Firmware Tde Macno

User's manual

# OPDE Energy application n°3


MW01501E00 V_1.3

# TABLE OF CONTENTS

# APPLICATION VERSION 3.04

# 1 OVERVIEW

The OPDE_Energy application integrates within the AFE converter all of the functions required to manage the "OPDE AFE Energy" converter used as:

- converter for photovoltaic applications (for example in the TDE Macno photovoltaic inverter "OPDE Solar");
- converter for hydroelectric and wind applications;
- converter for energy storage system (ESS).

In addition to the standard AFE converter parameters, which are described in the relevant **AFE user manual**, OPDE_Energy application includes a set of additional parameters and quantities, which may be grouped as follows:

- application parameters;
- application internal values;
- application oscilloscope values;
- application logic inputs;
- application logic outputs;
- application alarms.

The correct use of these parameters and quantities is described in the following sections.

# 2 CONNECTIONS

The OPDE_Energy application sw is used as control sw for the OPDE AFE Energy converter in different application like photovoltaic, hydroelectric, wind and storage. Therefore, two types of installation will be taken into consideration:

- photovoltaic application;
- application with rotating machine connected to an AC/DC inverter.
- storage application.

For a detailed description of the connections, refer to the OPDE AFE Energy Installation Manual.

The I/O connections differ depending on the type of application, as described below.

## 2.1 I/O CONNECTIONS FOR PHOTOVOLTAIC APPLICATION

In a photovoltaic application the converter "OPDE AFE Energy" has a PV field connected to the DC-Bus. In this case it's necessary to enable the MPPT function that regulates the DC-Bus voltage to generate the maximum power from the PV plant.
Furthermore, other external components must be connected to the AFE I/O to work properly. For a detailed description refer to the OPDE AFE Energy installation manual. The default I/O configuration is listed below.

| Default I/O – PV application | | |
|---|---|---|
| **Input** | **Default** | **Connection** |
| L.I.1 | I27 – Surge Protection Device OK | C01 = 27 |
| L.I.2 | I00 – Run command | C02 = 0 |
| L.I.3 | I31 – Interface protection OK | C03 = 31 |
| L.I.4 | I30 – PV switch close AND PV insulation OK | C04 = 30 |
| L.I.5 | I29 – Fan OK | C05 = 29 |
| L.I.6 | I28 – Grid contactor close AND line fuse OK | C06 = 28 |
| L.I.7 | Not Enabled (free input) | C07 = -1 |
| L.I.8 | Not Enabled (free input) | C08 = -1 |
| **Output** | **Default** | **Connection** |
| L.O.1 | O23 – Enable AFE fans | C10 = 23 |
| L.O.2 | O33 – On-grid contactor command | C11 = 33 |
| L.O.3 | O36 – Active power limitation | C12 = 36 |
| L.O.4 | O33 – On-grid contactor command | C13 = 33 |
| **Analog Output** | **Default** | **Connection** |
| A.O.1 | osc11 – Current module | C15 = 11 |
| A.O.2 | osc86 – P active limit | C16 = 86 |

*Tab. 1 – Default I/O configuration for PV application*

## 2.2 I/O CONNECTIONS FOR APPLICATION WITH ROTATING MACHINE CONNECTED TO AN AC/DC INVERTER

In an application with a rotating machine the converter “OPDE AFE Energy” has an AC/DC inverter connected to the DC-Bus. In this case it’s necessary to work only with the DC-Bus voltage regulation (default working mode).
The default I/O configuration is listed below.

| Default I/O – Rotating machine | | |
|---|---|---|
| **Input** | **Default** | **Connection** |
| L.I.1 | I08 – Reset alarms | C01 = 8 |
| L.I.2 | I02 – Extern enable | C02 = 2 |
| L.I.3 | I31 – Interface protection OK | C03 = 31 |
| L.I.4 | I00 – Run command | C04 = 0 |
| L.I.5 | Not Enabled (free input) | C05 = -1 |
| L.I.6 | Not Enabled (free input) | C06 = -1 |
| L.I.7 | Not Enabled (free input) | C07 = -1 |
| L.I.8 | I26 – PWM Synchronization input | C08 = 26 |
| **Output** | **Default** | **Connection** |
| L.O.1 | O23 – Enable AFE fans | C10 = 23 |
| L.O.2 | O33 – On-grid contactor command | C11 = 33 |
| L.O.3 | O36 – Active power limitation | C12 = 36 |
| L.O.4 | O33 – On-grid contactor command | C13 = 33 |
| **Analog Output** | **Default** | **Connection** |
| A.O.1 | osc11 – Current module | C15 = 11 |
| A.O.2 | osc86 – P active limit | C16 = 86 |

*Tab. 2 – Default I/O configuration for rotating machine*

## 2.3 I/O CONNECTIONS FOR ENERGY STORAGE SYSTEM (ESS)

In an energy storage system (ESS) the converter “OPDE AFE Energy” has a battery connected to the DC-Bus. In this case the AFE must be set to work in CSI mode (Current Source Inverter), in order to regulate the ac current without regulate the DC-Bus voltage (E25=1).
The default I/O configuration is listed below.

| Default I/O – Rotating machine | | |
|---|---|---|
| **Input** | **Default** | **Connection** |
| L.I.1 | I08 – Reset alarms | C01 = 8 |
| L.I.2 | I02 – Extern enable | C02 = 2 |
| L.I.3 | I31 – Interface protection OK | C03 = 31 |
| L.I.4 | I00 – Run command | C04 = 0 |
| L.I.5 | I25 – Enable stopping ramp | C05 = 25 |
| L.I.6 | Not Enabled (free input) | C06 = -1 |
| L.I.7 | Not Enabled (free input) | C07 = -1 |
| L.I.8 | Not Enabled (free input) | C08 = -1 |
| **Output** | **Default** | **Connection** |
| L.O.1 | O23 – Enable AFE fans | C10 = 23 |
| L.O.2 | O33 – On-grid contactor command | C11 = 33 |
| L.O.3 | O36 – Active power limitation | C12 = 36 |
| L.O.4 | O33 – On-grid contactor command | C13 = 33 |
| **Analog Output** | **Default** | **Connection** |
| A.O.1 | osc11 – Current module | C15 = 11 |
| A.O.2 | osc86 – P active limit | C16 = 86 |

*Tab. 3 - Default I/O configuration for ESS*

# 3 APPLICATION CONFIGURATION

## 3.1 APPLICATION PARAMETERS

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| CTRL_PF_F_LOCK_IN_OF | E02 - Lock-in frequency of P=f(F) curve in Over Frequency | 45.00 | 55.00 | 50.30 | Hz | 100 |
| CTRL_PF_SLOPE_OF | E03 - Percentage Slope of P=f(F) curve in Over Frequency | 2.0 | 5.0 | 2.4 | % GRID_FREQ_NOM / P_INST | 10 |
| V_GRID_MAX | E04 - Maximum grid voltage for enabling grid connection | 101 | 120 | 110 | % V_GRID_NOM | 1 |
| V_GRID_MIN | E05 - Minimum grid voltage for enabling grid connection | 80 | 99 | 85 | % V_GRID_NOM | 1 |
| F_GRID_MAX | E06 - Maximum grid frequency for enabling grid connection | 50.05 | 55.00 | 50.10 | % F_GRID_NOM | 100 |
| F_GRID_MIN | E07 - Minimum grid frequency for enabling grid connection | 45.00 | 49.95 | 49.90 | % F_GRID_NOM | 100 |
| GRID_WAIT_TIME_1 | E08 - Wait time for enabling grid connection | 1 | 900 | 30 | s | 1 |
| GRID_WAIT_TIME_2 | E09 - Wait time for enabling grid connection after SPI trigger or over frequency | 1 | 900 | 300 | s | 1 |
| ACT_PWR_RAMP_TIME | E10 - Active power ramp time | 1 | 900 | 300 | s | 1 |
| F_GRID_MAX_RUN | E11 - Maximum grid frequency for running | 50.05 | 54.00 | 52.00 | Hz | 100 |
| F_GRID_MIN_RUN | E12 - Minimum grid frequency for running | 46.00 | 49.95 | 47.00 | Hz | 100 |
| V_F_GRID_FILTER | E13 - Vgrid and Fgrid filter time constant | 0 | 999 | 100 | ms | 1 |
| K_TRANSF | E14 - Transformer turns ratio | 67.50 | 0.01 | 100.00 | | 100 |
| PRC_DELTA_VLT | E15 - Voltage drop due to transformer inductance | 0.01 | 100.00 | 2.00 | % V_GRID_NOM | 100 |
| PRC_DELTA_VRT | E16 - Voltage drop due to transformer resistor | 0.01 | 100.00 | 0.50 | % V_GRID_NOM | 100 |
| GRID_UNB_MAX | E17 - Maximum grid voltage unbalance for enabling run | 0.0 | 100.0 | 10.0 | % V_GRID_NOM | 10 |
| I_ACT_NOM | E18 - Active Current at nominal active power | 0.0 | 100.0 | 90.0 | % I_CONV_NOM | 10 |
| EXT_COSPHI_REF | E19 - External cosphi reference | -1.000 | 1.000 | 1.000 | | 1000 |
| THR_ERR_FRQ_ALL | E20 - Error Frequency Threshold for alarm | 0.0 | 10.0 | 10.0 | % GRID_FREQ_NOM | 10 |
| KAI | E21 - AI_Proportional gain for error frequency filtered | -100.0 | 100.0 | 10.0 | | 10 |
| FT_LOWPASS | E22 - AI_Cut Frequency Low Pass Filter | 1.00 | 30.00 | 10.00 | Hz | 100 |
| FT_HIGHPASS | E23 - AI_Cut Frequency High Pass Filter | 0.01 | 10.00 | 0.50 | Hz | 100 |
| N_SAMPLE | E24 - Number of sample for PV Sweep | 10 | 50 | 10 | | 1 |
| I_PV_MAX | E30 - Maximum PV input current | 0.0 | 2000.0 | 0.0 | A | 10 |
| V_GRID_MAX_UNB | E31 - Maximum grid voltage with unbalanced grid for enabling run | 0.0 | 200.0 | 115.0 | % V_GRID_NOM | 10 |
| V_GRID_MIN_UNB | E32 - Minimum grid voltage with unbalanced grid for enabling run | 0.0 | 200.0 | 80.0 | % V_GRID_NOM | 10 |
| PV_SWEEP_TIME_STEP | E33 - PV sweep time step | 1 | 999 | 200 | ms | 1 |
| PV_SWEEP_REP_PERIOD | E34 - PV sweep repetition period | 1 | 180 | 60 | min | 1 |
| DELTA_V | E35 - Voltage step MPPT Algorithm | 0 | 20 | 3 | V | 1 |
| TIME_STEP | E36 - Time step MPPT Algorithm | 0 | 19999 | 5000 | Tpwm | 1 |
| Tau_Ipv_filter | E37 - Time constant Ipv filter | 10 | 0 | 999 | ms | 1 |
| Kmult_IPV | E38 - Kmult_Ipv | 0 | 200 | 100 | % | 1 |
| K_MANUAL_MPPT | E39 - MPP in % respect Voc measured | 70 | 100 | 80 | %Voc | 1 |
| EXT_ACT_PWR_LIM | E40 - External active power limit | 0 | 200 | 100 | % P_ACT_NOM | 1 |
| P_START_MIN | E41 - Minimum power for starting sequence | 0 | 100 | 2 | % Ppv_NORM_COEFF | 1 |
| DELTA_V_PMIN | E42 - Delta V for minimum power measure | 0 | 100 | 70 | V | 1 |
| V_PV_START | E43 - PV voltage for starting sequence | 380 | 780 | 460 | V | 1 |
| T1_PMIN | E44 - Repetition time T1 of minimum power measurement | 0.1 | 10.0 | 1.0 | min | 10 |
| T2_PMIN | E45 - Repetition time T1 of minimum power measurement T2>T1 | 0.1 | 30.0 | 10.0 | min | 10 |
| Ton_1 | E46 - Waiting time Ton_1 | 0.1 | 10.0 | 0.1 | min | 10 |
| TEMP_ON_AFE_FAN | E47 - Switch on temperature for AFE fans | 30 | 80 | 60 | °C | 1 |
| TEMP_AMB_OFF | E48 - AFE switch off ambient temperature | 30 | 50 | 41 | °C | 1 |
| Kmult_Pac | E49 - Pac measured multiplication coefficient | | | | % | 1 |
| PERC_GRID_F_CNTRL | E50 - Percentage tolerance for grid frequency control | 0.6 | 10 | 1 | % | 10 |
| V_MPPT_MIN | E51 - Minimum MPPT voltage reachable | 360 | 460 | 360 | V | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| V_MPPT_MAX | E52 - Maximum MPPT voltage reachable | 680 | 780 | 780 | V | 1 |
| P_GRID_REF | E53 - Active power reference | -200.0 | 200.0 | 0.0 | % S_NOM | 10 |
| Q_GRID_REG | E54 - Reactive power reference | -200.0 | 200.0 | 0.0 | % S_NOM | 10 |
| VB_MAX | E55 - V Bus Max Limit in CSI | 0.0 | 1200.0 | 0.0 | V | 10 |
| VB_MIN | E56 - V Bus Min Limit in CSI | 0.0 | 1200.0 | 0.0 | V | 10 |
| KP_VB_LIM | E57 - Kp V Bus limit in CSI | 0.0 | 300.0 | 1.0 | | 10 |
| TI_VB_LIM | E58 - Ti V Bus Limit in CSI | 0.0 | 3000.0 | 60.0 | ms | 10 |
| TF_VB_LIM | E59 - Tf V Bus Limit in CSI | 0.0 | 3000.0 | 0.0 | ms | 10 |
| CTRL_CP_PWR_A | E60 - Power of point A cosfi=f(P) curve | 0 | 100 | 20 | % P_ACT_NOM | 1 |
| CTRL_CP_PWR_B | E61 - Power of point B cosfi=f(P) curve | 0 | 100 | 50 | % P_ACT_NOM | 1 |
| CTRL_CP_FV_COSPHI | E62 - Cosphi of point C cosfi=f(P) curve and cosphi of Q=f(V) curve | 0.00 | 1.00 | 0.90 | | 100 |
| CTRL_CP_V_LOCK_IN | E63 - Lock-in voltage of cosfi=f(P) curve | 100 | 100 | 105 | % V_GRID_NOM | 1 |
| CTRL_CP_V_LOCK_OUT | E64 - Lock-out voltage of cosfi=f(P) curve | 90 | 90 | 100 | % V_GRID_NOM | 1 |
| COSPHI_NOM | E65 - Nominal Cosphi for definition of D82-S_NOM | 0.00 | 0.00 | 0.90 | | 100 |
| CTRL_FV_V1S | E66 - V1S voltage of Q=f(V) curve | 80 | 120 | 108 | % V_GRID_NOM | 1 |
| CTRL_FV_V2S | E67 - V2S voltage of Q=f(V) curve | 80 | 120 | 110 | % V_GRID_NOM | 1 |
| CTRL_FV_V1I | E68 - V1I voltage of Q=f(V) curve | 80 | 120 | 92 | % V_GRID_NOM | 1 |
| CTRL_FV_V2I | E69 - V2I voltage of Q=f(V) curve | 80 | 120 | 90 | % V_GRID_NOM | 1 |
| CTRL_FV_PWR_LOCK_IN_REG | E70 - Lock-in power of Q=f(V) curve during regeneration | 0 | 100 | 20 | % P_ACT_NOM | |
| CTRL_FV_PWR_LOCK_OUT | E71 - Lock-out power of Q=f(V) curve | 0 | 50 | 100 | % P_ACT_NOM | 1 |
| CTRL_PV_V1S | E74 - V1S voltage of P(V) curve | 108 | 135 | 108 | % V_GRID_NOM | 1 |
| CTRL_PV_V2S | E75 - V2S voltage of P(V) curve | 110 | 135 | 110 | % V_GRID_NOM | 1 |
| CTRL_PV_P_LIM | E76 - Active power limit for P(V) curve | 0 | 200 | 20 | % P_ACT_NOM | 1 |
| CTRL_FV_PWR_LOCK_IN_ABS | E77 - Lock-in power of Q=f(V) curve during absorption | -100 | 0 | -20 | % P_ACT_NOM | 1 |
| CTRL_QV_K | E78 - K factor of Q=f(V) curve | -1.00 | 1.00 | 0.00 | % S_NOM | 100 |
| CTRL_QV_DELAY_ON | E79 - Activation delay time of Q=f(V) curve | 0 | 30 | 3 | s | 1 |
| PWM_SYNCH_PHASE | E88 - PWM synchronization angle | -175.0 | 175.0 | 0 | Degrees | 10 |
| CTRL_PF_DELAY_ON | E99 - Activation delay timed of P=f(F) curve | 0.00 | 10.00 | 0.00 | s | 100 |

## 3.2 APPLICATION CONNECTIONS

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_CURR_REF | E25 - Enable application current reference | 0 | 1 | 1 | | 1 |
| APPL_SEL | E26 - Application selection | Range<br>0 AFE_STD<br>1 Solar | | 0 | | 1 |
| EN_FLDBUS_REF | E27 - Enable FIELD-BUS reference values | 0 | 1 | 0 | | 1 |
| EN_MPPT | E80 - Enable MPPT Algorithm | 0 | 1 | 1 | | 1 |
| EN_MANUAL_MPPT | E81 - Enable Manual MPPT Algorithm | 0 | 1 | 0 | | 1 |
| EN_MANUT | E82 - Enable maintenance mode | 0 | 1 | 0 | | 1 |
| ENERGY_RESET | E83 - Reset produced energy counter | 0 | 1 | 0 | | 1 |
| EN_VAR_STEP | E84 - Enable variable step MPPT algorithm (unmanaged) | 0 | 1 | 0 | | 1 |
| EN_TEMP_OFF | E85 - Enable temperature controlled switch off | 0 | 1 | 0 | | 1 |
| EN_GRID_F_CNTRL | E86 - Enable grid frequency control | 0 | 1 | 0 | | 1 |
| EN_PWM_SYNCH | E87 - Enable PWM synchronization | 0 | 1 | 0 | | 1 |
| EN_PV_SWEEP | E89 - Enable PV sweep | Range<br>0 No<br>1 Automatic sweep (period=E64)<br>2 One-shot sweep | | 0 | | 1 |
| EN_REACT_PWR_CTRL_FP | E90 - Enable automatic reactive power control according to cosfi=f(P) curve | Range<br>0 No<br>1 Variable Cosphi<br>2 Fixed Cosphi | | 0 | | 1 |
| EN_REACT_PWR_CTRL_FV | E91 - Enable automatic reactive power control according to Q=f(V) curve | Range<br>0 No<br>1 Variable Cosphi<br>2 Fixed Cosphi | | 0 | | 1 |
| EN_ACT_PWR_CTRL_FF | E92 - Enable automatic active power control according to P=f(F) curve | 0 | 1 | 0 | | 1 |
| EN_GRID_CONN_MANAGE | E93 - Enable grid connection manage | Range | | 0 | | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 0 | No | | | |
| | | 1 | CEI 0-21 function (Italy) | | | |
| | | 2 | CGC/GF004 function (China) | | | |
| EN_EXT_CMND | E94 - Enable external commands | Range | | 0 | | 1 |
| | | 0 | No | | | |
| | | 1 | Ext. active power limitation | | | |
| | | 2 | Ext. reactive power limitation | | | |
| | | 3 | Ext. active and reactive power limitaton | | | |
| EN_LVFRT_MANAGE | E95 - Enable LVFRT manage | 1 | 0 | 0 | | 1 |
| EN_AI_FCN | E96 - Enable Anti Islanding function | 1 | 0 | 0 | | 1 |
| EN_V_DROP_COMP | E97 - Enable compensation for LCL filter voltage drop | 1 | 0 | 0 | | 1 |
| EN_ACT_PWR_CTRL_PV | E98 – Enable automatic active power control according to P(V) curve | 1 | 0 | 0 | | 1 |
| EN_ID_COMP | E210 - Enable Id compensation | 0 | 1 | 0 | | 1 |

## 3.3 APPLICATION INTERNAL VALUES

| Name | Description | u.m. | Scale |
|---|---|---|---|
| V_OC | D64 - PV Open Circuit Voltage | V | 1 |
| Ipv | D65 - PV current | A | 32 |
| Ppv | D66 - PV power | kW | 32 |
| Ppv_NORM_COEFF | D68 - Ppv normalization coefficient | kW | 16 |
| Stato | D69 - Status | | 1 |
| Pac | D70 - AC Power | kW | 128 |
| Iq | D71 - Active current Iq filtered | % I_CONV_ NOM | 40.96 |
| Id | D72 - Reactive current Id filtered | % I_CONV_ NOM | 40.96 |
| Tamb | D73 - Ambient temperature | °C | 1 |
| Energy_Wh | D74 - Produced Energy in Wh | Wh | 1 |
| Energy_kWh | D75 - Produced Energy in kWh | kWh | 1 |
| Energy_MWh | D76 - Produced Energy in MWh | MWh | 1 |
| Energy_GWh | D77 - Produced energy in GWh | GWh | 1 |
| EN_AUT_START | D78 - Enable automatic start | | 1 |
| APLL_STATUS_WORD | D79 - Application status word | | 1 |
| APPL_ALL_WORD | D80 - Application alarm word | | 1 |
| PWM_SYNC_DELAY | D81 - PWM SYNC delay | μs | 10 |
| S_NOM | D82 - Nominal Apparent Power | kVA | 16 |
| I_TA | D83 - TA current | A | 16 |
| Vgrid_CONN_MANAGE | D86 - Vgrid reading for Grid Connection Manage | % V_GRID_NOM | 1000 |
| Fgrid_CONN_MANAGE | D87 - Fgrid reading for Grid Connection Manage | % F_GRID_NOM | 1000 |
| Count_GRID_FAULT | D88 - Counter for A4.0 after Grid Fault event | s | 1 |
| Count_SPI | D89 - Counter for A4.0 after SPI trigger event | s | 1 |
| PRC_DC_BUS_REF_FLDBUS | D90 - Fieldbus DC Bus reference | % DC_BUS_REF | 163.84 |
| IQ_REF_FLDBUS | D91 - Fieldbus Iq active current reference | % I_CONV_ NOM | 163.84 |
| ID_REF_FLDBUS | D92 - Fieldbus Id reactive current reference | % I_CONV_ NOM | 163.84 |
| PRC_CONV_I_PEAK_FLDBUS | D93 - Fieldbus current limit | % I_CONV_ NOM | 163.84 |
| V_GRID_OVD_FLDBUS | D94 - Fieldbus Vgrid override reference | % V_GRID_ISL | 163.84 |
| FREQ_OVD_FLDBUS | D95 - Fieldbus Fgrid override reference | % F_GRID_NOM | 163.84 |
| VB_LIM_MAX_OVD_FLDBUS | D96 - Fieldbus maximum DC Bus voltage limit override | % VB_MAX | 163.84 |
| VB_LIM_MIN_OVD_FLDBUS | D97 - Fieldbus minimum DC Bus voltage limit override | % VB_MIN | 163.84 |
| P_GRID_REF_FLDBUS | D98 - Fieldbus active power reference | % S_NOM | 163.84 |
| Q_GRID_REF_FLDBUS | D99 - Fieldbus reactive power reference | % S_NOM | 163.84 |

