to interact with the user thanks to the cutting-edge included devices.

The AEL-MPSS has been designed to show any electric phenomenon that are present in real power systems, such as short circuits, over currents, over voltages, over frequencies, reverse power, generator runaway, etc.

A variable is any element or symbol of our system susceptible to be modified directly or indirectly by the user and the control system.

All power systems are formed by three fundamental parts:

1. Generation System.

2. Transmission/Distribution System.

3. Load System.

1. Generation System:

   Power generation is the point where all power systems born, where transmission lines emerge up to distribution lines and finally, to give electrical service to the final consumer. It is necessary a great quantity of control variables for a power system reliable, safe and optimal because of these variables depend the electrical energy quality. This is the reason why the generation systems of the AEL-MPSS includes the **145 control variables** most important that will allow user to interact with a sophisticated, real and intelligent generation system, which is able to respond automatically against energy demand, it is able to protect automatically against short circuits, with light indicators and alarms that will allow us to understand at all time the generation system state.

   See the 145 control variables in next page.

2. Transmission/Distribution System:

   After power generation, transmission and distribution systems are required to give power to the final consumer. These systems are highways of aluminum and steel which transport great quantities of power up to strategic points of the country and even other countries. In the transmission systems is very important to know variables such as transported energy, length transmission lines, capacitive effect, energy losses produced along kilometers and kilometers, etc. Besides, in a transmission line system is not enough a conventional protection system. For these systems are required distance protection relays able to detect changes in the line impedances and to sense undetectable anomalies for other conventional protection relays.

   Distribution substations adapt the transmission lines voltage levels up to lower voltage levels for energy distribution. On this point take importance the distribution transformer with voltage regulator, which are able to compensate the transmission liens drop voltages.

   The transmission/distribution power system of AEL-MPSS allows to study all these control variables and much more. In the following page the most important **76 control variables** that allow the user to interact with the transmission/distribution system are listed.

   See the 76 control variables in next page.

3. Load System:

   Once the energy is transported, this has to be carried to the consumption points through distribution lines. Final consumer provokes changes in the power balance of the system from generation up to distribution. On this way, all machinery of the system (generation, transmission and distribution) works in real time in order to the electrical parameters remain constants in the consumption points.

   In the consumption points is very important to ensure the electrical energy quality through reactive energy compensation devices. Besides, on this point are essential the feeders management protection relays, which are installed in strategic points of the distribution lines giving to the grid the required reliability, safety and efficiency. These protection relays monitor electrical variables such as frequency, voltage, current, power factor, etc. in order to protect the grid.

   In the following page the most important **64 control variables** which allow user to interact with the load system are listed.

   See the 64 control variables in next page.

The most important 285 control variables which allow user to interact with the load system are listed below:

1. **Generation System: the most important and used 145 physical variables in the industrial power systems.**

1.1. Some general control variables of the Turbine-Generator group.

- Manual Control Variable for emergency stop of the Turbine-Generator group.
- Control Variable for starting order of the Turbine-Generator in automatic mode.
- Permission Variable for synchronization in automatic mode.

1.2. Local Control Mode of Turbine-Generator group.

1.2.1. Local Control of the group in manual mode.

- Island mode:

- Manual Control Variable for turbine frequency/speed control with analog potentiometer.
- Manual Control Variable for synchronous generator excitation with analog potentiometer.
- Manual Control Variable for 52G breaker open/close.

- "Load sharing/parallel grid" mode:

- Manual Control Variable for synchronization the generator and the grid.
- Manual Control Variable for Active Power given to the grid.
- Manual Control Variable for Reactive Power given to the grid.
- Manual Control Variable for 52G breaker open/close.

1.2.2. Local Control of the group in automatic mode.

- Island mode:

- Automatic Control Variable for turbine frequency/speed control through AVR (Automatic Voltage Regulator).
- Automatic Control Variable for synchronous generator excitation/voltage control through AVR (Automatic Voltage Regulator).
- Automatic Control Variable for line and phase voltages.
- Automatic Control Variable for Reactive Power given to the grid.
- Automatic Control Variable for maximum line current.
- Automatic Control Variable for 52G breaker open/close.

- "Load sharing/parallel grid" mode:

- Automatic Control Variable for synchronization the synchronous generator with the grid.
- Automatic Control Variable for Active Power given to the grid.
- Automatic Control Variable for Active Power maximum limit.
- Automatic Control Variable for Reactive Power given to the grid.
- Automatic Control Variable for Reactive Power maximum limit.
- Automatic Control Variable for adjusting the synchronous generator optimum power factor.
- Automatic Control Variable for 52G breaker open/close.
- Automatic Control Variable for line and phase voltages.
- Automatic Control Variable for maximum line current.