## 3.4 APPLICATION EXTRA PARAMETERS

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| CTRL_PF_LOCK_OUT_WAIT_TIME | E200 - P(f) Lock-out waiting time | 0 | 900 | 300 | s | 1 |
| CTRL_PF_RAMP_TIME | E201 - P(f) active power ramp time | 1 | 900 | 300 | s | 1 |
| CTRL_PF_F_LOCK_IN_UF | E202 - Lock-in frequency of P=f(F) curve in Under Frequency | 45.00 | 49.70 | 55.00 | | 100 |
| CTRL_PF_SLOPE_UF | E203 - Percege Slope of P=f(F) curve in Over Frequency | 0.1 | 5.0 | 1.2 | % GRID_FREQ_NOM / % P_INST | 10 |
| CTRL_PF_F_LOCK_OUT_OF | E204 - Lock-out frequency of P=f(F) curve in Over Frequency | 50.05 | 51.00 | 50.10 | Hz | 100 |
| CTRL_PF_F_LOCK_OUT_UF | E205 - Lock-out frequency of P=f(F) curve in Under Frequency | 49.00 | 49.95 | 49.90 | Hz | 100 |
| STOP_RAMP_TIME | E206 - Stop ramp time | 1 | 900 | 10 | s | 1 |
| CTRL_PV_RAMP_TIME | E207 - P(V) active power ramp time | 1 | 900 | 300 | s | 1 |
| EN_ID_COMP | E210 - Enable Id compensation | 0 | 1 | 0 | | 1 |
| I_TA_NOM | E211 - TA (current sensor) rated current | 0.0 | 2000.0 | 0.0 | A | 10 |
| OFFSET_TA_U | E212 - TA (current sensor) phase U offset | -100.00 | 100.00 | 0.00 | % | 100 |
| OFFSET_TA_W | E213 - TA (current sensor) phase W offset | -100.00 | 100.00 | 0.00 | % | 100 |
| TA_ANG_SUM | E214 - TA (current sensor) sum angle | -179.9 | 180.0 | 0.0 | ° | 10 |
| I_TA_FILTER | E215 - TA (current sensor) filter time constant | 0.0 | 999.9 | 100.0 | ms | 10 |
| Q_POS_RAMP_UP_TIME | E245 - Reactive power ramp up time with Q>0 | 0 | 900 | 0 | s/S_NOM | 1 |
| Q_POS_RAMP_DOWN_TIME | E246 - Reactive power ramp down time with Q>0 | 0 | 900 | 0 | s/S_NOM | 1 |
| Q_NEG_RAMP_UP_TIME | E247 - Reactive power ramp up time with Q<0 | 0 | 900 | 0 | s/S_NOM | 1 |
| Q_NEG_RAMP_DOWN_TIME | E248 - Reactive power ramp down time with Q<0 | 0 | 900 | 0 | s/S_NOM | 1 |

## 3.5 APPLICATION OSCILLOSCOPE VALUES AND ANALOG OUTPUTS

The internal quantities for the oscilloscope and analog outputs of this application are as follows:

| Output | Internal variable assigned | u.m. | Scale |
|---|---|---|---|
| osc68 | Vbus_rif | 100% = 900V | 40.96 |
| osc69 | Pac_mio_norm | 100% = 1,732*P62*P63 | 40.96 |
| osc70 | Pin_k | 100% = 1,732*P62*P63 | 40.96 |
| osc71 | dP | 100% = 1,732*P62*P63 | 40.96 |
| osc72 | Rapp | 100% | 40.96 |
| osc73 | contatore_LVFRT | ms | 1 |
| osc74 | Ipv_filt | % I_PV_MAX | 40.96 |
| osc75 | Ppv_norm | 100% = Ppv_norm_coeff = D68 | 40.96 |
| osc76 | dV | | 40.96 |
| osc77 | PRC_Iq_filt | % I_CONV_NOM | 40.96 |
| osc78 | | | 163.84 |
| osc79 | STATUS | - | 1 |
| osc80 | wr_err | % F_GRID_NOM | 163.84 |
| osc81 | err_f | % F_GRID_NOM | 163.84 |
| osc82 | Id_AI_sf | % I_CONV_NOM | 163.84 |
| osc83 | Id_AI_filt | % I_CONV_NOM | 163.84 |
| osc84 | Iqref_abs | % I_CONV_NOM | 163.84 |
| osc85 | Id_AIv | % I_CONV_NOM | 163.84 |
| osc86 | P active limit | % S_NOM | 40.96 |
| osc87 | I_TA_U | % I_TA_NOM | 327.68 |
| osc88 | I_TA_W | % I_TA_NOM | 327.68 |
| osc89 | Iq_TA_to_AFE_prc | % I_CONV_NOM | 40.96 |
| osc90 | Id_TA_to_AFE_prc | % I_CONV_NOM | 40.96 |
| osc91 | Iq_TA_to_AFE_prc_filt | % I_CONV_NOM | 40.96 |
| osc92 | Id_TA_to_AFE_prc_filt | % I_CONV_NOM | 40.96 |
| osc93 | I_TA_module | % I_CONV_NOM | 40.96 |
| osc94 | presenza_LVFRT | (bool) | 1 |
| osc95 | IP | (bool) | 1 |
| osc96 | GRID_FAULT_CORE | (bool) | 1 |
| osc97 | OD_ON_GRID | (bool) | 1 |
| osc98 | GRID_FAULT_APPL | (bool) | 1 |
| osc99 | RUN_APPL | (bool) | 1 |

## 3.6 APPLICATION LOGIC INPUTS

| Input | Name | Description | Applications involved | | |
|---|---|---|---|---|---|
| | | | PV (E26=1) | Wind or Hydro | ESS (E25=1) |
| I00 | ID_RUN | Run command | ✓ | ✓ | ✓ |
| I02 | ID_EN_EXT | External enable | ✓ | ✓ | ✓ |
| I08 | ID_RESET_ALR | Reset alarms | ✓ | ✓ | ✓ |
| I13 | ID_EN_INS_PREC | Enable power soft start | ✓ | ✓ | ✓ |
| I14 | ID_EN_FLDBUS_REF | Enable FIELD-BUS reference values | ✓ | ✓ | ✓ |
| I22 | ID_EXT_START | External Start | ✓ | - | - |
| I23 | ID_EXT_STOP | External Stop | ✓ | - | - |
| I24 | ID_BLK_MEM_I_SPD | Freeze PI voltage regulator integral memory | ✓ | ✓ | ✓ |
| I25 | ID_STOP_RAMP | Enable stopping ramp | - | - | ✓ |
| I26 | ID_PWM_SYNCH | PWM Synchronization input | ✓ | ✓ | ✓ |
| I27 | ID_SPD_OK | Surge Protection Device OK | ✓ | - | - |
| I28 | ID_DISP_INT_CLOSE | Grid contactor close AND line fuse OK | ✓ | - | - |
| I29 | ID_FAN_OK | Fan OK | ✓ | - | - |
| I30 | ID_PV_OK | PV switch close AND PV insulation OK | ✓ | - | - |
| I31 | ID_PROT_INT_OK | Interface protection OK | ✓ | - | - |

*I00 – Run command*
Connect to this input a selector to enable the start sequence. If input is high then the run of converter is enabled, if low, the converter doesn't accept the run command. If input goes low during the run, converter will immediately stop.

*I14 – Enable FIELD-BUS reference values*

*I22 – External Start*
In case of PV application (E26=1), this input has the same function of run button on the remote keypad, refer to par. 7.2.

*I23 – External Stop*
In case of PV application (E26=1), this input has the same function of stop button on the remote keypad, refer to par. 7.2.

*I25 – Enable stopping ramp*
In case of ESS application (E25=1), this input activate a stopping ramp re

*I26 – PWM Synchronization input*
Input used to synchronize the PWM pulses of the AFE with that of another converter, refer to par. 4.13.

*I27 – Surge protection device OK*
Is it possible to connect to this input the signalling contacts of surge protection device that would be present on DC side or on AC side

*I28 – Grid contactor close AND line fuse OK*
This input is used to verify the closure of on-grid contactor and the status of line fuses put in series with the contactor (if presents). The closure of contactor correspond to an high logic level.

*I29 – Fan OK*
This input is used to signal any failure of cabinet fans. A low logic level indicates a fault presence.

*I30 – PV switch close AND PV insulation OK*
This input is used to verify the status of PV breaker and the status of an insulation control device (CI) that could be present on PV side. A low logic level indicates the closure of PV breaker and the absence of alarms on CI.

*I31 – Interface protection OK*
This input is used to verify the status of the Interface Protection Device (SPI). A low logic level indicates no alarms on the SPI.

## 3.7 APPLICATION LOGIC OUTPUTS

| Output | Name | Description | Applications involved | | |
|---|---|---|---|---|---|
| | | | PV (E26=1) | Wind or Hydro | ESS (E25=1) |
| O32 | OD_EN_AFE_FAN | Enable AFE fan | ✓ | ✓ | ✓ |
| O33 | OD_ON_GRID | On-Grid contactor command | ✓ | ✓ | ✓ |
| O34 | OD_SGANCIO_FV | PV breaking switch (unmanaged) | ✓ | - | - |
| O35 | OD_APPL_FAULT_1 | Application Fault 1 | ✓ | - | - |
| O36 | OD_P_ACTIVE_LIMIT | Active power limitation | ✓ | ✓ | ✓ |
| O37 | OD_IDC_OC | Idc overcurrent | ✓ | ✓ | ✓ |
| O38 | OD_CP | Cosphi(P) function active | - | ✓ | ✓ |
| O39 | OD_QV | Q(V) function active | - | ✓ | ✓ |
| O40 | OD_PF | P(F) function active | - | ✓ | ✓ |
| O41 | OD_PV | P(V) function active | - | ✓ | ✓ |
| O42 | OD_STOP_RAMP | Stopping ramp active | - | ✓ | ✓ |
| O44 | OD_DCBUS_OK | DC Bus voltage higher than P62*sqrt(2)*1,1 | - | ✓ | ✓ |

*O32 – Enable AFE fan*
This digital output allows the AFE converter fan to be turned on based on the radiator temperature. The fan turn-on temperature can be set via parameter **E47–TEMP_ON_AFE_FAN**.
Once on, the fan will turn off automatically when the radiator temperature drops below the preset threshold, i.e. E47-10°C.

*O33 – On-grid contactor command*
This digital output allows the opening/closing of the grid contactor.

*O34 – PV breaking switch*
Not managed.

*O35 – Application Fault 1*
This digital output signals fault conditions that can occur at the level of internal components of the cabinet, which have nothing to do with the AFE converter. In particular, this output is set in any of the following circumstances:
1) if the surge protection devices on the PV side have failed (see LI1); or
2) if the minimum threshold of the insulation resistance set in the insulation controller on the PV side (see LI4) is exceeded and the photovoltaic voltage is Vpv>170V; or
3) if the magnetic-thermal breaker of the cabinet fan (see LI5) has tripped; or
4) if there are problems with the interface protection (see LI3), for instance, because the grid, voltage and frequency parameters are not within the limits set in the interface protection; or
5) if, when you try to close the grid contactor (see LO3) it does not close due to it being stuck or due to blown line fuses.

*O36 – Active power limitation*
Indicates that the active power limit is active and that the value (D84 and osc86) is below 100%.

*O37 – Idc overcurrent*
Indicates that the DC current component on phase U, V, or W has exceed the threshold E223 or E240.

*O38 – Cosphi(P) function active*
Indicates the activation (Lock-in) of Cosphi(P) function.

*O39 – Q(V) function active*
Indicates the activation (Lock-in) of Q(V) function.

*O40 – P(F) function active*
Indicates the activation (Lock-in) of P(f) function.

*O41 – P(V) function active*
Indicates the activation (Lock-in) of P(V) function.

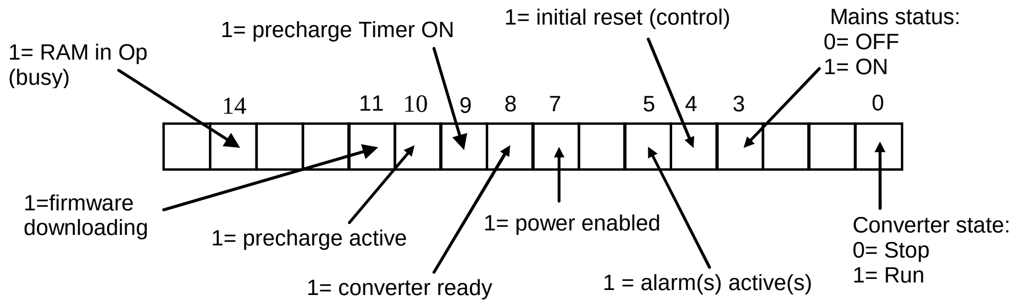
*O42 – Stopping ramp active*
Indicates that the execution of the stopping ramp related to I25-ID_STOP_RAMP.

*O44 – DC Bus voltage higher than P62*sqrt(2)*1,1*
Indicates that the DC Bus voltage D24 is higher than P62*sqrt(2)*1,1.

## 3.8 STATUS WORD

### 3.8.1 Core status word

The status variable of the AFE core sw is available on the fieldbus, hereinafter the meaning of the most important bit:




### 3.8.2 Application status word

The internal value **D79-APPL_STATUS_WORD** represents the PV state machine status word. Below the meaning of the bits.

| Bit | Significato |
|---|---|
| 0÷4 | PV state machine status = D69 |
| 5 | RUN_APPL |

Where RUN_APPL is an internal variable that commands the AFE run and that is activated automatically by the software when the machine moves through the different operating status.

## 3.9 APPLICATION ALARM WORD

The internal variable **D80-APPL_ALARM_WORD** represents the application alarm words in case of PV application. Below the meaning of the bits.

| Bit | Significato |
|---|---|
| 0 | Not (ID_PROT_INT_OK) |
| 1 | Not (ID_SPD_OK) |
| 2 | ALL_PV_INS |
| 3 | Not (ID_FAN_OK) |
| 4 | ALL_TL_ON_GRID_OR_GRID_FUSES |
| 5 | GRID_FAULT_APPL |

Where:

- ALL_PV_INS := (Vpv>170V) and (not(ID_PV_OK))
- ALL_TL_ON_GRID_OR_GRID_FUSES := OD_ON_GRID and (not(ID_DISP_INT_CLOSE))
- GRID_FAULT_APPL := GRID_FAULT_CORE or ERR_FREQ

GRID_FAULT CORE is the A02 AFE alarm grid-off.
ERR_FREQ is an alarm of the application that triggers if the frequency is bigger than the limit set on E50-PERC_GRID_F_CNTRL (the ERR_FREQ alarm triggers only if E86–EN_GRID_F_CNTRL=1).

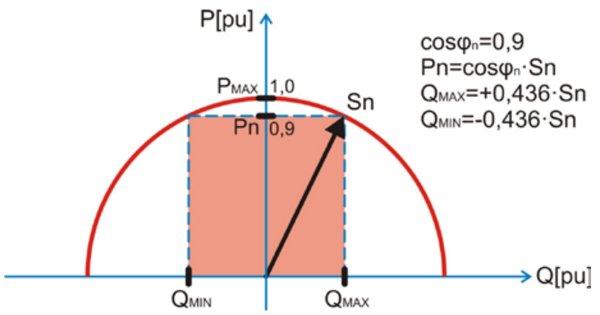
# 4 OPERATION

## 4.1 CAPABILITY

The OPDE AFE Energy is a four quadrant AC/DC converter that is suitable to be used for different P-Q capabilities (i.e. the working area in the plane P-Q). Some capabilities are described below.

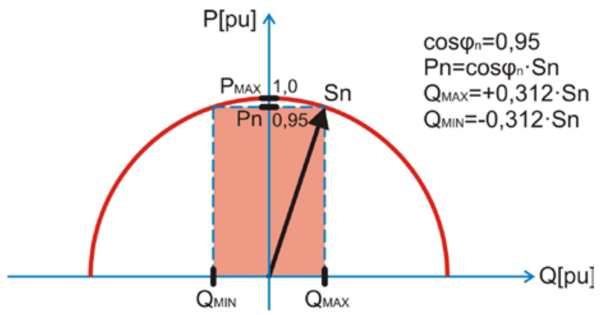
### 4.1.1 Capability for Wind/Hydro

In the figures that follow, the capability is indicated with the shaded area. The choice of the capability influences the execution of some functions described later - Q(V), cosphi(P) - hence is important to set properly some parameter as indicated below.



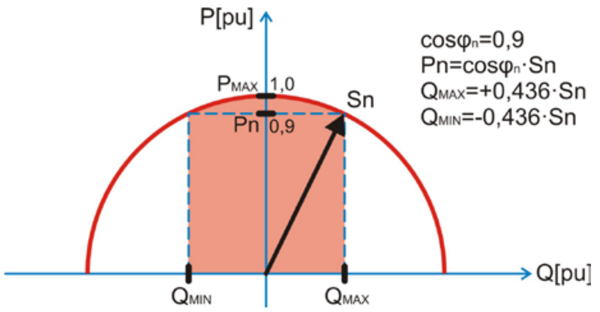

| | |
|---|---|
| E18 – I_ACT_NOM | 100% |
| E62 – CTRL_CP_QV_COSPHI | 0,90 |
| E28 – P_REGEN_MAX | N/A |
| E29 – P_ABSORPT_MAX | N/A |

*Figure 1 – Rectangular capability with cosφ$_n$=0,9*



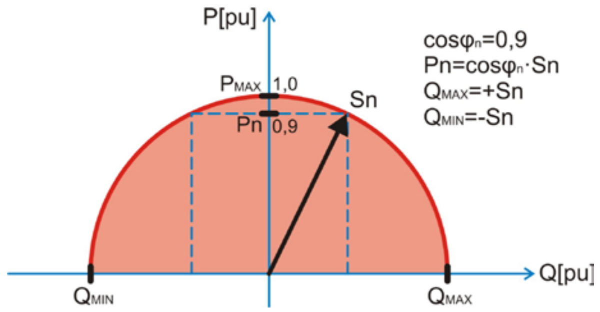

| | |
|---|---|
| E18 – I_ACT_NOM | 95% |
| E62 – CTRL_CP_QV_COSPHI | 0,95 |
| E28 – P_REGEN_MAX | N/A |
| E29 – P_ABSORPT_MAX | N/A |

*Figure 2 – Rectangular capability with cosφ$_n$=0,95*




| | |
|---|---|
| E18 – I_ACT_NOM | 100% |
| E62 – CTRL_CP_QV_COSPHI | 0,90 |
| E28 – P_REGEN_MAX | N/A |
| E29 – P_ABSORPT_MAX | N/A |

*Figure 3 – Rounded rectangular capability with cosφ$_n$=0,9*

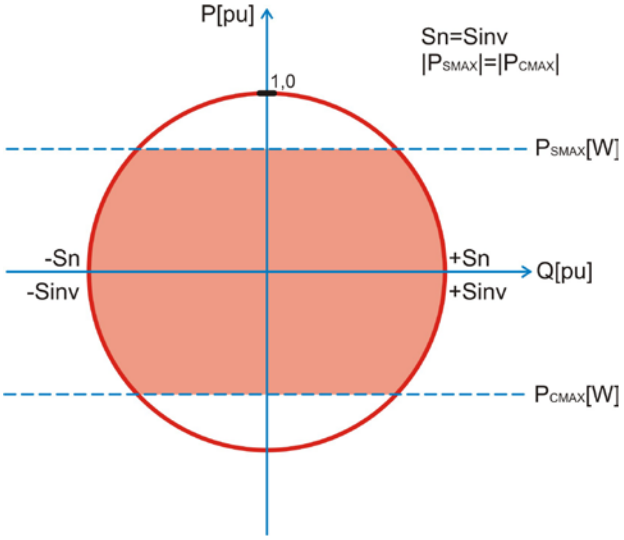



| | |
|---|---|
| E18 – I_ACT_NOM | 100% |
| E62 – CTRL_CP_QV_COSPHI | 0,90 |
| E28 – P_REGEN_MAX | N/A |
| E29 – P_ABSORPT_MAX | N/A |

*Figure 4 – Semicircular capability*

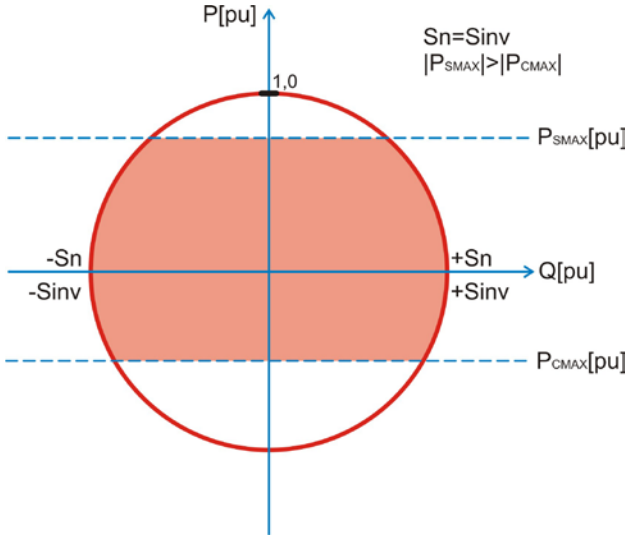
### 4.1.2 Capability for ESS

In the figures that follow, the capability is indicated with the shaded area. The choice of the capability influences the execution of some functions described later - Q(V), cosphi(P) - hence is important to set properly some parameter as indicated below.



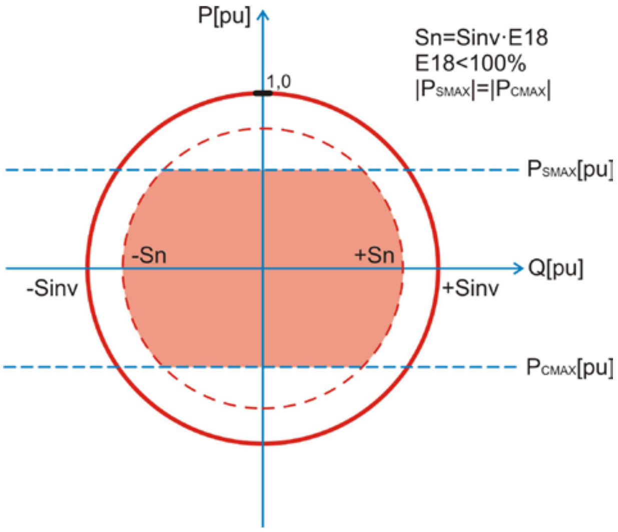

| | |
|---|---|
| E18 – I_ACT_NOM | 100% |
| E62 – CTRL_CP_QV_COSPHI | $\cos\varphi_n$ |
| E28 – P_REGEN_MAX | $P_{SMAX}$ |
| E29 – P_ABSORPT_MAX | $P_{CMAX}$ |

*Figure 5 – Circular cut capability*



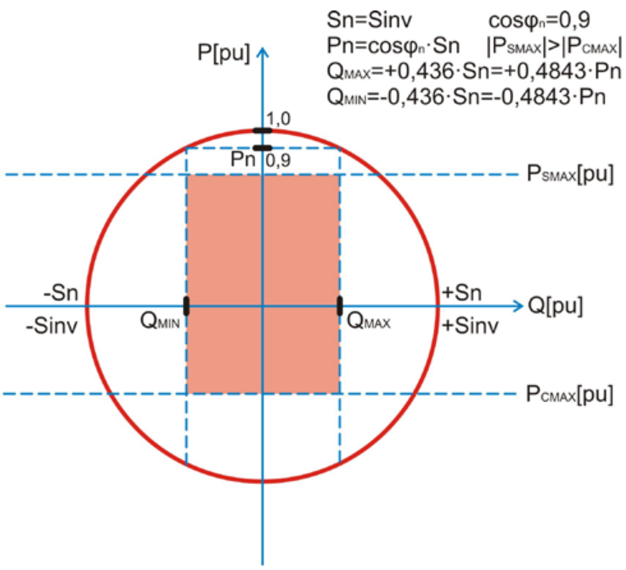

| | |
|---|---|
| E18 – I_ACT_NOM | 100% |
| E62 – CTRL_CP_QV_COSPHI | $\cos\varphi_n$ |
| E28 – P_REGEN_MAX | $P_{SMAX}$ |
| E29 – P_ABSORPT_MAX | $P_{CMAX}$ |

*Figure 6 – Circular asymmetric cut capability*




| | |
|---|---|
| E18 – I_ACT_NOM | <100% |
| E62 – CTRL_CP_QV_COSPHI | $\cos\varphi_n$ |
| E28 – P_REGEN_MAX | $P_{SMAX}$ |
| E29 – P_ABSORPT_MAX | $P_{CMAX}$ |

*Figure 7 – Circular cut capability limited*




| | |
|---|---|
| E18 – I_ACT_NOM | 100% |
| E62 – CTRL_CP_QV_COSPHI | 0,90 |
| E28 – P_REGEN_MAX | $P_{SMAX}$ |
| E29 – P_ABSORPT_MAX | $P_{CMAX}$ |

*Figure 8 – Rectangular capability*

## 4.2 APPLICATION SELECTION

The OPDE_Energy application sw is suitable for different applications. Some specific parameters must be set according to the application, as depicted in the table below.

| Application | E25<br>EN_CURR_REF | E26<br>APPL_SEL | C00<br>CONTROL_SEL | I20<br>VSI/CSI_CTRL |
|---|---|---|---|---|
| Photovoltaic | 0-No | 1-Solar | 0-AFE standard control | disregard |
| Rotating machine connected to AC/DC inverter (wind/hydro) | 0-No | 0-AFE_STD | 0-AFE standard control | disregard |
| Electrical Storage System | 1-Yes | 0-AFE_STD | 2-Micro-Grid control | 1-PLL active |

With parameter **E26–APPL_SEL** it's possible to choose between two mode of operation:

- E26 = 0–AFE_STD → This selection disable the state machine dedicated to the photovoltaic application and works with the DC-Bus voltage regulation, similar to a standard AFE. Use this setting in case of application with rotating machine connected to a AC/DC inverter (for example wind or hydroelectric application), or in case of Electrical Storage System (ESS).
- E26 = 1–Solar → This selection enable the photovoltaic state machine. Use in case of photovoltaic application.

With parameter **E25–EN_CURR_REF** it's possible to disable the DC-Bus voltage control loop: the converter works with active/reactive current reference and active/reactive power reference.

- E25 = 0–No → This selection disable leave the DC-Bus voltage control loop enabled. Use when it's required to regulate the DC-Bus voltage (photovoltaic and hydro/wind).
- E25 = 1–Yes → This selection disable the DC-Bus voltage control loop, the AFE can accept active/reactive current reference and active/reactive power reference. Use this settings in case of Electrical Storage System (ESS).

If E25–EN_CURR_REF=1 the OPDE_Energy recognizes that the AFE is working in a ESS and automatically adapts the working mode of many of the functions described in chapters below::

- Grid Connection Requirements
- Active Power Control P(F)
- Active Power Control P(V)
- Reactive Power Control Cosphi(P)
- Reactive Power Control Q(V)

For further information refer to the following paragraphs.

## 4.3 OPERATING SEQUENCES (ONLY WITH E26=1)

This section describes the converter operating sequences in case of a photovoltaic application (**E26–APPL_SEL = 1**). The state machine diagram is as follows:

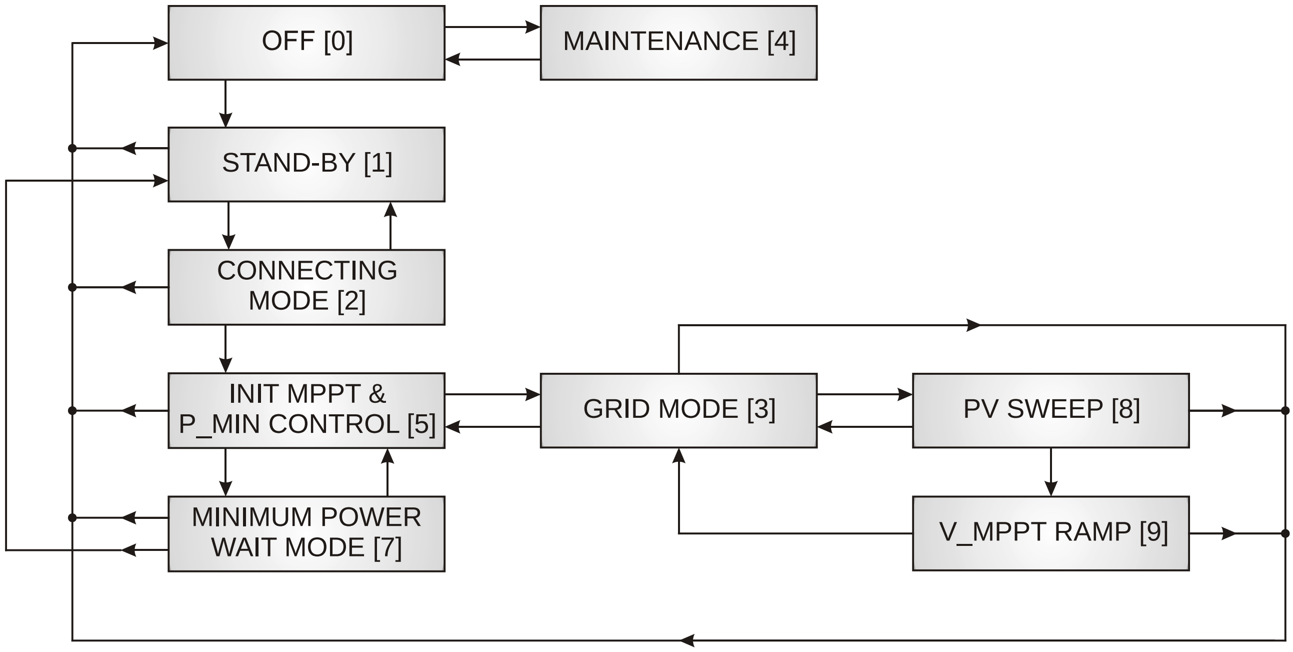



*Figure 9 – State Machine Diagram*

The inverter start-up sequence depends on some parameters that control the repetition times for the start-up attempts and the minimum power required for starting the unit.
The parameters and internal quantities involved in this function are the following ones:

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| P_START_MIN | E41 - Minimum power for starting sequence | 0 | 100 | 2 | % Ppv_NORM_ COEFF | 1 |
| DELTA_V_PMIN | E42 - Delta V for minimum power measure | 0 | 100 | 70 | V | 1 |
| V_PV_START | E43 - PV voltage for starting sequence | 380 | 780 | 460 | V | 1 |
| T1_PMIN | E44 - Repetition time T1 of minimum power measurement | 0.1 | 10.0 | 1.0 | min | 10 |
| T2_PMIN | E45 - Repetition time T1 of minimum power measurement T2>T1 | 0.1 | 30.0 | 10.0 | min | 10 |
| Ton_1 | E46 - Waiting time Ton_1 | 0.1 | 10.0 | 0.1 | min | 10 |
| STATUS | D69 - State machine status | - | - | - | - | 1 |
| EN_AUT_START | D78 - Enable automatic start | - | - | - | - | 1 |

| D69 | State machine status |
|---|---|
| 0 | Off |
| 1 | Stand-by |
| 2 | Connecting mode |
| 3 | Grid Mode |
| 4 | Maintenance |
| 5 | Init MPPT & P_MIN control |
| 7 | Minimum Power Wait Mode |
| 8 | PV sweep |
| 9 | Vmppt ramp |

The different operating statuses are described in detail hereafter.

### 4.3.1 Off Status [0]

When the converter is first powered up, it is in OFF status, disconnected from the mains (grid) and not in "run" mode.
To change the converter to the run mode you will need to press the start button on the remote keypad; this will switch the converter to the STAND-BY mode [1].

*NOTE* Whichever the status of the converter, pressing the stop button will stop the converter and return it to the OFF mode.

If you wish to manage the start and stop commands remotely, you can assign logic inputs **I23–EXTERNAL_START** and **I24–EXTERNAL_STOP** to the free digital inputs LI7 and LI8, and then connect normally open pushbuttons to the relevant digital inputs.
The start and stop commands can also be issued via field bus (Modbus, CanOpen, Profibus) by writing the word corresponding to the digital inputs.

After receiving the start command, the converter will switch from OFF to STAND-BY mode [1].
When issued, the start command remains stored. This means that the converter will not return automatically to OFF [0]. In fact, in case of mains voltage failure or PV voltage failure, the converter will switch to the STAND-BY mode [1]. Once the mains and PV parameters are back to correct values, the converter will switch automatically to the next status.
The internal quantity **D78–EN_AUT_START** indicates that the start command has been stored.

*NOTE* The start command will be enabled only if digital input **I01–Run command** is at high logic level, otherwise the command will be ignored (in the diagrams shown in Section 2, digital input I01 is assigned to physical input LI2).

### 4.3.2 Stand-By Status [1]

In this mode, the converter monitors the PV voltage to see whether it exceeds the value set in **E43–V_PV_START.** If this is verified, then the converter waits for a time equal to **E46–Ton_1** and then switches to CONNECTING MODE [2].

### 4.3.3 Connecting Mode Status [2]

In this mode, the converter attempts to connect to the mains by closing the on-grid contactor. This command is performed by logic output **O33–OD_ON_GRID**, which switches to high (in the diagrams shown in section 2, output O33 is assigned to digital output LO3).

When logic output **O33** is high, it will be verified that:
1) the contactor has closed, by checking digital input **I28–ID_DISP_INT_CLOSE** (in the diagrams shown in Section 2, digital input I28 is assigned to physical input LI6);
2) the grid is OK (that is, the grid present signal is there and the grid frequency control, if enabled, is not signalling a problem).

If the above is verified, then the converter will switch to INIT MPPT & PMIN CONTROL [5].

If the converter sees that:
- Vpv<375V; or that
- after 2 sec the grid is not OK (which means that either the grid fault alarm or grid frequency not OK alarm, if enabled, have been triggered);

it will switch to STAND-BY mode [1].

### 4.3.4 Init MPPT & PMIN Control Status [5]

The converter measures the no-load voltage of the photovoltaic field and displays it on the internal quantity **D64–V_OC**, it then starts running, regulating the PV voltage to a value indicated hereinafter as V_PV_PMIN, which is equal to:

V_PV_MIN = V_OC – DELTA_V_PMIN

where **DELTA_V_PMIN = E42** is a user settable parameter.

At this point, the converter measures the power on the PV side in % with respect to **D68–Ppv_NORM_COEFF**. If it exceeds the threshold set in **E41–P_START_MIN**, then the converter will switch to GRID_MODE, otherwise it means that the power measured does not exceed the minimum set point and the converter will go into MINIMUM POWER WAIT MODE [7].

D68 is equal to:

$$D68 - Ppv\_NORM\_COEFF = V\_MPPT\_MIN \cdot I\_PV\_MAX$$

where I_PV_MAX depends on the size, as indicated in the table below.

| AFE Energy Size | V_MPPT_MIN | I_PV_MAX | Ppv_NORM_COEFF |
|---|---|---|---|
| OPDE S 7 | 380 V | 7,3 A | 2,77 kW |
| OPDE S 15 | | 15,6 A | 5,92 kW |
| OPDE S 22 | | 23,2 A | 8,81 kW |
| OPDE S 32 | | 33,7 A | 12,8 kW |
| OPDE S 48 | | 50,3 A | 19,1 kW |
| OPDE S 60 | | 62,9 A | 23,9 kW |
| OPDE S 70 | 460 V | 83 A | 38,2 kW |
| OPDE S 90 | | 107 A | 49,2 kW |
| OPDE S 110 | | 113 A | 52,0 kW |
| OPDE S 150 | | 157 A | 72,2 kW |
| OPDE S 175 | | 202 A | 92,9 kW |
| OPDE S 220 | | 258 A | 118,7 kW |
| OPDE S 250 | | 293 A | 134,8 kW |
| OPDE S 310 | | 361 A | 166,1 kW |
| OPDE S 370 | | 430 A | 197,8 kW |
| OPDE S 460 | | 498 A | 229,1 kW |

### 4.3.5 Grid Mode Status [3]

The converter enables either function:

- automatic MPPT — if E80–EN_MPPT=1 and E81–EN_MANUAL_MPPT=0, or
- manual MPPT — if E80–EN_MPPT=1 and E81–EN_MANUAL_MPPT=1

When “automatic MPPT” is enabled, the converter regulates the PV voltage by operating about its maximum power point, by applying a P&O algorithm according to the following parameters:

**E35–DELTA_V** — Voltage step MPPT Algorithm [V]
**E36–TIME_STEP** — Time step MPPT Algorithm [Tpwm]

When “manual MPPT” in enabled, the converter adjusts the PV voltage according to a fixed voltage given by parameter **E39–K_MANUAL_MPPT,** which defines the operating voltage as a % of the open circuit voltage (Voc) measured in the INIT MPPT & PMIN Control mode [5].
For further details about MPPT see Section 4.2.

### 4.3.6 Minimum Power Wait Mode Status [7]

In this mode, the converter remains connected to the mains and performs three attempts to measure the minimum start power, spaced apart by a time delay interval set in parameter **E44–T1_PMIN**. If the power measured exceeds the threshold value, then the converter will switch to GRID MODE [3].
If both attempts fail, the converter will go into STAND-BY mode [1], i.e. it disconnects from the mains and waits for the time set in **E45–T2_PMIN** before it restarts the sequence.

### 4.3.7 PV Sweep Status [8]

In status [8] the inverter is executing the PV sweep function. If parameter **E89–EN_PV_SWEEP=1–Automatic sweep** or **E89–EN_PV_SWEEP=2–One-shot sweep** Refer to par. 0 for an explanation of the function.

### 4.3.8 Vmppt ramp [9]

In status [9] the inverter have just finished the PV sweep and moves the Vpv voltage to reach with a ramp the Vmppt value calculated in status [8].

### 4.3.9 Maintenance Status [4]

You can perform maintenance tasks by running the converter while disconnected from the PV field. To switch to maintenance mode, set the converter to OFF [0] and then E82=1. For further details see Section 4.7

## 4.4 LOCKING OF THE CONVERTER (ONLY WITH E26=1)

In specific alarm situations, the converter automatically switch off and goes on status OFF [0]. This happens if there is one of this events:

- AFE core alarm;
- **I01–Run command** input at low logic level;
- **I27–Surge protection device OK** input at low logic level;
- **I29–F an OK** input at low logic level;

- **I30–PV switch close and PV insulation OK** input at low logic level;
- **I31–Interface protection OK** input at low logic level;
- Ambient temperature higher than the threshold set in E48 (only with ambient temperature control function activated)**.**

## 4.5 MPPT FUNCTION (ONLY WITH E26=1)

### 4.5.1 Manual MPPT

By acting on parameter **E81–EN_MANUAL_MPPT** the inverter works with a fixed and constant photovoltaic voltage (Vpv). To enable this function set:

E81=1 (yes) E80=0 (no)

The value of the Vpv regulated voltage can be set by acting on parameter **E39–K_MANUAL_MPPT**, which determines the operating voltage as a percentage of the open circuit voltage (Voc) measured on the first daily power up of the inverter.

$$Vpv = K\_MANUAL\_MPPT \cdot Voc = P239 \cdot d64$$

Each time the run command is issued, the inverter will measure the open circuit voltage (Voc) of the photovoltaic field and so it will re-calculate the Vpv operating voltage.

### 4.5.2 Automatic MPPT

If automatic MPPT is enabled, the inverter will automatically track the maximum power point of the photovoltaic field by applying a P&O (Perturb-and-Observe) algorithm. To enable automatic MPPT act on parameter **E80–EN_MPPT**, as follows:

E80=1 (yes) E81=0 (no)

By acting on parameters **E35** and **E36** you can modify the dynamic behaviour of MPPT.
**E35–DELTA_V** represents the width of the DC-Bus voltage change, in Volts, which the P&O algorithm performs while tracking the MPPT, whereas **E36–TIME_STEP** is the repetition frequency of the perturbations in multiples of the PWM period.

*NOTE* **Do not change these parameter settings. Contact TDE MACNO for information if you wish to perform any calibrations.**

### 4.5.3 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_MPPT | E80 - Enable MPPT Algorithm | 0 | 1 | 1 | | 1 |
| DELTA_V | E35 - Voltage step MPPT Algorithm | 0 | 20 | 3 | V | 1 |
| TIME_STEP | E36 - Time step MPPT Algorithm | 0 | 19999 | 5000 | Tpwm | 1 |
| EN_MANUAL_MPPT | E81 - Enable Manual MPPT Algorithm | 0 | 1 | 0 | | 1 |
| K_MANUAL_MPPT | E39 - MPP in % respect Voc measured | 70 | 100 | 80 | %Voc | 1 |
| V_OC | D64 - PV Open Circuit Voltage | | | | V | 1 |

## 4.6 GRID FREQUENCY CONTROL FUNCTION (ONLY WITH E26=1)

By setting **E86–EN_GRID_F_CNTRL** to 1, a control function for the grid frequency read by the AFE is enabled. In particular, the converter verify if the frequency is within the range specified in **E50–PERC_GRID_F_CNTRL**.
The window within which no alarm will be generated concerning the grid frequency is the following one:

$$F_{RETE\_MIN} \leq F_{RETE} \leq F_{RETE\_MAX}$$

where

$$F_{RETE\_MIN} = P63 \cdot \frac{100 + P250}{100} \qquad F_{RETE\_MAX} = P63 \cdot \frac{100 - P250}{100}$$

If the frequency reading exceeds the threshold value by more than 40 ms, then an alarm will be generated.

### 4.6.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_GRID_F_CNTRL | E86 - Enable grid frequency control | 0 | 1 | 0 | | 1 |
| PERC_GRID_F_CNTRL | E50 - Percentage tolerance for grid frequency control | 0.6 | 10 | 1 | % | 10 |

## 4.7 MAINTENANCE FUNCTION (ONLY WITH E26=1)

For the commissioning and maintenance of the system, a “maintenance” mode is provided, which makes it possible to run the converter in the absence of a photovoltaic field.

ATTENTION To enable the “maintenance” mode you must make sure that the disconnector on the PV side is open, in order to prevent the PV field from being supplied a voltage that can damage the panels.

To enable this function, set **E82–EN_MANUT** to 1. When you do so, the inverter will automatically switch output **O33–OD_ON_GRID** to high. In this way, the DC-Bus capacitors will be precharged from the mains and the converter will connect to the power mains. Now you can start and stop the converter using the relevant pushbuttons on the remote keypad.
While it is “running”, the converter will regulate the DC-Bus voltage according to the voltage set in **P08–DC_BUS_REF**.

To exit the “maintenance” mode, set **E82–EN_MANUT** back to 0.

While E82=1, make sure not to save the parameters on EEprom, otherwise this value will be saved and the inverter will always go into maintenance mode.

### 4.7.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_MANUT | E82 - Enable maintenance mode | 0 | 1 | 0 | | 1 |

## 4.8 AMBIENT TEMPERATURE CONTROL FUNCTION (ONLY WITH E26=1)

It is possible to stop the converter if the ambient temperature read via input PTC/NTC exceeds a threshold value settable in E**85–TEMP_AMB_OFF**. To use this function, you will need to connect a temperature probe model Epcos B57703M103G to terminal block M4, on terminal M4-1 and M4-2.
This function can be enabled through parameter **E85–EN_TEMP_OFF**. The ambient temperature reading is displayed in the internal quantity **D73–Tamb**.

### 4.8.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_TEMP_OFF | E85 - Enable temperature controlled switch-off | 0 | 1 | 0 | | 1 |
| TEMP_AMB_OFF | E48 - AFE switch off ambient temperature | 30 | 50 | 41 | °C | 1 |
| Tamb | D73 - Ambient temperature | - | - | - | °C | 1 |

## 4.9 AC POWER MEASUREMENT – CALCULATION OF PRODUCED ENERGY

The converter is able to calculate the energy production by using the output power measurement on the AC side. The resulting datum is an estimate and, therefore, subject to some degree of error.
In fact, the calculation of AC power, though precise, may not be accurate, because it depends on several factors, such as reactance and transformer losses, which differ depending of the size and construction of the equipment. Therefore, such losses are merely an estimate.
The instantaneous power injected into the grid is displayed in internal quantity **D70–AC power**. There is a correction parameter **E49–Kmult_Pac** that acts as a multiplication coefficient and allows the correction of the AC power reading, so that this value is as close as possible to the real value, thus enabling a correct calculation of the energy production.

The energy output is displayed in internal quantities D74, D75, D76, D77, which show the energy broken down in multiples of Wh, kWh, MWh and GWh respectively. The overall energy is the sum of these four contributions.