1.3. Remote Control (SCADA) of Turbine-Generator group

1.3.1. Manual Remote Control (SCADA) of Turbine-Generator group.

- Island Mode:

- Manual Control Variable for turbine frequency/speed control with analog potentiometer.
- Manual Control Variable for synchronous generator excitation with analog potentiometer.
- Manual Control Variable for 52G breaker open/close.

- Load Sharing/Parallel Grid Mode:

- Manual Control Variable for synchronization the generator and the grid.
- Manual Control Variable for Active Power given to the grid.
- Manual Control Variable for Reactive Power given to the grid.
- Manual Control Variable for 52G breaker open/close.

1.3.2. Automatic Remote Control (SCADA) of Turbine-Generator group.

- Island Mode:

- Automatic Control Variable for turbine frequency/speed control through AVR (Automatic Voltage Regulator).
- Automatic Control Variable for synchronous generator excitation/voltage control through AVR (Automatic Voltage Regulator).
- Automatic Control Variable for line and phase voltages.
- Automatic Control Variable for Reactive Power given to the grid.
- Automatic Control Variable for maximum line current.
- Automatic Control Variable for 52G breaker open/close.

- Load Sharing/Parallel Grid Mode:

- Automatic Control Variable for synchronization the synchronous generator with the grid.
- Automatic Control Variable for Active Power given to the grid.
- Automatic Control Variable for Active Power maximum limit.
- Automatic Control Variable for Reactive Power given to the grid.
- Automatic Control Variable for Reactive Power maximum limit.
- Automatic Control Variable for adjusting the synchronous generator optimum power factor.
- Automatic Control Variable for 52G breaker open/close.
- Automatic Control Variable for line and phase voltages.
- Automatic Control Variable for maximum line current.

1.4. Control Variables for protection system.

1.4.1. Over Current and Earth fault protection relay.

- Configuration variable for the current transformer relationship.
- Configuration variable for the voltage transformer relationship.
- Configuration variable for the removing fault time (TRIP duration).
- Configuration variable for Level 1 instantaneous overcurrent 50P1P.
- Configuration variable for Level 2 instantaneous overcurrent 50P2P.
- Configuration variable for Level 3 instantaneous overcurrent 50P3P.
- Configuration variable for Level 4 instantaneous overcurrent 50P4P.
- Configuration variable for Level 5 instantaneous overcurrent 50P5P.
- Configuration variable for Level 6 instantaneous overcurrent 50P6P.
- Configuration variable for the inverse time overcurrent parameter threshold.
- Configuration variable for inverse time curve type 51P1T: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.

1.4.1. Over Current and Earth fault protection relay. (continuation)

- Configuration variable for the 51P1T Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for the 51P2T inverse time curve threshold.
- Configuration variable for inverse time curve type 51P2T: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for the 51P2P Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50N1 neutral instantaneous overcurrent threshold.
- Configuration variable for 50N2 neutral instantaneous overcurrent threshold.
- Configuration variable for 51N1T inverse time neutral overcurrent parameter threshold.
- Configuration variable for inverse time curve type 51N1T: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for the 51N1T Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50G1 instantaneous residual overcurrent parameter threshold.
- Configuration variable for 50G2 instantaneous residual overcurrent parameter threshold.
- Configuration variable for 50G1T inverse time residual overcurrent parameter threshold.
- Configuration variable for inverse time curve type 51G1T: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for the 51G1T Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 51Q1P negative sequence instantaneous overcurrent parameter threshold.
- Configuration variable for 51Q2P negative sequence instantaneous overcurrent parameter threshold.
- Configuration variable for 51Q1T inverse time overcurrent parameter threshold.
- Configuration variable for inverse time curve type 51Q1T: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for the 51Q1T Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 51Q2T inverse time overcurrent parameter threshold.
- Configuration variable for inverse time curve type 51Q2T: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for the 51Q2T Time-Dial of the inverse time overcurrent protection curve parameter.

1.4.2. Differential Protection Relay of Step-Up power transformer

- Configuration variable for the current transformer relationship.
- Configuration variable for the voltage transformer relationship.
- Configuration variable for the removing fault time (TRIP duration).
- Configuration variable for power transformer connection type.
- Configuration variable for measurement transformer connection type.
- Configuration variable for 87P differential protection element.
- Configuration variable for SLP1 restriction percentage of 87P differential element.
- Configuration variable for SLP2 restriction percentage of 87P differential element.