The Energy count can be zeroed by setting parameter **E83–ENERGY_RESET** to 1, after which the parameter will return automatically to 0.

### 4.9.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| Kmult_Pac | E49 - Pac measured multiplication coefficient | 0 | 1 | 0 | | 1 |
| ENERGY_RESET | E83 - Reset produced energy counter | 0 | 1 | 0 | | 1 |
| Pac | D70 - AC Power | 0.00 | - | - | kW | 128 |
| Energy_Wh | D74 - Produced Energy in Wh | 0 | 999 | - | Wh | 1 |
| Energy_kWh | D75 - Produced Energy in kWh | 0 | 999 | - | kWh | 1 |
| Energy_MWh | D76 - Produced Energy in MWh | 0 | 999 | - | MWh | 1 |
| Energy_GWh | D77 - Produced Energy in GWh | 0 | 999 | - | GWh | 1 |

## 4.10 MANAGING THE INTERFACE PROTECTION

In many Countries, for being allowed to connect to the power mains and inject energy into it, a system must comply with specific technical regulations. In Italy, these regulations impose a duty to use an interface device (DDI) between the photovoltaic system and the public utility network (namely, the Enel distribution network) in order to disconnect the two systems in case of failure or malfunction of the distribution network. The DDI is controlled by the interface protection system (SPI), a device that monitors the mains voltage and frequency and sends an alarm signal when these parameters exceed the protection device settings. Normally, this alarm is signalled via a clean contact.

The OPDE_Energy Application allows the management of a SPI, the SPI status contact must be connected to logic input **I31–Interface protection OK**.

Moreover, the grid-connection regulations require that the contact of the SPI cuts directly the power supply of the DDI control coil.

## 4.11 CURRENT REFERENCE

With parameter **E25–EN_CURR_REF**=1-Yes  it's possible to disable the DC-Bus voltage loop control and enable only the current loop control.
Use **E00–IQ_REF** and **E01–ID_REF** to give the active and reactive current references.

The active sign convention is used, i.e. the current toward the grid is considered positive.

A *positive* value in E00 means that active current flows from the AFE to the grid.
A *negative* value in E00 means that active current flows from the grid to the AFE

A *positive* value in E01 means the current produced can compensate inductive loads (**AFE acts as a capacitor**).
A *negative* value in E01 means the current produced can compensate capacitive loads (**AFE acts as an inductor**).

### 4.11.1 Function Parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_CURR_REF | E25 - Enable application current reference | 0 | 1 | 0 | | 1 |
| IQ_REF | E00 - Reference for active current Iq | -100.00 | 100.00 | 0 | % I_CONV_NOM | 100 |
| ID_REF | E01 - Reference for reactive current Id | -100.00 | 100.00 | 0 | % I_CONV_NOM | 100 |

## 4.12 FIELDBUS REFERENCE AND LIMIT

With parameter **E27–EN_FLDBUS_REF**=Yes it's possible to enable the fieldbus reference.

### 4.12.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_FLDBUS_REF | E27 - Enable FIELD-BUS reference values | 0 | 1 | 0 | | 1 |
| PRC_DC_BUS_REF_FLDBUS | D90 - Fieldbus DC-Bus Reference | | | | % DC_BUS_REF | 163.84 |
| IQ_REF_FLDBUS | D91 - Fieldbus Iq active current reference | | | | % I_CONV_NOM | 163.84 |
| ID_REF_FLDBUS | D92 - Fieldbus Id reactive current reference | | | | % I_CONV_NOM | 163.84 |
| PRC_CONV_I_PEAK_FLDBUS | D93 - Fieldbus current limit | | | | % I_CONV_NOM | 163.84 |
| V_GRID_OVD_FLDBUS | D94 - Fieldbus Vgrid override reference | | | | % V_GRID_ISL | 163.84 |
| FREQ_OVD_FLDBUS | D95 - Fieldbus Fgrid override reference | | | | % F_GRID_NOM | 163.84 |
| VB_LIM_MAX_OVD_FLDBUS | D96 - Fieldbus maximum DC Bus voltage limit override | | | | % VB_MAX | 163.84 |
| VB_LIM_MIN_OVD_FLDBUS | D97 - Fieldbus minimum DC Bus voltage limit override | | | | % VB_MIN | 163.84 |
| P_GRID_REF_FLDBUS | D98 - Fieldbus active power reference | | | | % S_NOM | 163.84 |
| Q_GRID_REF_FLDBUS | D99 - Fieldbus reactive power reference | | | | % S_NOM | 163.84 |

## 4.13 PWM SYNCHRONIZATION

In application where there is an AFE-Inverter system, or in application with many AFE working together in the same power plants, there is the possibility to synchronize the converter at PWM level. To do this it’s necessary to connect the converter ad shown below**Errore. L'origine riferimento non è stata trovata.**.

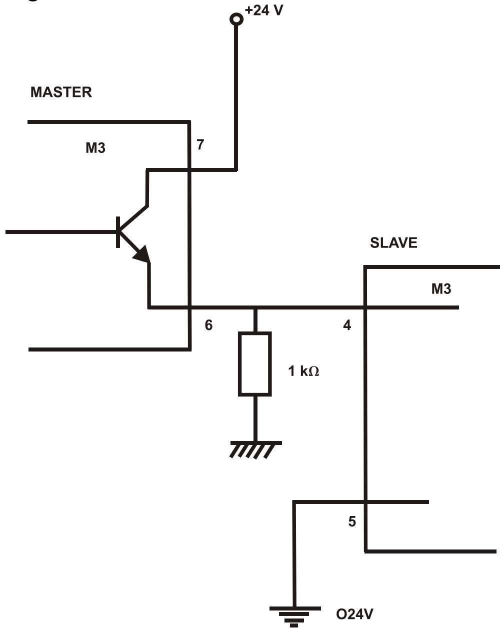



*Figure 10 – Connections for PWM Synchronization*

Parameter **E87–EN_PWM_SYNCH** is used to select the drive function:

a) E87=1-Master → Physical output n° 3 (P.O.3) is configured like “O31-PWM synchronization output”.

b) E87=2-Slave → Physical Input n° 8 (P.I.8) is configured like “I26-PWM synchronization input”.

In the slave there is a tracking loop with gain Kp (P11) e Ta (P12). It’s possible to set also the phase between master and slave with parameter E88.

Note1: Master and slave have to be set with the same PWM frequency (P101)
Note2: If the PWM frequency is great than 5kHz is necessary to use a pull-down 1kΩ resistance 1W.

### 4.13.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_PWM_SYNCH | E87 - Enable PWM synchronization | Scale: 0 No; 1 Master; 2 Slave | | 0 | | 1 |
| PWM_SYNCH_PHASE | E88 - PWM synchronization angle | -175.0 | 175.0 | 0 | Degrees | 10 |
| PWM_SYNC_DELAY | D81 - PWM SYNC delay | -400.0 | 400.0 | 0.0 | µs | 10 |

## 4.14 ACTIVE POWER CONTROL P(F)

With P(F) function is possible to:

- limit the active power P in case of grid over-frequency (OF), or
- control the active power P in case of grid over-frequency (OF) and under-frequency (UF).

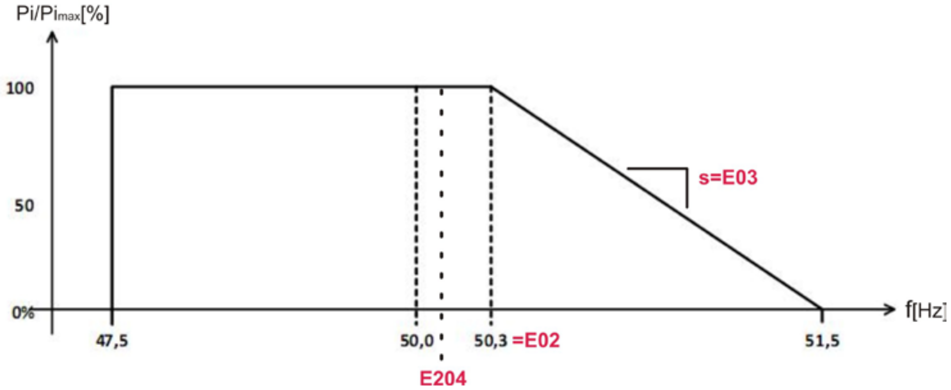
The working mode depends on the value of parameter E25-EN_CURR_REF that identify if the application is an ESS or a PV/Hydro/Wind. The P *control* in OF and UF is enabled only for ESS, in the other cases the P is *limited*.

To enable the function set **E92-EN_ACT_PWR_CTRL_PF=1** o **2**. The table below describes the different working mode of P(F) function, further details in the following paragraphs.

| Application | E25-EN_CURR_REF | E92-EN_ACT_PWR_CTRL_PF | P(F) working mode | | |
|---|---|---|---|---|---|
| | | | limit/control | OF/UF | Block at Pmin |
| PV | 0-No | 0-No | not activated | - | - |
| | | 1-Yes, with power blocked at Pmin | P limit | OF | No |
| | | 2-Yes, without power blocked at Pmin | | | Yes |
| Hydro/Wind | 0-No | 0-No | not activated | - | - |
| | | 1-Yes, with power blocked at Pmin | P limit | OF | No |
| | | 2-Yes, without power blocked at Pmin | | | Yes |
| ESS | 1-Yes | 0-No | not activated | - | - |
| | | 1-Yes, with power blocked at Pmin | P control | OF and UF | No |
| | | 2-Yes, without power blocked at Pmin | | | Yes |

### 4.14.1 P(F) for PV and Wind/Hydro

In a PV or Wind/Hydro application, the P(F) function *limits* the active power injected in the grid in case of a grid over frequency event. The control rule is depicted in the Figure below.




Pi = instantaneous power
$Pi_{max}$ = instantaneous power when frequency increase over threshold E02
s = slope, i.e. frequency variation in %GRID_FREQ_NOM that produce a power variation of 100% of Pi

*Figure 11 – Active power reduction in over frequency*

The function is activated (Lock-in) when the frequency increase over threshold **E02–CTRL_FF_F_LOCK_IN_OF**. In lock-in status, if frequency increases more and more, the instantaneous power Pi decreases linearly, depending on the slope set in **E03–CTRL_FF_SLOPE_OF**.

If later the grid frequency decreases, the behaviour depends on selection done with **E92-EN_ACT_PWR_CTRL_PF**:

*E92=1 - Yes, with power blocked at Pmin*

The active power will be limited to the minimum value reached during the over frequency event (Pmin). If the frequency stays stable in the interval fixed by **E205–CTRL_PF_F_LCOK_OUT_UF** and **E204–CTRL_PF_F_LCOK_OUT_OF** (default interval is 50±1Hz) for a minimum continuous time equal to **E200–CTRL_PF_LOCK_OUT_WAIT_TIME** (default time is 300s), the function is deactivated (Lock-out).
After this 300s waiting time, the active power limit return to $Pi_{max}$ following a linear ramp with a slope equal to 20%*$Pi_{max}$/min or, in any case, not less than 5%*Pnom/min.
When the power limit reaches $Pi_{max}$, the linear ramp continuous with the same slope until 100% power limit is reached.

*E92=2 Yes, without power blocked at Pmin*

The P(F) curve is executed backward, on the opposite direction, and the power is increased.

The activation (Lock-in) of P(F) function is signalled on digital output **O40–P(F) function active**. The value of the power limit is written in variable **D84-P_active_limit** or **osc86 – P_active_limit**, with scale 4096 and u.m [% D82-S_NOM].

For further information about the active power limitation management in Full Converter system refer to paragraph 5.1.

### 4.14.2 P(F) for ESS

In an Energy Storage System, the P(F) function *controls* the active power injected in the grid in case of a grid over/under frequency event. The active power reference that is set by the "User" and that was executed before the over/under frequency event is ignored and a new active power set-point generated by the P(F) function is used. The control rule is depicted in the Figure below.

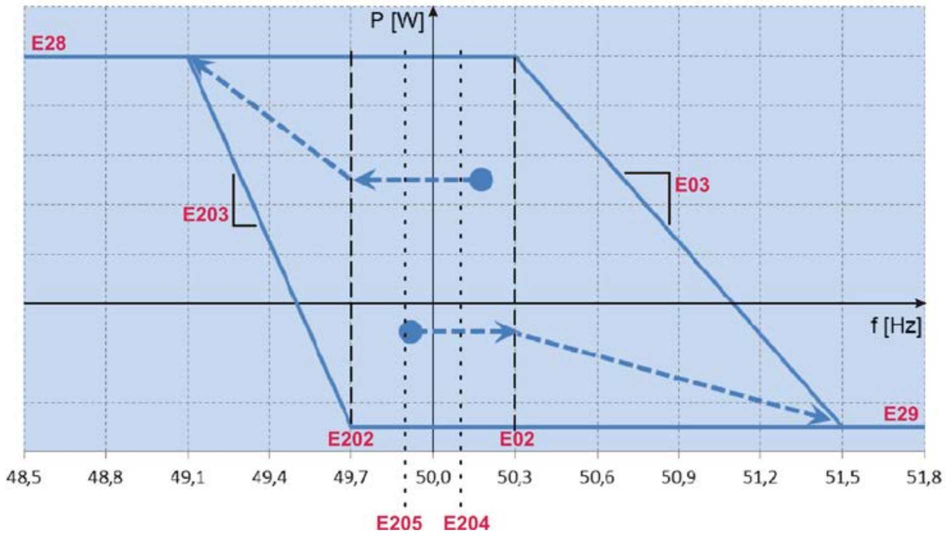



*Figure 12 – Active power regulation in over and under frequency for ESS*

The function is activated (Lock-in) when:

- the frequency increases over threshold **E02–CTRL_FF_F_LOCK_IN_OF** that means an *OF lock-in*, or
- the frequency decreases under the threshold **E202–CTRL_FF_F_LOCK_IN_UF** that means an *UF lock-in*.

An activation time delay can be set with **E99-CTRL_PF_DELAY_ON**.

In *OF lock-in* status, if frequency increases more and more, the instantaneous power Pi decreases linearly, depending on the slope set in **E03–CTRL_FF_SLOPE_OF**. In *UF lock-in* status, if frequency decreases more and more, the instantaneous power Pi increases linearly, depending on the slope set in **E203–CTRL_FF_SLOPE_UF**.

If we have a OF lock-in/UF lock-in and later the grid frequency decreases/increases, the behaviour depends on selection done with **E92-EN_ACT_PWR_CTRL_PF**:

*E92=1 - Yes, with power blocked at Pmin*

The active power will be limited to the minimum/maximum value reached during the over/under frequency event (Pmin). If the frequency stays stable in the interval fixed by **E205–CTRL_PF_F_LCOK_OUT_UF** and **E204–CTRL_PF_F_LCOK_OUT_OF** (default interval is 50±1Hz) for a minimum continuous time equal to **E200–CTRL_PF_LOCK_OUT_WAIT_TIME** (default time is 300s), the function is deactivated (Lock-out).
After this 300s waiting time, the active power value return to the User active power reference following a linear ramp with a slope equal to **E201-CTRL_PF_RAMP_TIME**. When the power limit reaches the Users set point the P(F) function is deactivated

*E92=2 Yes, without power blocked at Pmin*

The P(F) curve is executed backward, on the opposite direction, and the power is increased/decreased linearly, without any waiting time or ramp.

The activation (Lock-in) of P(F) function is signalled on digital output **O40–P(F) function active**.

### 4.14.3 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_ACT_PWR_CTRL_PF | E92 - Enable automatic active power control according to P=f(F) curve | Range: 0 No; 1 Yes, with power blocked at Pmin; 2 Yes, without power blocked at Pmin | | 0 | | 1 |
| CTRL_PF_F_LOCK_IN_OF | E02 - Lock-in frequency of P=f(F) curve in Over Frequency | 45.00 | 55.00 | 50.30 | Hz | 100 |
| CTRL_PF_F_LOCK_IN_UF | E202 - Lock-in frequency of P=f(F) curve in Under Frequency | 45.00 | 49.70 | 55.00 | | 100 |
| CTRL_PF_SLOPE_OF | E03 - Percentage Slope of P=f(F) curve in Under Frequency | 0.1 | 5.0 | 2.4 | % GRID_FREQ_NOM / % P_INST | 10 |
| CTRL_PF_SLOPE_UF | E203 - Percentage Slope of P=f(F) curve in Over Frequency | 0.1 | 5.0 | 1.2 | % GRID_FREQ_NOM / % P_INST | 10 |
| CTRL_PF_F_LOCK_OUT_OF | E204 - Lock-out frequency of P=f(F) curve in Over Frequency | 50.05 | 51.00 | 50.10 | Hz | 100 |
| CTRL_PF_F_LOCK_OUT_UF | E205 - Lock-out frequency of P=f(F) curve in Under Frequency | 49.00 | 49.95 | 49.90 | Hz | 100 |
| CTRL_PF_LOCK_OUT_WAIT_TIME | E200 - P(f) Lock-out waiting time | 0 | 900 | 300 | s | 1 |
| CTRL_PF_DELAY_ON | E99 - Activation delay timed of P=f(F) curve | 0.00 | 10.00 | 0.00 | s | 100 |
| CTRL_PF_RAMP_TIME | E201 - P(f) active power ramp time | 1 | 900 | 300 | s | 1 |

## 4.15 ACTIVE POWER CONTROL P(V)

With P(V) function it's possible to limit/control the active power in case of a grid over-voltage. Set **E98-EN_ACT_PWR_CTRL_PV=1-Yes** to enable this function.

If parameter **E25-EN_CURR_REF=0-No**, that identify PV/Hydro/Wind application, then the P(V) function works as a P *limit*. If parameter **E25-EN_CURR_REF=1-Yes**, that identify if the application is an ESS, then the P(V) function works as a P *control*.

| Application | E25-EN_CURR_REF | E98-EN_ACT_PWR_CTRL_PV | P(F) working mode |
|---|---|---|---|
| PV/Hydro/Wind | 0-No | 0-No | not activated |
| | | 1-Yes | P limit |
| ESS | 1-Yes | 0-No | not activated |
| | | 1-Yes | P control |

### 4.15.1 P(V) for PV and Wind/Hydro

In case of PV or Wind/Hydro application the P(V) function limits the active power according to Figure 13. When the grid voltage increases over the threshold **E74-CTRL_PV_V1S**, the power is automatically limited with a linear characteristic that decreases the power to a minimum value equal to **E76-CTRL_PV_P_LIM** at voltage **E75-CTRL_PV_V2S**.
When the voltage decrease, the P(V) characteristic is executed in the opposite way and will stop at the current power value.

The activation (Lock-in) of P(V) function is signalled on digital output **O41 – P(V) function active**.

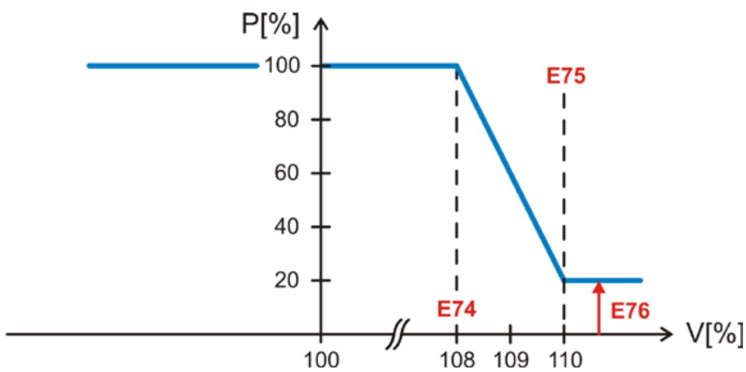



*Figure 13 – P(V) characteristic for PV/Hydro/Wind*

### 4.15.2 P(V) for ESS

In an Energy Storage System, the P(V) function *controls* the active power injected in the grid in case of a grid over voltage event.
The P(V) function activates when the grid voltage increases over the threshold **E74-CTRL_PV_V1S**. The active power reference that is set by the "User" is ignored and a new active power set-point generated by the P(V) function is used.
The new reference has a linear characteristic that starts from the instantaneous power Pi down to a value equal to **E76-CTRL_PV_P_LIM** at voltage **E75-CTRL_PV_V2S**, and is generated through a ramp settable with **E207-CTRL_PV_RAMP_TIME**.
The control rule is depicted in the Figure 14.

When the voltage decrease, the P(V) characteristic is executed in the opposite way and stops automatically when it reaches the input power reference value.

The activation (Lock-in) of P(V) function is signalled on digital output **O41 – P(V) function active**.

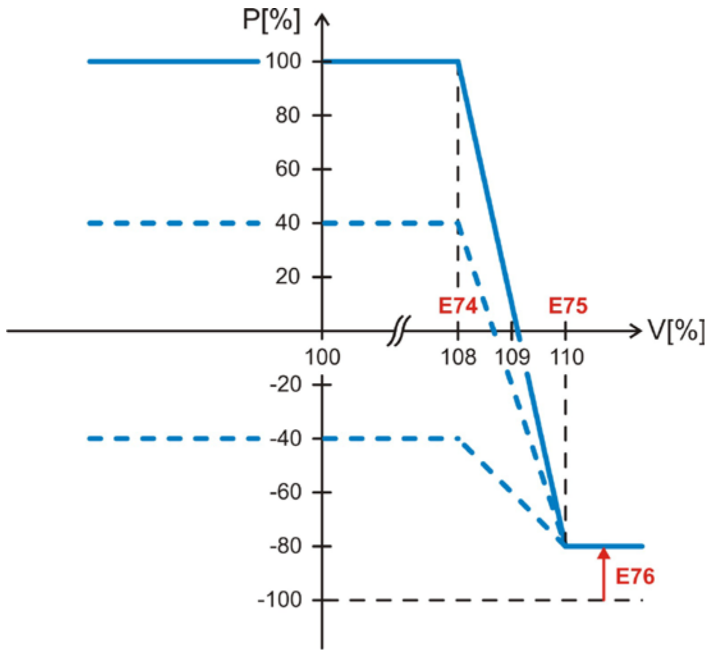



*Figure 14 - P(V) characteristic for ESS*

### 4.15.3 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_ACT_PWR_CTRL_PV | E98 - Enable automatic active power control according to P(V) curve | 0 | 1 | 0 | | 1 |
| CTRL_PV_V1S | E74 - V1S voltage of P(V) curve | 108 | 135 | 108 | % V_GRID_NOM | 1 |
| CTRL_PV_V2S | E75 - V2S voltage of P(V) curve | 110 | 135 | 110 | % V_GRID_NOM | 1 |
| CTRL_PV_P_LIM | E76 - Active power limit for P(V) curve | 0 | 200 | 20 | % P_ACT_NOM | 1 |
| CTRL_PV_RAMP_TIME | E207 - P(V) active power ramp time | 1 | 900 | 300 | s | 1 |

## 4.16 GRID CONNECTION REQUIREMENTS

With parameter **E93–EN_GRID_CONN_MANAGE** it's possible to enable the management of the grid connection according to the Italian Standard CEI 0-21 or to the Chinese standard CGC/GF004.

The voltage and frequency values used for this function come from "osc46-Grid Voltage" and "osc44-Grid Freq", later filtered with an LPF filter with time constant E13. The values are shown in:

D86–Vgrid_CONN_MANAGE
D87–Fgrid_CONN_MANAGE

### 4.16.1 CEI 0-21 operating mode (E93=1)

If **E93=1** the CEI 0-21 operating mode is activated. The connection to the grid is done only if:

a) the grid voltage filtered (**D86–Vgrid_CONN_MANAGE**) is between **E05–V_GRID_MIN** and **E04–V_GRID_MAX** (default interval is 85% - 110% of nominal voltage P62); and

b) the grid frequency filtered (**D87–Fgrid_CONN_MANAGE**) is between **E07–F_GRID_MIN** and **E06–F_GRID_MAX** (default interval is 49,90 Hz – 50,10 Hz);

for a minimum time set in **E08–GRID_WAI_TIME_1** (default time 30s); and

c) the protection interface (PI) status signal - connected to input **I31-Interface protection ok** - is at high level.

If the inverter execute a connection after a disconnection caused by the interface protection (PI), then the waiting time is equal to **E09–GRID_WAIT_TIME_2** [1].

The counter related to E08–GRID_WAIT_TIME_1 is displayed in D88 – Counter_GRID_FAULT.
The counter related to E09–GRID_WAIT_TIME_2 is displayed in D89 – Counter_SPI.

Alarm "**A4.0 – Waiting time for grid voltage and frequency control**" is shown:

a) when input **I31-Interface protection ok** is at low level; or
b) when the inverter is not connected to the grid; or
c) when the inverter is connected to the grid but Vgrid or Fgrid are out of the acceptance thresholds, or
d) when voltage and frequency have the right value but the waiting time is not ended.

After the waiting time, the power increases with a linear ramp whose slope is fixed by **E10–ACT_PWR_RAMP_TIME**. The value of the power limit is written in variable **D84-P_active_limit** or **osc86 – P_active_limit**, with scale 4096 and u.m [% D82-S_NOM].

When the inverter is running it continuously monitors the grid voltage and frequency. If:

a) the grid voltage is outside the range **E05–V_GRID_MIN** and **E04–V_GRID_MAX** (default interval is 85% - 110% of nominal voltage); or
b) the grid frequency is outside the range **E12–F_GRID_MIN_RUN** and **E11–F_GRID_MAX_RUN** (default interval is 47,50 Hz – 51,50 Hz);

then it stops and gives alarm A4.0.

### 4.16.2 CGC/GF004 operating mode (E93=2)

If E93=2 the CGC/GF004 operating mode is activated. In this case the response to grid frequency is depicted below.

| Frequency range | Response of inverter |
|---|---|
| Fgrid < E12–F_GRID_MIN_RUN | The inverter stops operating within 0,2s and disconnect from the grid.<br>At that moment, if the frequency is back to normal value, the inverter automatically connects to the grid and start to operate. |
| E12–F_GRID_MIN_RUN < Fgrid < E07–F_GRID_MIN | The inverter operates for a time equal to E09–GRID_WAIT_TIME_2, then stops.<br>At that moment, if the frequency is back to normal value, the inverter automatically connects to the grid and start to operate. |
| E07–F_GRID_MIN < Fgrid < E06–F_GRID_MAX | The inverter operates normally |
| E06–F_GRID_MAX < Fgrid < E11–F_GRID_MAX_RUN | The inverter operates for a time equal to E08-GRID_WAIT_TIME_1, then stops.<br>Alarm "**A4.2–Grid Over Frequency during run**" is shown<br>At that moment, if the frequency is back to normal value, the inverter doesn't automatically start to operate. A reset command is needed. |
| Fgrid > EF_GRID_MAX_RUN | The inverter stops operating within 0,2s<br>Alarm "**A4.2–Grid Over Frequency during run**" is shown<br>At that moment, if the frequency is back to normal value, the inverter doesn't automatically start to operate. A reset command is needed. |
| E05–V_GRID_MIN < Vgrid < E04–V_GRID_MAX | The inverter operates normally |
| E05–V_GRID_MIN < Vgrid | The inverter stops operating within 0,2s<br>Alarm "**A4.3– Grid Over/Under Voltage during run**" is shown<br>At that moment, if the frequency is back to normal value, the inverter doesn't automatically start to operate. A reset command is needed. |
| Vgrid < E04–V_GRID_MAX | The inverter stops operating within 0,2s<br>Alarm "**A4.3– Grid Over/Under Voltage during run**" is shown<br>At that moment, if the frequency is back to normal value, the inverter doesn't automatically start to operate. A reset command is needed. |

Default values for Chinese standard CGC/GF004 are:

E06=50,2Hz E07=49,5Hz E11=50,5Hz E12=48Hz E08=120s E09=600s

[1] The PI tripping is recognized only if the AFE remains powered during the grid fault, for example using an external UPS to generate the 24 Vdc power supply.

### 4.16.3 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_GRID_CONN_MANAGE | E93 - Enable grid connection manage | Range<br>0 | No<br>1 | CEI 0-21 function (Italy)<br>2 | CGC/GF004 function (China) | | 0 | | 1 |
| V_GRID_MAX | E04 - Maximum grid voltage for enabling grid connection | 101 | 120 | 110 | % V_GRID_NOM | 1 |
| V_GRID_MIN | E05 - Minimum grid voltage for enabling grid connection | 80 | 99 | 85 | % V_GRID_NOM | 1 |
| F_GRID_MAX | E06 - Maximum grid frequency for enabling grid connection | 50.05 | 50.10 | 51.00 | Hz | 100 |
| F_GRID_MIN | E07 - Minimum grid frequency for enabling grid connection | 49.00 | 49.95 | 49.90 | Hz | 100 |
| GRID_WAIT_TIME_1 | E08 - Wait time for enabling grid connection | 1 | 900 | 30 | s | 1 |
| GRID_WAIT_TIME_2 | E09 - Wait time for enabling grid connection after SPI trigger or over frequency | 1 | 900 | 300 | s | 1 |
| ACT_PWR_RAMP_TIME | E10 - Active power ramp time | 1 | 900 | 300 | s/S_NOM | 1 |
| F_GRID_MAX_RUN | E11 - Maximum grid frequency for running | 50.05 | 54.00 | 51.50 | Hz | 100 |
| F_GRID_MIN_RUN | E12 - Minimum grid frequency for running | 46.00 | 49.95 | 47.50 | Hz | 100 |
| V_F_GRID_FILTER | E13 - Vgrid and Fgrid filter time constant | 0 | 999 | 100 | ms | 1 |
| GRID_UNB_MAX | E17 - Maximum grid voltage unbalance for enabling run | 0.0 | 100.0 | 10.0 | % V_GRID_NOM | 10 |
| V_GRID_MAX_UNB | E31 - Maximum grid voltage with unbalanced grid for enabling run | 0.0 | 200.0 | 115.0 | % V_GRID_NOM | 10 |
| V_GRID_MIN_UNB | E32 - Minimum grid voltage with unbalanced grid for enabling run | 0.0 | 200.0 | 80.0 | % V_GRID_NOM | 10 |
| Vgrid_CONN_MANAGE | D86 - Vgrid reading for Grid Connection Manage function | | | | % V_GRID_NOM | 1000 |
| Fgrid_CONN_MANAGE | D87 – Fgrid reading for Grid Connection Manage function | | | | % F_GRID_NOM | 1000 |
| Count_GRID_FAULT | D88 - Counter for A4.0 after Grid Fault event | | | | s | 1 |
| Count_SPI | D89 - Counter for A4.0 after SPI trigger event | | | | s | 1 |

## 4.17 REACTIVE POWER CONTROL Q(V)

### 4.17.1 Q(V) for PV and Wind/Hydro

The Q=f(V) function injects reactive power Q into the grid in case of a grid over/under voltage event. The control rule is depicted in Figure 15.

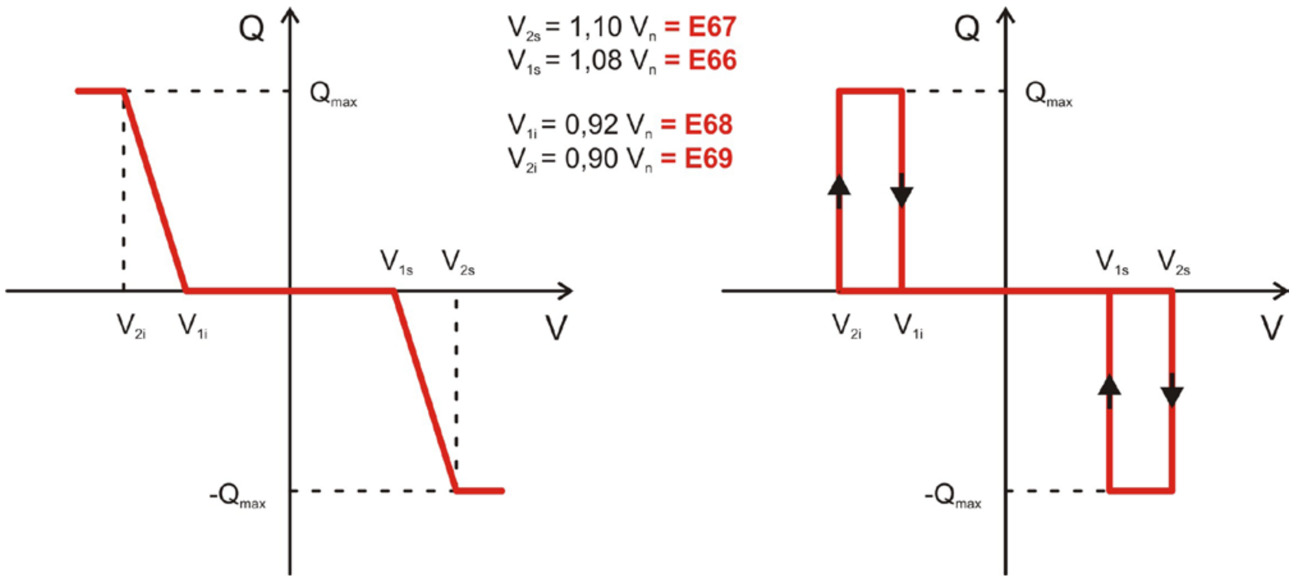



*Figure 15 – Q=f(V) curves for PV/Hydro/Wind type a) left, type b) right*

The convention is:

- Inductive = reactive power absorbed from the grid, as an inductor. The inverter current is leading with the grid voltage, with passive sign convention. Reactive power Q<0.
- Capacitive = reactive power injected in the grid, as a capacitor. The inverter current is lagging with the grid voltage, with passive sign convention. Reactive power Q>0.

Using parameter **E90–EN_REACT_PWR_CTRL_FV** it's possible to choose two different regulation curves for the Q=f(V) function, as depicted in Figure 15:

- E90=0-No → Q=f(V) disabled
- E90=1-Variable Q → Q is a function of the active power P: type a) curve.
- E90=2-Fixed Q → Q is fixed and settable: type b) curve.

For **type a)** curve, the function is activated (Lock-in) when:

- The grid voltage exceeds the threshold **E66–CTRL_FV_V1S** or decreases under the threshold **E68–CTRL_FV_V1I**; and
- the active power P exceeds the power threshold fixed by parameter E70–CTRL_FV_PWR_LOCK_IN.

If at least one of this conditions is not satisfied, the inverter injects power into the grid with cosphi=1.

For **type b)** curve, the function is activated (Lock-in) when:

- The grid voltage exceeds the threshold **E67–CTRL_FV_V2S** or decreases under the threshold **E69–CTRL_FV_V2I**; and
- the active power P exceeds the power threshold fixed by parameter **E70–CTRL_FV_PWR_LOCK_IN**.

If at least one of this conditions is not satisfied, the inverter injects power into the grid with cosphi=1.

The function is deactivated (Lock-out) when:

- the active power decrease under the threshold **E71–CTRL_FV_PWR_LOCK_OUT**; or
- the voltage is between the range **E66–CTRL_FV_V1S** < Vgrid < **E68–CTRL_FV_V1I**

The activation (Lock-in) of Q(V) function is signalled on digital output **O39 – Q(V) function active**.

### 4.17.2 Q(V) for ESS

In an Energy Storage System, the Q(V) is that of Figure 16, that is similar to the previous one with an extra parameter **E78-CTRL_QV_K** that can be used to fix the reactive current at a value different from 0 during the Lock-out.

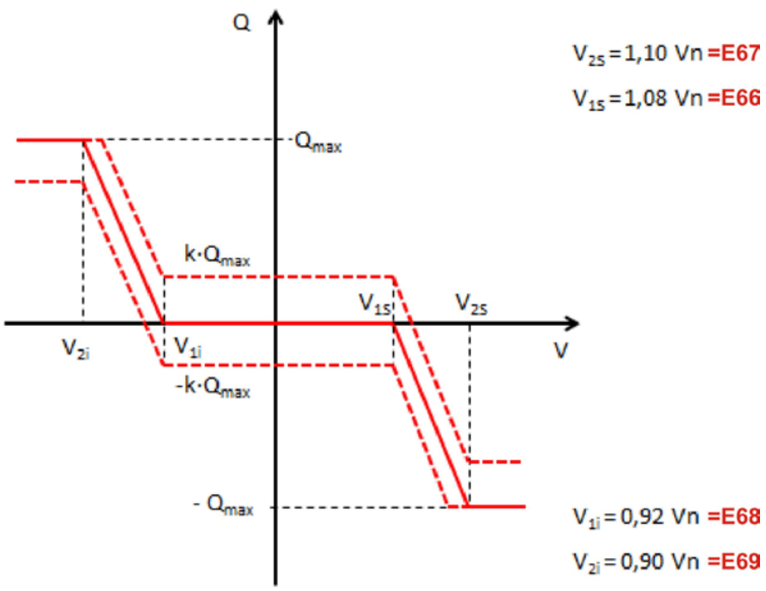



*Figure 16 – Q=f(V) curve for ESS*

### 4.17.3 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_REACT_PWR_CTRL_QV | E91 - Enable automatic reactive power control according to Q=f(V) curve | Scale: 0 No; 1 Variable Q; 2 Fixed Q | | 0 | | 1 |
| CTRL_FP_FV_COSPHI | E62 - Cosphi of point C cosfi=f(P) curve and cosphi of Q=f(V) curve | 0.00 | 1.00 | 0.90 | | 100 |
| CTRL_FV_V1S | E66 - V1S voltage of Q=f(V) curve | 80 | 120 | 108 | % V_GRID_NOM | 1 |
| CTRL_FV_V2S | E67 - V2S voltage of Q=f(V) curve | 80 | 120 | 110 | % V_GRID_NOM | 1 |
| CTRL_FV_V1I | E68 - V1I voltage of Q=f(V) curve | 80 | 120 | 92 | % V_GRID_NOM | 1 |
| CTRL_FV_V2I | E69 - V2I voltage of Q=f(V) curve | 80 | 120 | 90 | % V_GRID_NOM | 1 |
| CTRL_FV_PWR_LOCK_IN_REG | E70 - Lock-in power of Q=f(V) curve during regeneration | 0 | 100 | 20 | % P_ACT_NOM | |
| CTRL_FV_PWR_LOCK_OUT | E71 - Lock-out power of Q=f(V) curve | 0 | 50 | 100 | % P_ACT_NOM | 1 |
| CTRL_FV_PWR_LOCK_IN_ABS | E77 - Lock-in power of Q=f(V) curve during absorption | -100 | 0 | -20 | % P_ACT_NOM | 1 |
| CTRL_QV_K | E78 - K factor of Q=f(V) curve | -1.00 | 1.00 | 0.00 | % S_NOM | 100 |
| CTRL_QV_DELAY_ON | E79 - Activation delay time of Q=f(V) curve | 0 | 30 | 3 | s | 1 |

## 4.18 REACTIVE POWER CONTROL COSPHI=f(P)

The function cosphi=f(P) injects reactive power into the grid in case of a grid over voltage event. The goal of the function is to limit the grid over voltage caused by the active power injected by the inverter into the grid. The control rule is depicted in Figure 17.

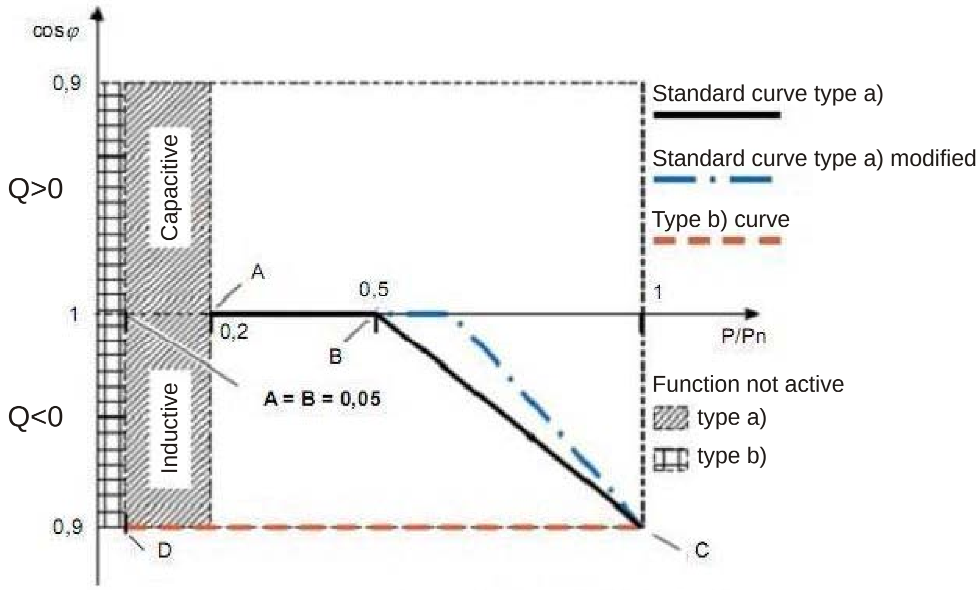



*Figure 17 – Cosphi=f(P) curve and modification, defined using three points*

The convention is:

- Inductive = reactive power absorbed from the grid, as an inductor. The inverter current is leading with the grid voltage, with passive sign convention. Reactive power Q<0.
- Capacitive = reactive power injected in the grid, as a capacitor. The inverter current is lagging with the grid voltage, with passive sign convention. Reactive power Q>0.

Using parameter **E90–EN_REACT_PWR_CTRL_FP** it's possible to choose two different regulation curves for the cosphi=f(P) function, as depicted in Figure 17:

- E90=1-Variable Cosphi → cosphi is a function of the active power P: type a) curve.
- E90=1-Fixed Cosphi → cosphi is fixed and settable: type b) curve.

With parameters E60, E61 it's possible to modify the active power value associated to point A and B of the type a) curve. With parameter E62 it's possible to set the cosphi for point C of the type a) curve.

The function is activated (Lock-in) when:

- the working point P/Pn exceeds the power threshold fixed by parameter **E61–CTRL_FP_PWR_B**; and
- the grid voltage increases over threshold **E63–CTRL_FP_V_LOCK_IN**.

If at least one of this conditions is not satisfied, the inverter injects power into the grid with cosphi=1.
During the lock-in, the inverter injects the reactive current necessary to reach the working point fixed by Figure 8 depending on the actual active power level.
The function is deactivated (Lock-out) when:

- the active power decreases under the power threshold **E61–CTRL_FP_PWR_B**, or
- the voltage grid decreases under the lock-out value **E64–CTRL_FP_V_LOCK_OUT**.

The activation (Lock-in) of cosphi(P) function is signalled on digital output **O38 – Cosphi(P) function active**.

### 4.18.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_REACT_PWR_CTRL_CP | E90 - Enable automatic reactive power control according to cosfi=f(P) curve | Range<br>0 No<br>1 Variable Cosphi<br>2 Fixed Cosphi | | 0 | | 1 |
| CTRL_CP_PWR_A | E60 - Power of point A cosfi=f(P) curve | 0 | 100 | 20 | % P_ACT_NOM | 1 |
| CTRL_CP_PWR_B | E61 - Power of point B cosfi=f(P) curve | 0 | 100 | 50 | % P_ACT_NOM | 1 |
| CTRL_CP_QV_COSPHI | E62 - Cosphi of point C cosfi=f(P) curve and cosphi of Q=f(V) curve | 0.00 | 1.00 | 0.90 | | 100 |
| CTRL_CP_V_LOCK_IN | E63 - Lock-in voltage of cosfi=f(P) curve | 100 | 100 | 105 | % V_GRID_NOM | 1 |
| CTRL_CP_V_LOCK_OUT | E64 - Lock-out voltage of cosfi=f(P) curve | 90 | 90 | 100 | % V_GRID_NOM | 1 |

## 4.19 REACTIVE POWER Q RAMP (E25=0)

When E25-EN_CURR_REF=0 a ramp block can be enabled in the reactive current reference, i.e. reference generated from:

- E01-ID_REF
- Cosphi(P) function (E90)
- Q(V) function (E91)
- External command (E94)

### 4.19.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| Q_POS_RAMP_UP_TIME | E245 - Reactive power ramp up time with Q>0 | 0 | 900 | | s/S_NOM | 1 |
| Q_POS_RAMP_DOWN_TIME | E246 - Reactive power ramp down time with Q>0 | 0 | 900 | 0 | s/S_NOM | 1 |
| Q_NEG_RAMP_UP_TIME | E247 - Reactive power ramp up time with Q<0 | 0 | 900 | 0 | s/S_NOM | 1 |
| Q_NEG_RAMP_DOWN_TIME | E248 - Reactive power ramp down time with Q<0 | 0 | 900 | 0 | s/S_NOM | 1 |

## 4.20 THERMAL PROTECTION

Using logic output "**O32-Enable AFE fans**", it's possible to switch on and off the internal fans of the converter AFE. For the connections refer to Figure 18.
Logic output O32 will move to logic level:

- High → when the heatsink temperature read in internal value D25 increase over the threshold **E47–TEMP_ON_AFE_FAN**;
- Low → when the heatsink temperature read in internal value D25 decrease under the value E47-10°C.