- Configuration variable for 2° harmonic restriction percentage.
- Configuration variable for 4° harmonic restriction percentage.
- Configuration variable for 5° harmonic restriction percentage.
- Configuration variable for 50P1P instantaneous overcurrent level of the primary winding power transformer.
- Configuration variable for 51P1D define time instantaneous overcurrent level of the primary winding power transformer.
- Configuration variable for 51P1P inverse time overcurrent threshold of the power transformer primary winding.
- Configuration variable for inverse time curve type 51P1P: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for the 51P1P Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50Q1P negative sequence instantaneous overcurrent threshold of the power transformer primary winding.
- Configuration variable for 51Q1P negative sequence inverse time overcurrent threshold of the power transformer primary winding.
- Configuration variable for inverse time curve type 51Q1P: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for 51Q1P Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50N1P instantaneous residual overcurrent threshold of the power transformer primary winding.
- Configuration variable for 50N1P inverse time residual overcurrent threshold of the power transformer primary winding.
- Configuration variable for inverse time curve type 51N1P: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for 51N1P Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50P2P instantaneous overcurrent level of the power transformer secondary winding.
- Configuration variable for 50P2D define time instantaneous overcurrent level of the power transformer secondary winding.
- Configuration variable 51P2P inverse time overcurrent threshold of the power transformer secondary winding.
- Configuration variable for inverse time curve type 51P2P: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for 51P2P Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50Q2P negative sequence instantaneous overcurrent threshold of the power transformer secondary winding.
- Configuration variable for 51Q2P negative sequence inverse time overcurrent threshold of the power transformer secondary winding.
- Configuration variable for inverse time curve type 51Q2P: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for 51Q2P Time-Dial of the inverse time overcurrent protection curve parameter.
- Configuration variable for 50N2P instantaneous residual overcurrent threshold of the power transformer secondary winding.
- Configuration variable for 50N2P inverse time residual overcurrent threshold of the power transformer primary winding.
- Configuration variable for inverse time curve type 51N2P: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5.
- Configuration variable for 51N2P Time-Dial of the inverse time overcurrent protection curve parameter.

1.4.3. Protection Relay of Turbine-Generator Group.

- Configuration variable of synchronous generator nominal power.
- Configuration variable of synchronous generator poles number.
- Configuration variable of instantaneous overcurrent protection threshold.
- Configuration variable of inverse time overcurrent protection threshold.
- Configuration variable of overvoltage protection threshold.
- Configuration variable of undervoltage protection threshold.
- Configuration variable of overfrequency protection threshold.
- Configuration variable of subfrequency protection threshold.
- Configuration variable of reverse power level.
- Configuration variable of Proportional, Integral and Derivative (PID) for Turbine-Generator group control and regulation.

1.5. Control variables of double bus bar generation substation switchgear. Local and remote control possibility (SCADA).

- Control variable of open/close 89GC1-1 coupling disconnector.
- Control variable of open/close 89GC1-2 coupling disconnector.
- Control variable of open/close 52GC1-1 coupling breaker.
- Control variable of open/close 89GT1-1 transformer disconnector.
- Control variable of open/close 89GT1-2 transformer disconnector.
- Control variable of open/close 89GT1-3 transformer disconnector.
- Control variable of open/close 52GT1-1 transformer breaker.
- Control variable of open/close 52NET grid breaker.
- Control variable of open/close 52G1 generation breaker.

1.6. Control variables for faults selection.

1.6.1. Local/Remote control (SCADA):

- Control variable for direct single phase short preselection.
- Control variable for single phase short circuit with fault impedance.
- Control variable for direct two phases to ground short circuit preselection.
- Control variable for two phases to ground short circuit preselection with fault impedance.
- Control variable for direct two phase short circuit preselection.
- Control variable for two phase short circuit preselection with fault impedance.
- Control variable for direct three-phase phase short circuit preselection.
- Control variable for three-phase phase short circuit preselection with fault impedance.
- Control variable for fault injection.

2. **Transmission/Distribution System: the most important and used 76 physical variables in the industrial power systems.**

2.1. Control variables of double bus bar emitter substation switchgear. Possibility to control both local and remote modes (SCADA).
- Control variable of open/close 89T1-1 disconnector.
- Control variable of open/close 89T1-2 disconnector.
- Control variable of open/close 89T1-3 disconnector.
- Control variable of open/close 52T1-1 breaker.

2.2. Control variables of double bus bar receptor substation switchgear. Possibility to control both local and remote modes (SCADA).
- Control variable of open/close 89L1-1 disconnector.
- Control variable of open/close 89L1-2 disconnector.
- Control variable of open/close 89L1-3 disconnector.
- Control variable of open/close 52T2-1 breaker.