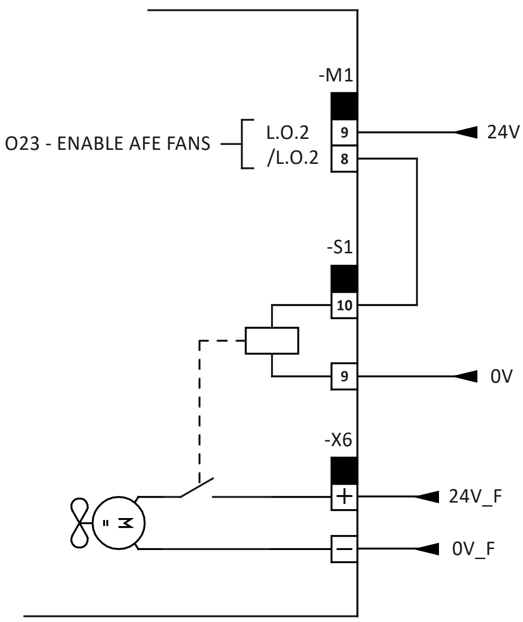



*Figure 18 – Connections for the thermal control of internal AFE fans*

### 4.20.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| TEMP_ON_AFE_FAN | E47 – O32 switch on temperature of AFE fans | 30 | 80 | 60 | °C | 1 |

## 4.21 EXTERNAL COMMANDS

With parameter E94 it's possible to enable the external commands. External commands are parameters:

- E40–EXT_ACT_PWR_LIM → used to limit the active power injected into the grid
- E19–EXT_Q_GRID_REF → used to give a reactive power reference (E19>0 is for Q<0 inductive, E19<0 is for Q>0 capacitive).

### 4.21.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_EXT_CMND | E94 - Enable external commands | Range:<br>0 = No<br>1 = Ext. active power limitation<br>2 = Ext. reactive power limitation<br>3 = Ext. active and reactive power limitaton | | 0 | | 1 |
| EXT_ACT_PWR_LIM | E40 - External active power limit | 0 | 100 | 100 | % P_ACT_NOM | 10 |
| EXT_Q_GRID_REF | E19 - External grid reactive power (Q) reference | -100.00 | 100.00 | 0 | % P_ACT_MAX | 1000 |
| S_NOM | D82 - Nominal Apparent Power | | | | kVA | 10 |

## 4.22 ANTI ISLANDING FUNCTION

The Anti Islanding (AI) function is intended to avoid the happening of islanding situations that could occur when the grid voltage switch off and there is an equilibrium in the power coming from inverter through loads, together with the resonance frequency of the loads that is near to the grid nominal frequency so that the 3-phase voltage could persists even if the grid is switched off.

To enable the function use parameter **E96–EN_AI_FCN**. When the function is active, a little reactive current is injected on the grid as an overlapped noise component. This reactive current is used to move the frequency in the case of islanding situations.

When the error frequency is greater than **E20–THR_ER_FRQ_ALL**, alarm **A4.1–Anti-Islanding frequency error** is generated and output O33-On-grid contactor command moves to low logic level. In fact, with E96=1 output O33 becomes:

O33 = O33 AND (NOT (A4.1))

### 4.22.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_AI_FCN | E96 - Enable Anti Islanding function | 0 | 1 | 0 | | 1 |
| THR_ERR_FRQ_ALL | E20 - Error Frequency Threshold for alarm | 0.0 | 10.0 | 10.0 | % GRID_FREQ_NOM | 10 |
| KAI | E21 - AI_Proportional gain for error frequency filtered | -100.0 | 100.0 | 10.0 | | 10 |
| FT_LOWPASS | E22 - AI_Cut Frequency Low Pass Filter | 1.00 | 30.00 | 10.00 | Hz | 100 |
| FT_HIGHPASS | E23 - AI_Cut Frequency High Pass Filter | 0.01 | 10.00 | 0.50 | Hz | 100 |

## 4.23 VOLTAGE DROP COMPENSATION

With the voltage drop compensation function it’s possible to obtain a more accurate adjustment of the cosphi measured at the top of the transformer, on 400Vac side. This function compensate the voltage drop and the voltage phase shift introduced by the 400/270 transformer (and/or by the secondary inductance of the LCL filter).

To enable the function use parameter **E97–E_V_DROP_COMP**.
Parameter **E14–K_TRANSF** is used to set the transformer turn ratio. For the transformer it’s considered to have a star-star connection hence with no phase-shift. In case of delta-star connection, the phase-shift introduced by the transformer must be put into parameter P75 summing it or subtracting it to the default value P75=4° already set into P75.

The inductance and the resistor of the transformer must be put into parameter **E15–PRC_DELTA_VLT** and **E16–PRC_DELTA_VRT**.

### 4.23.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_V_DROP_COMP | E97 - Enable compensation for LCL filter voltage drop | 0 | 1 | 0 | | 1 |
| K_TRANSF | E14 - Transformer turns ratio | 67.50 | 0.01 | 100.00 | | 100 |
| PRC_DELTA_VLT | E15 - Voltage drop due to transformer inductance | 0.01 | 100.00 | 2.00 | % V_GRID_NOM | 100 |
| PRC_DELTA_VRT | E16 - Voltage drop due to transformer resistor | 0.01 | 100.00 | 0.50 | % V_GRID_NOM | 100 |

## 4.24 LVFRT

The LVFRT manage function gives the possibility to comply to the LVFRT requirements depicted in the Italian standard CEI 0-21. To enable the LVFRT manage use parameter **E95–EN_LVFRT_MANAGE**.
The (V-t) characteristic that is implemented is rectangular as depicted in Figure 19, and can be set using parameters **P50–MIN_V_GRID**, **E72–LVFRT_T_MAX** as described in the following.
This rectangular settable (V-t) characteristic is suitable to comply with a lot of different (V-t) characteristics specified into the national standards. All the (V-t) characteristics with a shape that can be placed inside the rectangle are manageable.
Some example of (V-t) characteristic that can be managed are depicted in Figures 9, 10, 11.

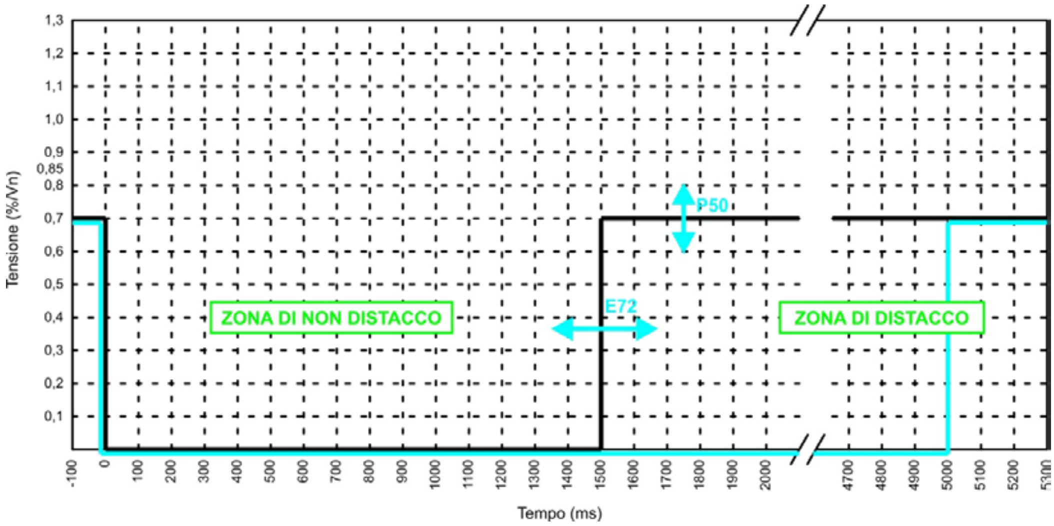



*Figure 19 – LVFRT (v-t) characteristic*

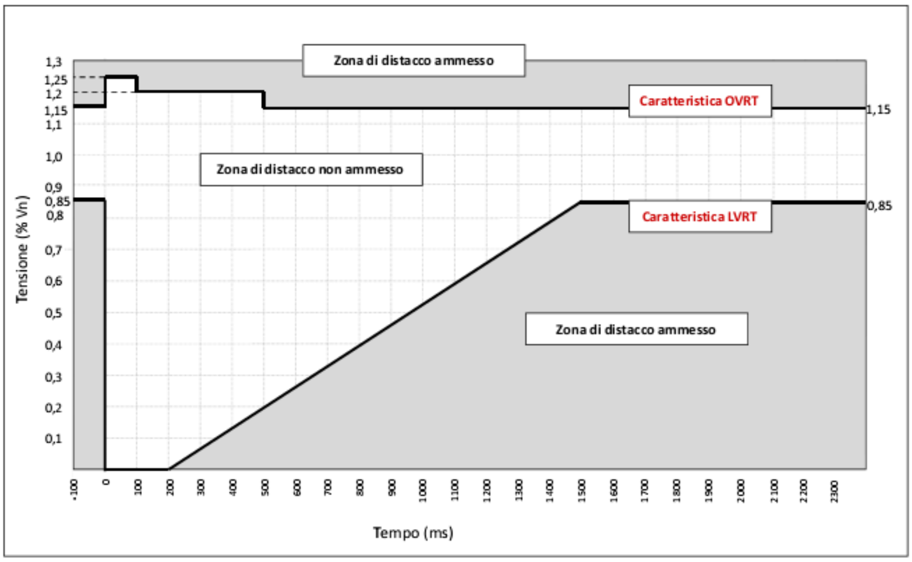



*Figure 20 – "CEI 0-16;V1:2013-12" (V-t) characteristic for static generator*

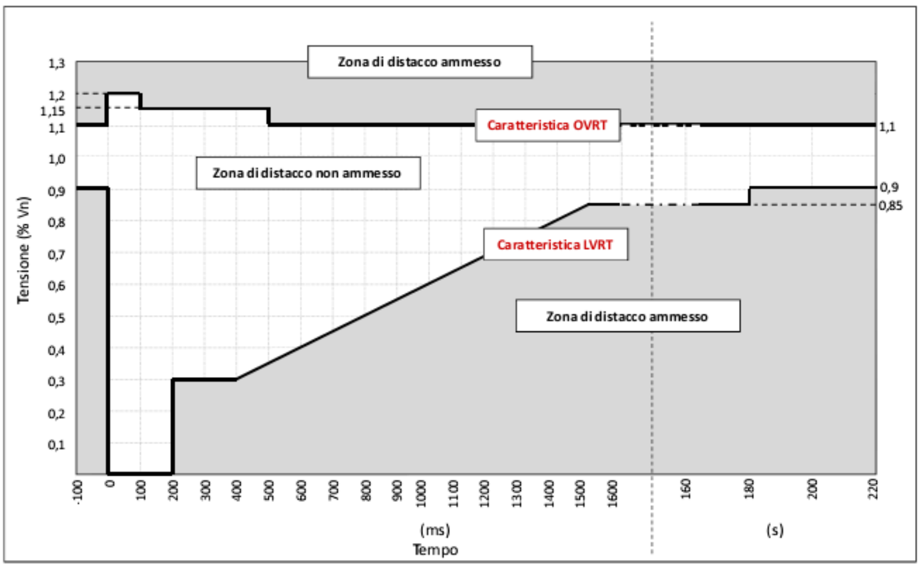



*Figure 21 – "CEI 0-16;V1:2013-12" (V-t) characteristic for wind generator*

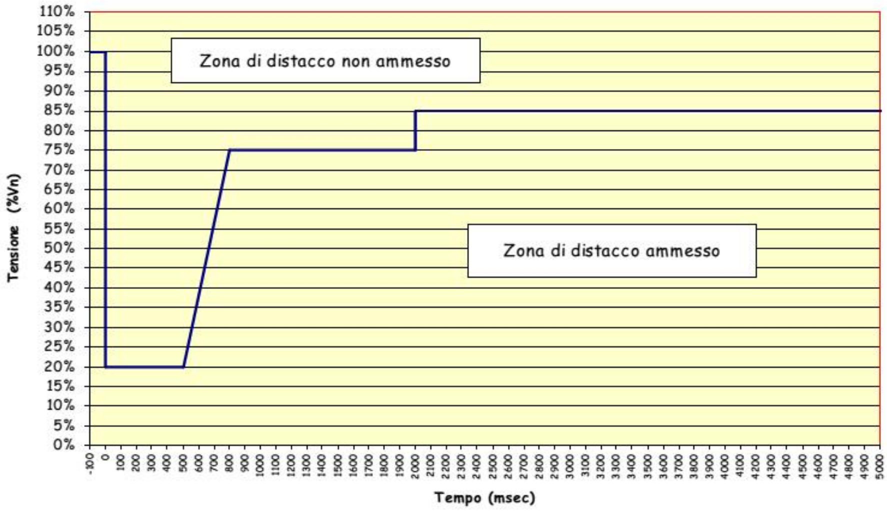



*Figure 22 – "Terna, Allegato A17" (V-t) characteristic for wind generator*

By default this function is not active, therefore in case of a grid voltage drop the inverter will automatically disconnect from the grid opening the grid main contactor. The disconnection is done because the grid voltage decreases under the threshold **P50–MIN_V_GRID**.

When the function is activated (E95=Yes), if there is a grid voltage drop with:

- Vgrid < **P50–MIN_V_GRID**;
- voltage drop duration < **E72–LVFRT_T_MAX**;

then the inverter stops to supply power into the grid but doesn't disconnect from the grid, i.e. the grid contactor KM02 doesn't open and the inverter gives alarm "A02.0 – Alarms for grid fault / sequence of phase L1, L2, L2 not connected".
If within the maximum waiting time set in E72 there is a voltage grid restoration, then the inverter automatically resets and comes back to run after the waiting time set in **P65–WaitAfeReady**.
If within the maximum waiting time set in E72 there is not a voltage grid restoration, then at the end of the waiting time the inverter disconnects from the grid by opening the grid main contactor KM02.

### 4.24.1 LVFRT hardware connection

When the LVFRT management is activated (E95=1), the main contactor KM01 and pre-charge contactor KM02 toward the grid must be controlled according to the indications on the AFE Energy installation manual, that are:

- Use of logic output "O33-ON-GRID CONTACTOR COMMAND" to allow the closing of KM01 even during the voltage fall;
- Power supply of AFE, KM01, KM02 from UPS;
- Adjustment of the interface protection (SPI) in order to avoid spurious tripping during the voltage drop.

Refer to AFE Energy installation manual for further details and schematics.

### 4.24.2 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_LVFRT_MANAGE | E95 - Enable LVFRT manage | 0 | 1 | 0 | | 1 |
| LVFRT_T_MAX | E72 - LVFRT maximum duration | 0.10 | 5.00 | 1.00 | s | 100 |
| GRID_UNB_MAX | E17 - Maximum grid voltage unbalance for enabling run | 0.0 | 100.0 | 10.0 | % V_GRID_NOM | 10 |
| V_GRID_MAX_UNB | E31 - Maximum grid voltage with unbalanced grid for enabling run | 0.0 | 200.0 | 115.0 | % V_GRID_NOM | 10 |
| V_GRID_MIN_UNB | E32 - Minimum grid voltage with unbalanced grid for enabling run | 0.0 | 200.0 | 80.0 | % V_GRID_NOM | 10 |
| MIN_V_GRID | P50 - Alarm level for minimum grid voltage | 5.0 | 95.0 | 70.0 | % V_GRID_NOM | 10 |

## 4.25 ENERGY AND POWER

### 4.25.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| Energy_Wh | D74 - Produced energy in Wh | 0 | 999 | | Wh | 1 |
| Energy_kWh | D75 - Produced energy in kWh | 0 | 999 | | kWh | 1 |
| Energy_MWh | D76 - Produced energy in MWh | 0 | 999 | | MWh | 1 |
| Energy_GWh | D77 - Produced energy in GWh | 0 | 999 | | GWh | 1 |
| ENERGY_RESET | E83 - Reset produced energy counter | | | No | | 1 |
| Ppv_ | D66 - PV power | kW | | | | 10 |
| Ppv_NORM_COEFF_ | D68 - Ppv normalization coefficient | kW | | | | 100 |
| Pac | D70 - AC Power | kW | | | | 100 |
| S_NOM | D82 - Nominal Apparent Power | kVA | | | | 10 |
| Kmult_Pac | E49 - Kmult_Pac | | | | | 10 |
| COSPHI_NOM | E65 - Nominal Cosphi for definition of D82-S_NOM | 0.00 | 0.00 | 0.90 | | 100 |

## 4.26 DC INPUT

When the OPDE AFE Energy includes a current sensor on DC input, the measured DC current is displayed in **D65–PV current**, the current is considered positive if it comes into the + terminal. The Full Scale value of the current reading is defined in **E30–I_PV_MAX**, a low-pass filter with time constant **E37–Tau_Ipv_filter** is used to filter the signal.

The DC power **D66–PV power** is calculated as:

D66 = D24 · D65

### 4.26.1 Function parameters

<table>
<tr><th>Name</th><th>Description</th><th colspan="2">Min</th><th>Max</th><th>Def</th><th>u.m.</th><th>Scale</th></tr>
<tr><td>I_PV_MAX</td><td>E30 - Maximum PV input current</td><td colspan="2">0</td><td>999</td><td></td><td>A</td><td>10</td></tr>
<tr><td>Tau_Ipv_filter</td><td>E37 - Time constant Ipv filter</td><td colspan="2">0</td><td>999</td><td>10</td><td>ms</td><td>1</td></tr>
<tr><td rowspan="3">DIS_Ipv_filter</td><td rowspan="3">E208 – Disable Ipv filter</td><td colspan="3">Range</td><td rowspan="3">0</td><td rowspan="3"></td><td rowspan="3">1</td></tr>
<tr><td>0</td><td colspan="2">No</td></tr>
<tr><td>1</td><td colspan="2">Yes</td></tr>
<tr><td>Ipv_</td><td>D65 - PV current</td><td colspan="2">0</td><td>999</td><td></td><td>A</td><td>32</td></tr>
<tr><td>Ppv_</td><td>D66 - PV power</td><td colspan="2">0</td><td>999</td><td></td><td>kW</td><td>32</td></tr>
<tr><td>Ppv_NORM_COEFF_</td><td>D68 - Ppv normalization coefficient</td><td colspan="2">0</td><td>999</td><td></td><td>kW</td><td>16</td></tr>
</table>

## 4.27 PV SWEEP (ONLY WITH E26=1)

The power curve of a PV plant in case of partially shadowing of one of the strings has more than one local maximum power point. Only one of this is the global maximum power point.

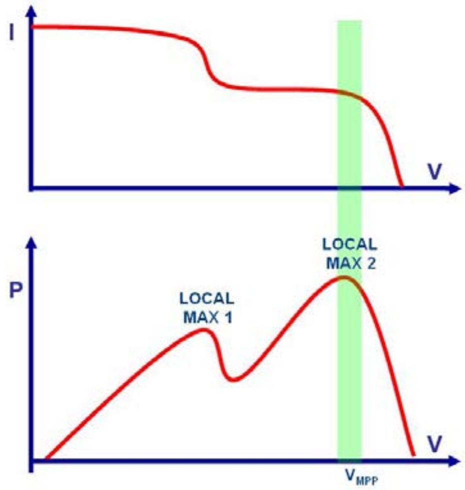



*Figure 23 – Example of power curve in case of partially shadowing.*

*The global maximum is the local max 2*

With the PV sweep function it's possible to identify this global maximum power point obtaining an increase efficiency of the MPPT algorithm avoiding that the MPPT tracks a maximum that is not the global maximum.
To activate the function set **E89–EN_PV_SWEEP=1-Automatic sweep**. The function execute a sweep of the characteristic V-I of the PV plants with a step change of the PV voltage from the Voc value down to the **E51–V_MPPT_MIN** value in a number of step equal to **E24–N_SAMPLE** executed with a period fixed by **E34–PV_SWEEP_REP_PERIOD**.
When the PV sweep function is executed, the MPPT algorithm is stopped. At the end of the sweep, the MPPT algorithm works again and starts from the voltage working point identified by the PV sweep function.

The voltage/current values measured by this function can be plotted in the PV_sweep page on OPDE Explorer, as below. Press the "Read" button under the chart to download and print the graphs.

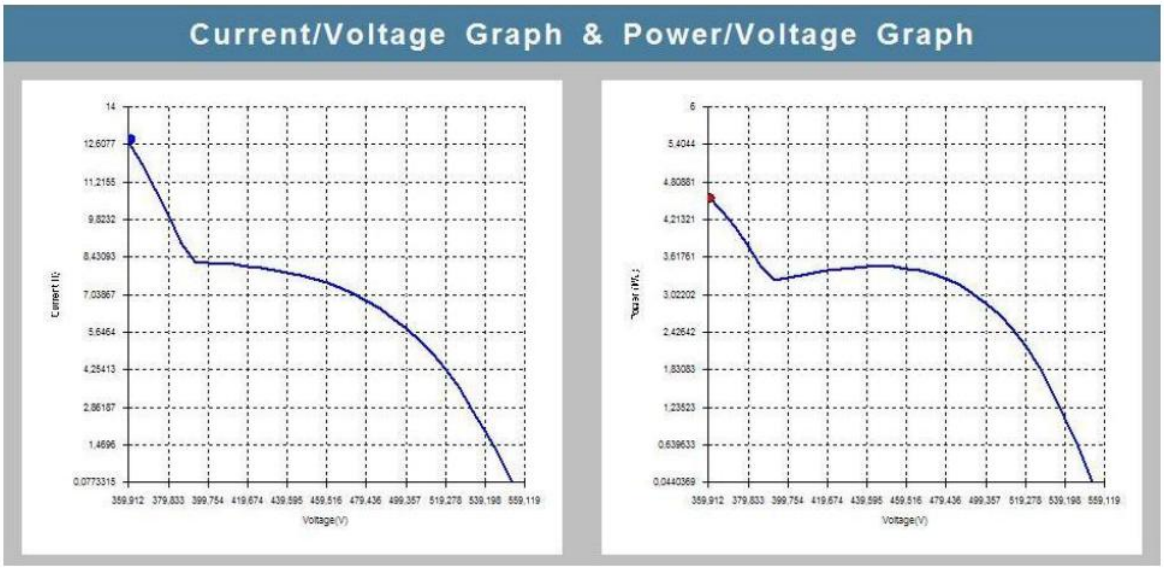



*Figure 24 – Example of I-V and P-V characteristics measured with the pv-sweep function*

Furthermore, it's possible to force the execution of a single PV sweep independently of the automatic sweep functionality. This can be useful to verify the V-I and the V-P characteristics of the PV plant during the commissioning or during the maintenance operation executed periodically along the entire life-time of the PV plant.
To do this, first put the inverter on status [0] pushing the stop button. Then set **E89–EN_PV_SWEEP = 1–One-Shot sweep**. Doing this, the inverter connects to the grid (status[4]) and wait for the pushing of the run button. Pushing the run button, a single pv-sweep is executed and at the end of the sweep the inverter automatically stops, but stay connected to the grid.
After the single pv-sweep, it's possible to view the measured I-V and P-V characteristics on PV-sweep page on OPDE Explorer. A subsequent press of the run button, results in the execution of a new pv-sweep.
To disable the one-shot sweep, set **E89–EN_PV_SWEEP=0-No**, the inverter goes to status[0] and disconnects from the grid.

### 4.27.1 Function parameters

<table>
<tr><th>Name</th><th>Description</th><th>Min</th><th>Max</th><th>Def</th><th>u.m.</th><th>Scale</th></tr>
<tr><td rowspan="4">EN_PV_SWEEP</td><td rowspan="4">E89 - Enable PV sweep</td><td colspan="2">Range</td><td rowspan="4">0</td><td rowspan="4"></td><td rowspan="4">1</td></tr>
<tr><td>0</td><td>No</td></tr>
<tr><td>1</td><td>Automatic sweep</td></tr>
<tr><td>2</td><td>One-shot sweep</td></tr>
<tr><td>N_SAMPLE</td><td>E24 - Number of samples for PV Sweep</td><td>10</td><td>50</td><td>10</td><td></td><td>1</td></tr>
<tr><td>PV_SWEEP_TIME_STEP</td><td>E33 - PV sweep time step</td><td>1</td><td>999</td><td>200</td><td>ms</td><td>1</td></tr>
<tr><td>PV_SWEEP_REP_PERIOD</td><td>E34 - PV sweep repetition period</td><td>1</td><td>180</td><td>60</td><td>min</td><td>1</td></tr>
</table>

## 4.28 Id COMPENSATION

The “Id compensation” function can be used to read and compensate the reactive current (Id) of a load (typically an asynchronous motor) connected to the same 3-phase grid where is connected the AFE.
AC current transducers must be connected on phase U and W and read using optional card 4S0024 according to Figure 25. Load resistors for current transducers must be put in 4S0024 according to Figure 26.

For guidance on the choice of current transducer and load resistors please contact TDE Macno.

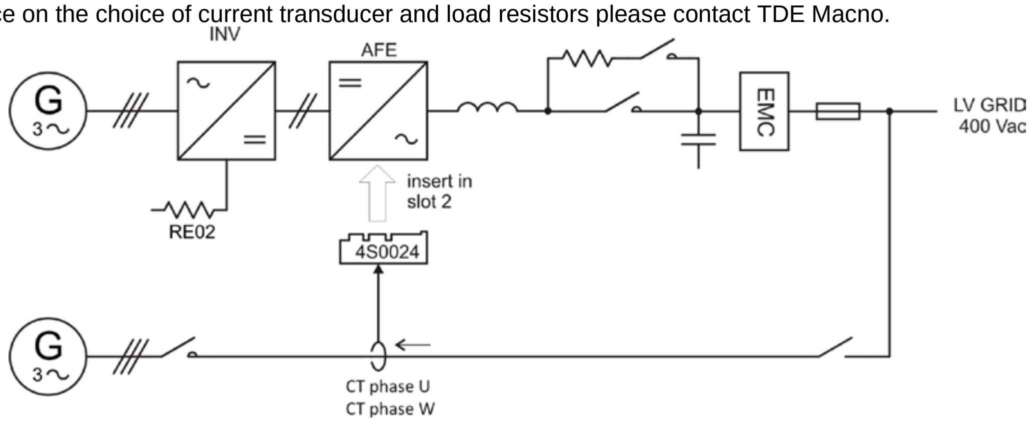



*Figure 25 – Id compensation*

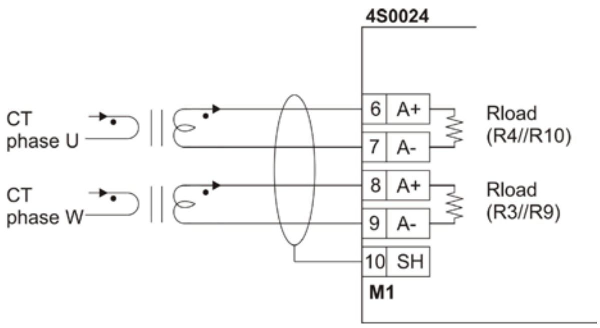



*Figure 26 – Id compensation: connection to 4S0024 board*

### 4.28.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_ID_COMP | E210 - Enable Id compensation | 0 | 1 | 0 | | 1 |
| I_TA_NOM | E211 - TA (current sensor) rated current | 0.0 | 2000.0 | 0.0 | A | 10 |
| OFFSET_TA_U | E212 - TA (current sensor) phase U offset | -100.00 | 100.00 | 0.00 | % | 100 |
| OFFSET_TA_W | E213 - TA (current sensor) phase W offset | -100.00 | 100.00 | 0.00 | % | 100 |
| TA_ANG_SUM | E214 - TA (current sensor) sum angle | -179.9 | 180.0 | 0.0 | ° | 10 |
| I_TA_FILTER | E215 - TA (current sensor) filter time constant | 0.0 | 999.9 | 100.0 | ms | 10 |
| I_TA | D83 - TA current | | | | A | 10 |

## 4.29 GRID ISLAND CONTROL (ONLY WITH E25=1)

In an Energy Storage System the AFE works as an AC current generator (CSI) with the DC voltage controller disabled (E25=1) because the DC voltage is provided by the batteries.

In this working mode, an algorithm that limits the active current reference is automatically enabled to avoid that the DC voltage goes outside the voltage limits specified in parameters **E55-VB_MAX**, **E56-VB_MIN**.

### 4.29.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| VB_MAX | E55 - V Bus Max Limit in CSI | 0.0 | 1200.0 | 0.0 | V | 10 |
| VB_MIN | E56 - V Bus Min Limit in CSI | 0.0 | 1200.0 | 0.0 | V | 10 |
| KP_VB_LIM | E57 - Kp V Bus limit in CSI | 0.0 | 300.0 | 1.0 | | 10 |
| TI_VB_LIM | E58 - Ti V Bus Limit in CSI | 0.0 | 3000.0 | 60.0 | ms | 10 |
| TF_VB_LIM | E59 - Tf V Bus Limit in CSI | 0.0 | 3000.0 | 0.0 | ms | 10 |

## 4.30 STORAGE (ONLY WITH E25=1)

In an Energy Storage System the AFE works as an AC current generator (CSI). Active and reactive power references can be provided with parameters **E53-P_GRID_REF** and **E54-QGRID_REF**.

E28 and E29 are used to define the capability of the ESS, refer to par. 4.1.2.

### 4.30.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| P_REGEN_MAX | E28 - Maximum regeneration power | 0.0 | 200.0 | 100.0 | % S_NOM | 10 |
| P_ABSORPT_MAX | E29 - Maximum absorption power | -200.0 | 0.0 | -100.0 | % S_NOM | 10 |
| P_GRID_REF | E53 - Active power reference | -200.0 | 200.0 | 0.0 | % S_NOM | 10 |
| Q_GRID_REG | E54 - Reactive power reference | -200.0 | 200.0 | 0.0 | % S_NOM | 10 |

## 4.31 TRANSFORMERLESS

The transformerless function (AFE Tless) limits the DC current injected toward the grid and can be used instead of the insulation transformer when the grid code requires to limit the DC current.

A current sensing module and an optional card 4S0024 must be connected according to Figure 27. The transformer must be replaced with a secondary inductance (refer to AFE Energy installation manual).

Logic output **O37-Idc overcurrent** is used to open the grid circuit breaker (DG) when the DC current on phase U, V, or W exceeds one of these thresholds:
- E223 - TLESS_IDC_THRa with Idc filter time constant E237-TLESS_LPF2a_TF, or
- E240 - TLESS_IDC_THRb with Idc filter time constant E238-TLESS_LPF2b_TF.

During the Idc overcurrent event the alarm **A4.5 – Idc overcurrent** is generated.
The status of O37 is equal to the status of alarm A4.5, therefore O37 stays at high logic level until alarm A4.5 is reset.

A derivative filter on the signal “osc11-current module” is used to recognize the AFE load transients, another derivative filter on the signal “osc44-frequency” is used to recognize transients that happens on the grid that are not coming from the AFE. These two derivative filter are used to disable the Idc overcurrent recognition during transient events.

To enable the AFE Tless function select **E216-EN_TLESS=1**, then execute the Rgrid tuning as described in paragraph 4.31.1.

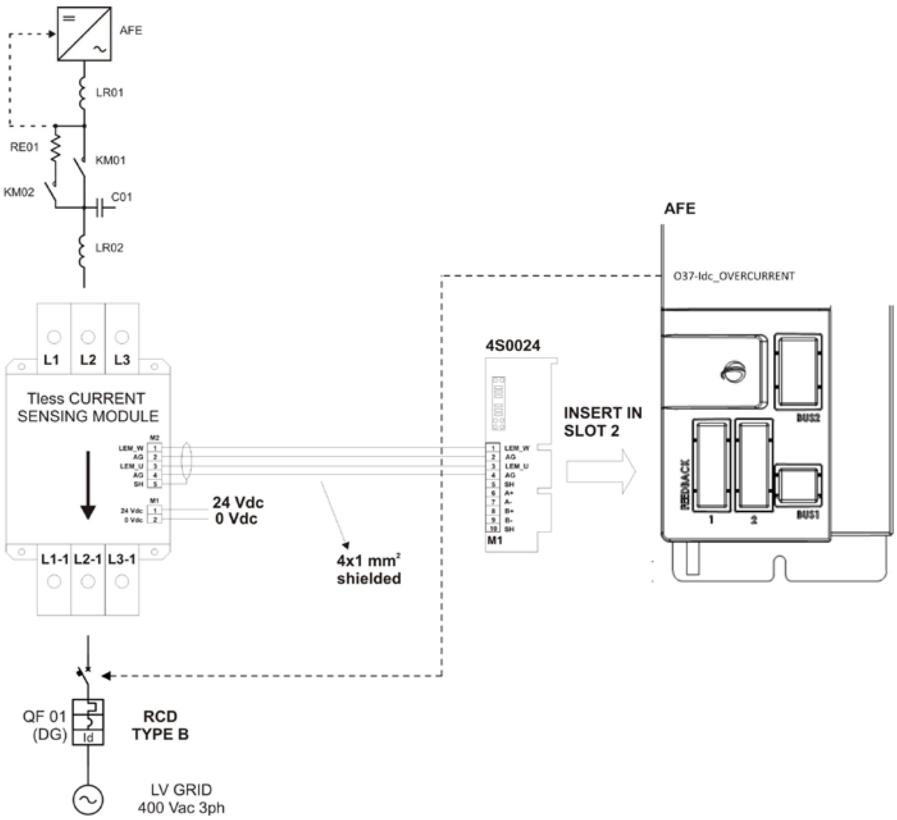



*Figure 27 – AFE Tless connection*

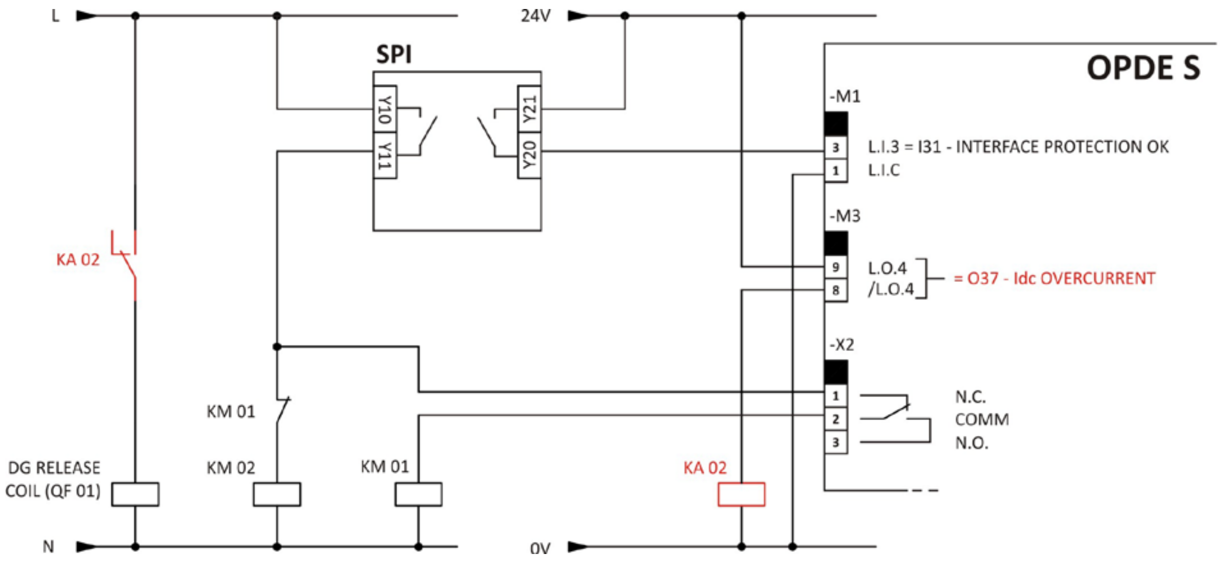


*Figure 28 – O37 connection for AFE Tless*

#### 4.31.1 Rgrid tuning

The Rgrid tuning function measures the resistance that the AFE sees toward the grid, this data is used to regulate automatically the proportional gain of the Tless function. During the tuning a reactive current must be injected into the grid, P68 is used to set temporarily this value, at the end of the tuning P68 must be restored at the original value.

Connect the AFE to the grid and verify that it's in stop with no alarm. Set **E225-EN_R_GRID_TUNING**=1 and **P68**=30%. Drag and drop **E226-PRC_DELTA_VRG**, **E229-TLESS_IDC_U** in the monitor window on OPD Explorer.

Give run, after 5s the AFE will generate a DC ramping voltage on phase U that generates a DC current on phase U. The DC voltage ramp will stop when:

- the DC current on phase U reaches the +100% value, or
- the DC voltage reaches the maximum value equal to E227*5.

After 5s the DC voltage go back to zero and the Rgrid measured value is written in E226.
During the test the value displayed in E229 will increase. The test is finished when E229 decreases back to approximately zero and E226 changes its value. At this moment is possible to remove the run command, E225 will automatically restore to 0.

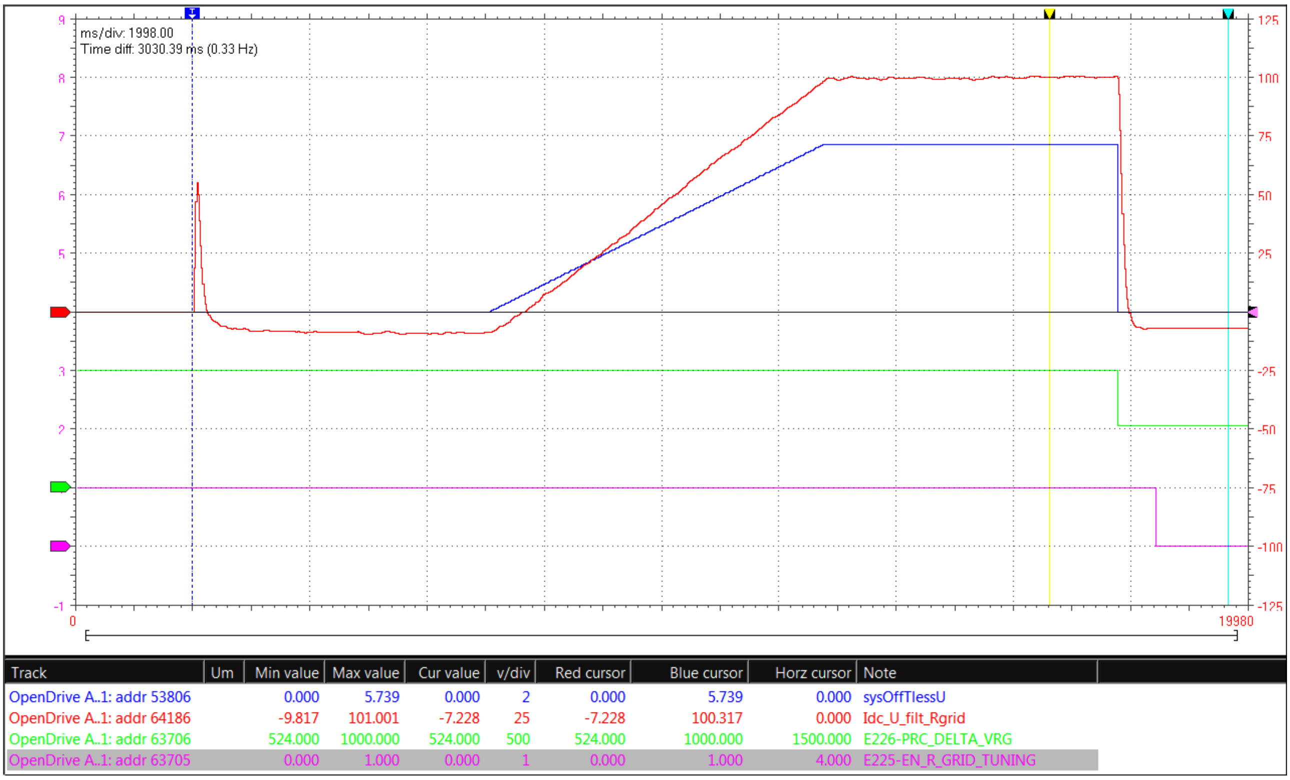



*Figure 29 – Rgrid tuning*

### 4.31.2 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| EN_TLESS | E216 - Enable Transformerless | Range | | 0 | - | 1 |
| | | 0 | No | | | |
| | | 1 | Yes | | | |
| TLESS_REG_KP | E217 - Kp Tless regulator gain | 0.01 | 100.0 | 3.50 | - | 100 |
| TLESS_REG_TI | E218 - Ti Tless regulator lead time constant | 0.1 | 3000.0 | 50.0 | ms | 10 |
| TLESS_REG_TF | E219 - Tf Tless regulator filter time constant | 0.0 | 0.0 | 3000.0 | ms | 10 |
| TLESS_NOTCH_F0 | E220 - Tless Notch Filter natural frequency | 0.0 | 100.0 | 50.0 | Hz | 10 |
| TLESS_NOTCH_FB | E221 - Tless Notch Filter bandwidth | 0.0 | 100.0 | 25.0 | Hz | 10 |
| TLESS_NOTCH_DMP | E222 - Tless Notch filter damping factor | 0.0 | 100.0 | 0.0 | % | 10 |
| TLESS_IDC_THRa | E223 - Tless Idc threshold a | 0.1 | 100.0 | 0.5 | % I_CONV_NOM | 10 |
| TLESS_IDC_NOM | E224 - Tless Idc rated current | 0.001 | 32.767 | 0.0 | A | 1000 |
| EN_R_GRID_TUNING | E225 - Enable Rgrid tuning | Range | | 0 | - | 1 |
| | | 0 | No | | | |
| | | 1 | Yes | | | |
| PRC_DELTA_VRG | E226 - Voltage drop due to total resistor toward the grid | 0.01 | 100.00 | 10.00 | % | 100 |
| TLESS_OFF_MAX | E227 - Tless maximum voltage offset | 0.1 | 5.0 | 2.0 | % V_CONV_NOM | 10 |
| TLESS_REG_MAX | E228 - Tless regulator maximum output | 0 | 400 | 200 | % | 1 |
| TLESS_IDC_U | E229 - Tless Idc U current | - | - | - | A | 1000 |
| TLESS_IDC_W | E230 - Tless Idc W current | - | - | - | A | 1000 |
| TLESS_DER_I_TF | E231 - Tless current derivative filter time constant | 0.0 | 3000.0 | 10.0 | ms | 10 |
| TLESS_DER_I_TD | E232 - Tless current derivative time constant | 0.1 | 3000.0 | 20.0 | ms | 10 |
| TLESS_DER_I_THR | E233 - Tless current derivative threshold | 0.0 | 100.0 | 10.0 | % | 10 |
| TLESS_DER_F_TF | E234 - Tless frequency derivative filter time constant | 0.0 | 3000.0 | 10.0 | ms | 10 |
| TLESS_DER_F_TD | E235 - Tless frequency derivative time constant | 0.1 | 3000.0 | 200.0 | ms | 10 |
| TLESS_DER_F_THR | E236 - Tless frequency derivative threshold | 0.0 | 100.0 | 10.0 | % | 10 |
| TLESS_LPF2a_TF | E237 - Tless LPF2a filter time constant | 0.1 | 3000.0 | 200.0 | ms | 10 |
| TLESS_LPF2b_TF | E238 - Tless LPF2b filter time constant | 0.1 | 3000.0 | 25.0 | ms | 10 |
| TLESS_LPF2_DMP | E239 - Tless LPF2a and LPF2b damping factor | 0.01 | 1.00 | 0.90 | - | 100 |
| TLESS_IDC_THRb | E240 - Tless Idc threshold b | 0.1 | 999.9 | 1.0 | A | 10 |
| TLESS_U_KP | E243 - Tless U amplitude compensation | 0.0 | 200.0 | 100.0 | % | 10 |
| TLESS_W_KP | E244 - Tless W amplitude compensation | 0.0 | 200.0 | 100.0 | % | 10 |

## 4.32 CYCLIC

The AFE on-board PLC has a cyclic task with a period settable with E241-CYCLICPERIOD.

### 4.32.1 Function parameters

| Name | Description | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|
| CYCLICPERIOD | E241 - Cyclic period duration | 0.2 | 10.0 | 1.0 | ms | 10 |

## 4.33 AUTOMATIC ALARM RESET (ONLY WITH E26=1)

The automatic alarm reset function, automatically resets the AFE if there is an active alarm and the AFE is in Off Status (D69-STATUS=0). In the presence of an active alarm with Status=0, the automatic reset command is continuously repeated with a period given by **E73–RES_REP_TIME**.

Alarm “A02.0–Alarms for grid fault / sequence of phase L1, L2, L3 not connected” and “A4.3–Grid Over Frequency” are not automatically reset.