2.3. Control variables of distribution transformer voltage regulator. Possibility to control both local and remote modes (SCADA).
- Control variable for voltage regulation at 0 %.
- Control variable for voltage regulation at 2, 5 %.
- Control variable for voltage regulation at 5 %.
- Control variable for voltage regulation at 7, 5 %.
- Control variable for voltage regulation at -2, 5 %.
- Control variable for voltage regulation at -5 %.
- Control variable for voltage regulation at -7,5 %.

2.4. Control variables of transmission line parameters. Local and remote control possibility (SCADA).
- Variable control for line resistor.
- Variable control for line inductance.
- Variable control for line capacitance.
- Variable control for breaking line 1.
- Variable control for breaking line 1 and line 2.
- Variable control for breaking line 1, line 2 and line 3.

2.5. Control variables of distance protection relay.
- Configuration variable for current transformer relationship.
- Configuration variable for voltage transformer relationship.
- Configuration variable for remove fault duration.
- Configuration variable for line impedance.
- Configuration variable for length line.
- Configuration variables for Mho distance elements.
  - Configuration variable for Z1P instantaneous distance element of zone 1.
  - Configuration variable for Z2P instantaneous distance element of zone 2.
  - Configuration variable for Z3P instantaneous distance element of zone 3.
  - Configuration variable for Z4P instantaneous distance element of zone 4.
  - Configuration variable for 50PP1 instantaneous overcurrent element of zone 1.
  - Configuration variable for 50PP2 instantaneous overcurrent element of zone 2.
  - Configuration variable for 50PP3 instantaneous overcurrent element of zone 3.
  - Configuration variable for 50PP4 instantaneous overcurrent element of zone 4.
  - Configuration variable for Z1MG ground impedance element of zone 1.

- Configuration variable for Z2MG ground impedance element of zone 2.
- Configuration variable for Z3MG ground impedance element of zone 3.
- Configuration variable for Z4MG ground impedance element of zone 4.
- Configuration variable for Z1D time distance element of zone 1.
- Configuration variable for Z2D time distance element of zone 2.
- Configuration variable for Z3D time distance element of zone 3.
- Configuration variable for Z4D time distance element of zone 4.

- Configuration variable for 50P1P instantaneous overcurrent element of level 1.
- Configuration variable for 50P2P instantaneous overcurrent element of level 2.
- Configuration variable for 50P3P instantaneous overcurrent element of level 3.
- Configuration variable for 50P4P instantaneous overcurrent element of level 4.
- Configuration variable for 67P1D define time overcurrent element of level 1.
- Configuration variable for 67P2D define time overcurrent element of level 2.
- Configuration variable for 67P3D define time overcurrent element of level 3.
- Configuration variable for 67P4D define time overcurrent element of level 4.
- Configuration variable for 50G1P residual instantaneous overcurrent element of level 1.
- Configuration variable for 50G2P residual instantaneous overcurrent element of level 2.
- Configuration variable for 50G3P residual instantaneous overcurrent element of level 3.
- Configuration variable for 50G4P residual instantaneous overcurrent element of level 4.
- Configuration variable for 67G1P residual define time overcurrent element of level 1.
- Configuration variable for 67G2P residual define time overcurrent element of level 2.
- Configuration variable for 67G3P residual define time overcurrent element of level 3.
- Configuration variable for 67G4P residual define time overcurrent element of level 4.
- Configuration variable for 50Q1P negative sequence instantaneous overcurrent element of level 1.
- Configuration variable for 50Q2P negative sequence instantaneous overcurrent element of level 2.
- Configuration variable for 50Q3P negative sequence instantaneous overcurrent element of level 3.
- Configuration variable for 50Q4P negative sequence instantaneous overcurrent element of level 4.
- Configuration variable for 67Q1D negative sequence define time overcurrent element of level 1.
- Configuration variable for 67Q2D negative sequence define time overcurrent element of level 2.
- Configuration variable for 67Q3D negative sequence define time overcurrent element of level 3.
- Configuration variable for 67Q4D negative sequence define time overcurrent element of level 4.

2.5. Control variables of distance protection relay. (continuation)

- Configuration variable for 51PP inverse time overcurrent element of level 1.

- Configuration variable for 51PP inverse time overcurrent element type: U1-U5, C1-C5.

- Configuration variable for 51PP "Time Dial".

- Configuration variable for 51GP inverse time residual overcurrent element.

- Configuration variable for 51GP inverse time overcurrent element type: U1-U5, C1-C5.

- Configuration variable for 51GP "Time Dial".

- Configuration variable for 51QP inverse time negative sequence overcurrent element.

- Configuration variable for 51QP inverse time overcurrent element type: U1-U5, C1-C5.

- Configuration variable for 51QP "Time Dial".

- Configuration variable for directional element.

3. **Load System: the most important and used 64 physical variables in the industrial power systems.**

3.1. Control variables of double bus bar emitter distribution substation switchgear. Local and remote control possibility (SCADA).

- Control variable of open/close 89T2-1 disconnector.
- Control variable of open/close 89T2-2 disconnector.
- Control variable of open/close 89T2-3 disconnector.
- Control variable of open/close 52T2-1 breaker.
- Control variable of open/close 89T1-1 disconnector.
- Control variable of open/close 89T1-2 disconnector.
- Control variable of open/close 89T1-3 disconnector.
- Control variable of open/close 52T1-1 breaker.

3.2. Control variables for the connected type load. Possibility to control both local and remote modes (SCADA).

- Control variable for minimum resistive load.
- Control variable for medium resistive load.
- Control variable for maximum resistive load.
- Control variable for minimum inductive load.
- Control variable for medium inductive load.
- Control variable for maximum inductive load.
- Control variable for minimum capacitive load.
- Control variable for medium capacitive load.
- Control variable for maximum capacitive load.

3.3. Control variables for load power factor compensation. Possibility to control both local and remote modes (SCADA).

The load system has an automatic power factor controller able to remain constant the load power factor according to the set point previously adjusted by the user. Six capacitor steps give more or less reactive power in function of the connected load.

3.4. Control variables of feeder management protection relay

- Configuration variable for current transformer relationship.
- Configuration variable for voltage transformer relationship.
- Configuration variable for remove fault duration.
- Configuration variable for 50P1P instantaneous overcurrent of element 1.
- Configuration variable for 50P1D define time overcurrent of element 1.
- Configuration variable for 50P2P instantaneous overcurrent of element 2.
- Configuration variable for 50P2D define time overcurrent of element 2.
- Configuration variable for 50P3P instantaneous overcurrent of element 3.
- Configuration variable for 50P3D define time overcurrent of element 3.
- Configuration variable for 50P4P instantaneous overcurrent of element 4.
- Configuration variable for 50P4D define time overcurrent of element 4.
- Configuration variable for 50N1P instantaneous to neutral overcurrent of element 1.
- Configuration variable for 50N1D define time neutral overcurrent of element 1.
- Configuration variable for 50N2P instantaneous to neutral overcurrent of element 2.
- Configuration variable for 50N2D define time neutral overcurrent of element 2.
- Configuration variable for 50N3P instantaneous to neutral overcurrent of element 3.
- Configuration variable for 50N3D define time neutral overcurrent of element 3.
- Configuration variable for 50N4P instantaneous to neutral overcurrent of element 4.
- Configuration variable for 50N4D define time neutral overcurrent of element 4.
- Configuration variable for 50G1P instantaneous residual overcurrent of level 1.
- Configuration variable for 50G1D define time residual overcurrent of element 1.
- Configuration variable for 50G2P instantaneous residual overcurrent of level 2.
- Configuration variable for 50G2D define time residual overcurrent of element 2.
- Configuration variable for 50G3P instantaneous residual overcurrent of level 3.
- Configuration variable for 50G3D define time residual overcurrent of element 3.
- Configuration variable for 50G4P instantaneous residual overcurrent of level 4.
- Configuration variable for 50G4D define time residual overcurrent of element 4.
- Configuration variable for 50Q1P instantaneous negative sequence of element 1.
- Configuration variable for 50Q1D define time negative sequence overcurrent of element 1.
- Configuration variable for 50Q2P instantaneous negative sequence of element 2.
- Configuration variable for 50Q2D define time negative sequence overcurrent of element 2.
- Configuration variable for 50Q3P instantaneous negative sequence of element 3.
- Configuration variable for 50Q3D define time negative sequence overcurrent of element 3.
- Configuration variable for 50Q4P instantaneous negative sequence of element 4.
- Configuration variable for 50Q4D define time negative sequence overcurrent of element 4.
- Configuration variable for 55 power factor element.
- Configuration variable for 3PW power element.
- Configuration variable for 87D1TP frequency element 1.
- Configuration variable for 87D2TP frequency element 2.
- Configuration variable for 87D3TP frequency element 3.
- Configuration variable for 87D4TP frequency element 4.
- Configuration variable for 87D5TP frequency element 5.
- Configuration variable for 87D6TP frequency element 6.
- Configuration variable for 27P1P sub-voltage element 1.
- Configuration variable for 27P2P sub-voltage element 2.
- Configuration variable for 59P1P over-voltage element 1
- Configuration variable for 59P2P over-voltage element 2.