## 4.34 MAPPED OBJECT - FIELDBUS OBJECT DICTIONARY

The AFE core sw has its own default mapped variable, they are listed in the table below (for detailed information refer to the **Fieldbus Object Dictionary** in the fieldbus manual – for Profibus, CAN, EtherCAT – and to the **Data Mapping Table** for Modbus):

| Index [hex] | | Object | Type | Name | Description | Access |
|---|---|---|---|---|---|---|
| Profibus | Modbus | | | | | |
| 200D | 0000 | ARRAY[200] | INT16 | Tab_par [200] | Table of parameters (P00 - P199) | R/W |
| 200E | 00C8 | ARRAY[100] | INT16 | Tab_con [100] | Table of connections (C00 - C99) | R/W |
| **200F** | 0380 | **ARRAY[128]** | **INT16** | **Tab_int [128]** | **Table of internal values (D00 - D127)** | **R** |
| **2010** | - | **ARRAY[32]** | **INT16** | **Tab_inp_dig [32]** | **Current values of standard input logic functions** | **R** |
| **2011** | - | **ARRAY[32]** | **INT16** | **Tab_out_dig [32]** | **Current values of standard output logic functions** | **R** |
| **2012** | 0C00 | **ARRAY[100]** | **INT16** | **Tab_osc [100]** | **Current monitorable size values (osc0 – osc99)** | **R** |
| **2013** | - | **VAR** | **UINT16** | **Input** | **Logic 8 input status to terminal board** | **R** |
| **2014** | - | **VAR** | **UINT16** | **Input_hw** | **Logic 3 input status from power** | **R** |
| **2015** | - | **VAR** | **UINT16** | **Output_hw** | **Logic 4 digital output status** | **R** |
| **2016** | 0340 | **VAR** | **UINT32** | **Out_dig_appl** | **Application output function reading via fieldbus** | **R** |
| **2017** | 0200 | **VAR** | **UINT16** | **Status** | **Converter variable status** | **R** |
| **2018** | 0202 | **VAR** | **UINT16** | **Alarms** | **Converter alarm status** | **R** |
| **2019** | 0203 | **VAR** | **UINT16** | **Enable_alarms** | **Converter alarm enabling word** | **R** |
| **201E** | 012C | **ARRAY[100]** | **INT16** | **Tab_dati_applicazione [100]** | **Table of application paramters (E00 - E99)** | **R/W** |
| **201F** | 0360 | **VAR** | **UINT32** | **Inp_dig_field** | **Input logic function writing via fieldbus** | **W** |
| **2020** | 0300 | **VAR** | **UINT32** | **Inp_dig** | **Input logic function reading via fieldbus** | **R** |
| **2021** | 0320 | **VAR** | **UINT32** | **Out_dig** | **Standard logic output reading via fieldbus** | **R** |
| **2022** | - | **VAR** | **UINT16** | **Word_vuota** | **Unused word** | **R/W** |
| **2023** | - | **VAR** | **UINT32** | **double_vuota** | **Unused double word** | **R/W** |
| **2025** | - | **ARRAY[16]** | **INT16** | **Tab_codice_allarmi [16]** | **Subcode table of active alarms** | **R** |
| 2027 | - | ARRAY | UINT16 | tabProcessData | Process variable mapping | R/W |
| | | | | | | |
| - | 052C | ARRAY[200] | UINT16 | | Table of parameters format | R |
| - | 084C | ARRAY[100] | UINT16 | | Table of connections formats | R |
| - | 0C00 | ARRAY[100] | UINT16 | | Table of monitor and analog outputs values | R |
| - | 0D00 | ARRAY[100] | UINT16 | | Table of application parameters formats | R |
| - | 09DC | ARRAY[128] | UINT16 | | Table of internal values format | R |

NOTE:: In case of Profibus, the variables shown in **bold** are mappable in the process area.

In addition to the variables already mapped by default with the AFE core sw, some additional variables have been mapped in order to be used as commands/references through the fieldbus. They are listed in the table below.

| Index [hex] Profibus/ Modbus | Obj | Type | Name | Description | Acc. | Min | Max | Def | u.m. | Scale |
|---|---|---|---|---|---|---|---|---|---|---|
| 2100 | VAR | UINT16 | VbusOvdFieldbus | Fieldbus DC Bus voltage override | R/W | 0.0 | $100 \cdot \frac{P107}{P08}$ | 100.0 | %P08- DC_BUS_REF | 16384 |
| 2101 | VAR | INT16 | IqRefFiedlbus | Fieldbus active current reference | R/W | -100.0 | 100.0 | 0.0 | %P53-I_CONV_NOM | 16384 |
| 2102 | VAR | INT16 | IdRefFiedlbus | Fieldbus reactive current reference | R/W | -100.0 | 100.0 | 0.0 | %P53-I_CONV_NOM | 16384 |
| 2103 | VAR | UINT16 | MaxIqFieldbus | Fieldbus active current limit | R/W | 0.0 | 200.0 | 200.0 | %P53-I_CONV_NOM | 16384 |
| 2104 | VAR | UINT16 | VgridOvdFieldbus | Fieldbus AC voltage override | R/W | 0.0 | 200.0 | 100.0 | %P10- V_GRID_ISL | 16384 |
| 2105 | VAR | UINT16 | FreqOvdFieldbus | Fieldbus AC frequency override | R/W | 0.0 | 200.0 | 100.0 | %P63- F_GRID_NOM | 16384 |
| 2106 | VAR | UINT16 | VBLimMaxOvdFieldbus | Fieldbus DC Bus max limit override | R/W | 0.0 | 100.0 | 100.0 | %E55-VB_MAX | 16384 |
| 2107 | VAR | UINT16 | VBLimMinOvdFieldbus | Fieldbus DC Bus min limit override | R/W | 0.0 | 100.0 | 100.0 | %E56-VB_MIN | 16384 |
| 2108 | VAR | INT16 | PgridRefFieldbus | Fieldbus active power reference | R/W | -100.0 | 100.0 | 0.0 | %D82-S_NOM | 16384 |
| 2109 | VAR | INT16 | QgridRefFieldbus | Fieldbus reactive power reference | R/W | -100.0 | 100.0 | 0.0 | %D82-S_NOM | 16384 |

# 5 ITALIAN GRID CODE OVERVIEW

The tables below list the functions required by the Italian grid code:

- standard CEI 0-21 for Low Voltage connection;
- standard CEI 0-16 for Medium Voltage Connection;

and indicate the activation method and if they are relevant depending on the application.

| Function | | CEI 0-21 (LV) | | | | |
|---|---|---|---|---|---|---|
| | | Activation method | | | Applicable | |
| | | by default | on demand from DSO | choice of the plant owner | Static Converter (PV/ESS) | Full Converter (WIND/HYDRO) |
| Grid connection requirements | | ✓ | - | - | ✓ | ✓ (power ramp excluded) |
| Q | cosphi(P) | - | ✓ | - | ✓ | ✓ |
| | Q external command | - | ✓ | - | ✓ | ✓ |
| | Q(V) | | ✓ | | ✓ | ✓ |
| P | P(V) | - | - | ✓ | ✓ | ✓ |
| | P(f) | ✓ | | - | ✓ | ✓ |
| | P external limit | - | ✓ | - | ✓ | ✓ |
| VFRT | LVFRT | ✓ | - | - | ✓ | - |
| | OVFRT | - | - | - | - | - |

| Function | | CEI 0-16 (MV) | | | | |
|---|---|---|---|---|---|---|
| | | Activation method | | | Applicable | |
| | | by default | on demand from DSO | choice of the plant owner | Static Converter (PV/ESS) | Full Converter (WIND/HYDRO) |
| Grid connection requirements | | ✓ | - | - | ✓ | ✓ |
| Q | cosphi(P) | - | ✓ | - | ✓ | ✓ |
| | Q external command | ✓ (Static Conv) | ✓ (Full Conv) | - | ✓ | ✓ |
| | Q(V) | | ✓ | | ✓ | ✓ |
| P | P(V) | - | - | ✓ | ✓ | ✓ |
| | P(f) | ✓ | | - | ✓ | ✓ |
| | P external limit | - | ✓ | - | ✓ | ✓ |
| VFRT | LVFRT | ✓ | - | - | ✓ | - |
| | OVFRT | ✓ | - | - | - | - |

## 5.1 ACTIVE POWER LIMITATION MANAGEMENT

Some of the functions required by the CEI 0-21 or CEI 0-16 standards will limit the active power injected into the grid. This power reduction is performed automatically by OPDE AFE ENERGY converter that signals the insertion of the active power limit with the logic output **O36 - Active Power Limitation** and indicates in the variable **D84-P_active_limit** and **osc86 – P_active_limit**, the instantaneous value of the power limit, with scale 4096 and u.m [% D82-S_NOM].

The automation system (hydro, wind, ORC or other), which manages the power converted by the generator must appropriately use this power limit in order to limit the power generated from the inverter, in order to ensure a safe operation of the plant and avoid a DC bus over voltage alarm.152

Because the active power limitation of the AFE is executed instantaneously, the automation system must immediately reduce the power generated from the inverter. Usually the automation system takes some seconds to reduce the power, therefore an external braking resistor must be used to dissipate the transient power surplus.

The following figure shows schematically an example of an automation system with hydro turbine where it is highlighted the exchange of signals O36 and osc86 thorough the communication bus between OPDE AFE ENERGY and the PLC control/automation system.

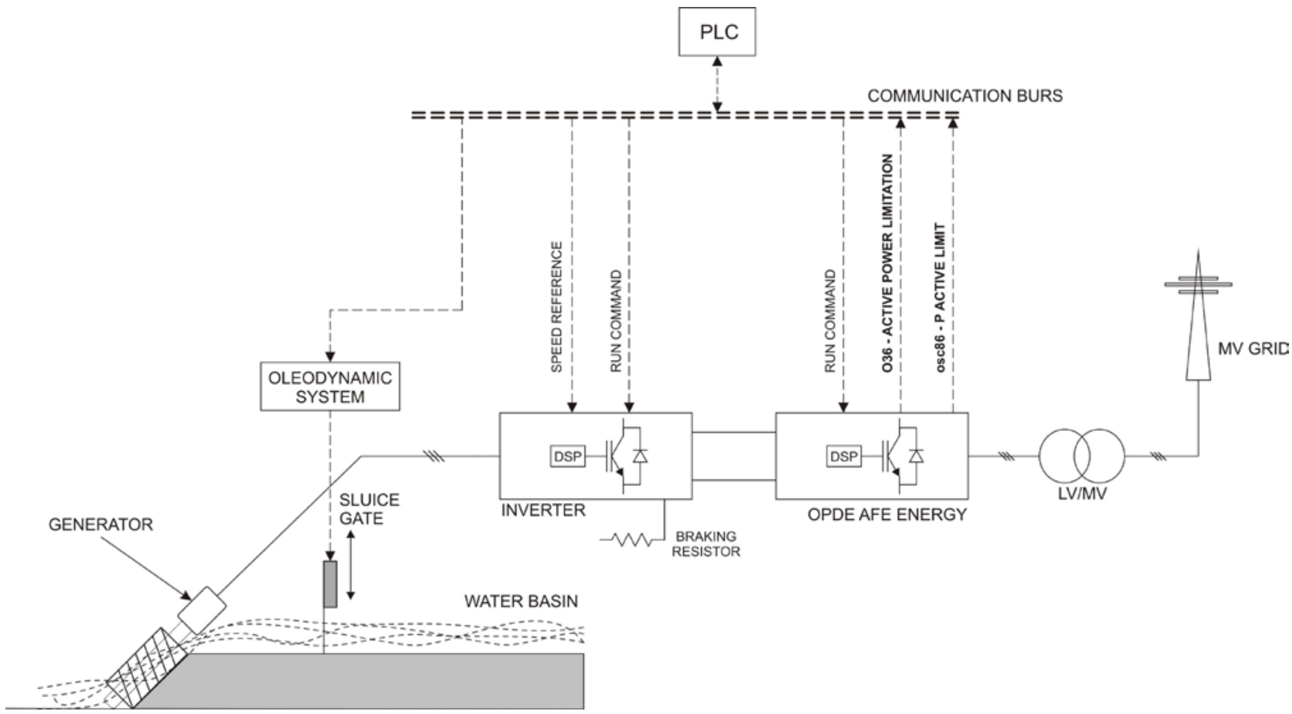



*Figure 30 – Example of hydro power generation system*

# 6 ALARMS

The converter has a set of alarms that stop the converter if there is a fault in order to prevent damage. In case of an alarm event, the converter output phases (U,V,W) are blocked and the DC Bus Voltage is no longer controlled.
If one or more of the alarms occur, they are signalled on the displays, which start to blink and to show a cycle of all the alarms triggered (the 7-segment display shows the alarms that have been set off in hexadecimal).
In case of failure of the converter, or if an alarm is triggered, check the possible causes and act accordingly.
If the causes cannot be traced or if parts are found to be faulty, contact TDE MACNO and provide a detailed description of the problem and its circumstances.
The alarm indication is divide in 16 categories (A0÷A15) and for each alarm there's a sub-code to better identify the alarm (AXX.YY)

| **ALARM** | | | **DESCRIPTION** | **CORRECTIVE ACTION** |
|---|---|---|---|---|
| **HEX** | **DEC** | | | |
| A.1.0.H | A01.0 | EEPROM alarm<br><br>Read failure | A Check Sum error occurred while the EEPROM was reading the values. Default values loaded automatically. | Try to reread the values with the EEPROM. The reading may have been disturbed in some way. If the problem continues contact TDE as there must a memory malfunction. |
| A.1.1.H | A01.1 | EEPROM alarm<br><br>Write failure | When data is being written in the EEPROM the required values are always shown afterwards: an alarm triggers if differences are detected. | Try to rewrite the values in the EEPROM.<br>The information may have been disturbed in some way.<br>If the problem continues contact TDE as there must be a memory malfunction. |
| A2.0 H | A02.0 | Alarm for grid fault / sequence of phase L1, L2, L3 not connected | The grid voltage amplitude (D21) read with the synchronization signal is below threshold P50. | If the grid voltage has not been connected to the AFE, this is a normal alarm.<br>Otherwise check the connection on the gride side and the synchronization signals. |
| A.3.0.H | A03.0 | Power fault | The converter output current has reached a level that has set off an alarm; this may be caused by an overcurrent due to leakage in the wires. There may also be a fault on the regulation card or a problem in the synchronization wires. | Check the connection wires on the line side, in particular on the terminals, in order to prevent leakages or short circuits.<br><br>Check that the connections of the synchronization circuit is correct according to the Installation manual (OPDE_AFE_INSTALLATION). |
| A.4.0.H | A04.0 | Waiting time for grid voltage and frequency control | Only with E93=1. Possible causes:<br>a) input **I31-Interface protection ok** is at low level;<br>b) the inverter is not connected to the grid;<br>c) the inverter is connected to the grid but D86-Vgrid or D87-Fgrid are out of the acceptance thresholds,<br>d) voltage and frequency have the right value but the waiting time is not ended. | Check status of external Interface Protection (PI) connected to input I31.<br><br>Check D86-Vgrid_CONN_MANAGE value that should be:<br>E05 < D86 < E04<br>and D87-Fgrid_CONN_MANAGE value that should be:<br>E07 < D87 < E06<br><br>Check if counter D88 and counter D89 are running.<br><br>Refer to par. 4.16.1 |
| A.4.1.H | A04.1 | Anti-Islanding frequency error | Only with E96=1. | Refer to par. 4.22 |
| A.4.2.H | A04.2 | Grid Over Frequency during run | Only with E93=2.<br>D87-Fgrid has exceeded the threshold E06 or E11 | Check D87-Fgrid_CONN_MANAGE value that should be:<br>D87 < E06<br><br>Refer to par. 4.16.2 |
| A.4.3.H | A04.3 | Grid Over/Under Voltage during run | Only with E93=2.<br>D86-Vgrid has exceeded the threshold E05 or E04 | Check D86-Fgrid_CONN_MANAGE value that should be:<br>E05 <D86 < E04<br><br>Refer to par. 4.16.2 |
| A.4.4.H | A04.4 | Fieldbus problem | | |
| A.4.5.H | A04.5 | Idc overcurrent | Only with E216=1. The Idc current on phase U, V or W has exceed threshold E223 with time filter E237 or threshold E240 with time filter E238. | Verify that the Rgrid tuning test has been executed (E226 should be different from default value) |

| | | | | |
|---|---|---|---|---|
| A.5.0.H | A05.0 | Thermal alarm.<br><br>Reactor temperature too high | Connection C46 manages a range of heat probes. If C46=1 or 2, a PTC/NTC is being used and its Ohm value (**D41**) has exceeded the safety threshold (**P95).** If C46 = 3 a digital input has been configured to I23 logical input function and this input is in not active state. If C46=4, a KTY84 is being used: the temperature reading (**D26**) must be higher than the maximum temperature (**P91**). | Check the temperature reading in D26 and then check the reactor. With a KTY84, if -273.15 appears the electrical connection towards the reactor heat probe has been interrupted. If the reading is correct and the reactor is overheating, check that the reactor cooling circuit is intact. Check the fan, its power unit, the vents, and the air inlet filters on the cabinet. Replace or clean as necessary. Ensure that the ambient temperature around the reactor is within the limits permitted by its technical characteristics. |
| A.5.1.H | A05.1 | Thermal alarm. Heat sink temperature too high | The heatsink temperature (D25) is higher than the maximum (P118). | Check the temperature read in D25 and then check the heat sink. If -273.15 is displayed, the electrical connection towards the heat sink heat probe has been interrupted. If the reading is correct and the reactor is overheating, check the converter cooling circuit being intact. Check the fan, its power unit, the vents, and the air inlet filters on the cabinet. Replace or clean as necessary. Ensure that the ambient temperature around the converter is within the limits permitted by its technical characteristics.<br>Check parameter P118 is set correctly. |
| A.5.4.H | A05.4 | Thermal alarm. Reactor thermal probe not connected | Thermal probe of the reactor not detected | Check the connection of the probe. |
| A.5.5.H | A05.5 | Thermal alarm. Run with T_heat_sink too high | Run with T_heat_sink > P119 | Check the heat sink temperature (D25) |
| A.7.0.H | A07.0 | Grid over-voltage (Vmains) | The grid voltage amplitude (D21) read with the synchronization signal increase over threshold P51. | Grid fault or distribution grid not adequate to the load conditions. |
| A.8.0.H | A08.0 | External alarm. Missing enable logic input from the field (I08) | A digital input has been configured to I02 logical input function and this input is in not at high logic level. | The external safety switch has cut in disabling converter enable. Restore and reset.<br>The connection has been broken. Check and eliminate the fault.<br>Input function has been assigned, but enable has not been given. Authorise or do not assign the function. |
| A.8.1.H | A08.1 | External alarm. Watchdog alarm LogicLab | A LogicLab watchdog alarm on slow cycle appears. | Check if the LogicLab slow task duration is greater than 500 ms and try to reduce this execution time. |
| A.8.2.H | A08.2 | External alarm. Fast task LogicLab too long in execution time | The LogicLab fast task is too long in time | Try to reduce the LogicLab fast task execution time under admitted limit.<br>Please refer to the specific documentation. |
| A.8.3.H | A08.3 | External alarm. Application out of service | There is no valid application running in the converter. | Reload the application using OPDExplorer. |
| A.A.0.H | A10.0 | Minimum power circuit voltage. DC Bus under minimum threshold admitted (DC_MIN, P106) | DC Bus voltage (D24) has dropped below the minimum value (P106). | If the grid voltage has not been connected to the AFE, this is a normal alarm. Otherwise, a grid fault occurred, or the distribution grid is not adequate to the load conditions. |
| A.B.1.H | A11.1 | Power circuit overvoltage. HW detection | DC Bus voltage (D24) has exceeded the HW threshold. | |
| A.B.2.H | A11.2 | Power circuit overvoltage. SW detection | DC Bus voltage (D24) has exceeded the threshold P107 | |
| A.B.3.H | A11.3 | Power circuit overvoltage. HW + SW detection | A11.0 and A11.1 appears | |

| | | | | |
|---|---|---|---|---|
| A.C.0.H | A12.0 | Internal alarm. C29 different from 1 | C29 different from 1 | Check and enable connection C29 “Converter software enable” |
| A.C.0.H | A12.0 | Internal alarm. C29 different from 1 | C29 different from 1 | Check and enable connection C29 “Converter software enable” |
| A.C.1.H | A12.1 | Internal alarm. Run without power soft start | RUN without Power Soft start | Check why the Power Soft start did not charge the bus |
| A.E.0.H | A14.0 | Missing loading of the bus during precharge | The grid voltage amplitude (D21) read with the synchronization signals is within the allowable range, but the DC Bus has not been precharge. | Check the power connections towards the grid. |

# 7 DISPLAY - REMOTE KEYPAD

## 7.1 DISPLAY PHYSICAL DISPOSITION

The keypad has three buttons, "**S**" ( selection), "**+**" (increase), "**-**" (reduce) and a four numbers and half display, with the decimal points and the sign "**-**".

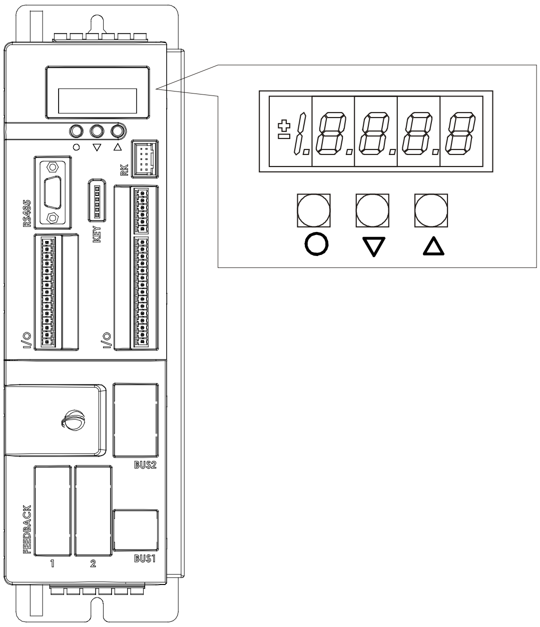


*Figure 31 – Display*

## 7.2 REMOTE KEYPAD PHYSICAL DISPOSITION

The keypad has 5 LEDs, 5 seven-segment display with sign and 6 buttons. In case of PV application the meaning of LEDs and buttons is described below.

| LED Name | Meaning |
|---|---|
| ON GRID (green) | Inverter connected to the grid, interface protection device closed |
| GRID OK (yellow) | Grid parameters (voltage and frequency) controlled by protection interface and by AFE are correct, and the fuses on grid side are ok |
| PV OK (yellow) | Photovoltaic voltage is within the limits, that are from 380V to 780V |
| INS OK (yellow) | With PV switch closed and in presence of PV voltage, indicate that the insulation resistance on PV side is within the limit of the insulation control device |
| MPPT ON (green) | steady ligth = MPPT enabled<br>fast blinking = manual MPPT enabled<br>slow blinking = the run command has been memorized and the inverter is ready to start conversion |

| Button Name | Meaning |
|---|---|
| S | Selection |
| ▲ | Increase |
| ▼ | Reduce |
| RUN | Starts the inverter |
| RESET | Resets an alarm (after that it has been eliminated the condition tha has generated it) |
| STOP | Stops the inverter |


*Figure 32 – Remote keypad for PV application*

## 7.3 DISPLAY – REMOTE KEYPAD USE

For a complete description on how to use the display and the remote keypad refer to the **AFE user manual**.

# 8 REVISION HISTORY

| OPDE Energy Application Revsion | Date | Changes introduced in different versions |
|---|---|---|
| Rev 1.00 | 28/03/2017 | First release |
| | | |
| | | |

Via dell'Oreficeria, 41
36100 Vicenza - Italy
Tel +39 0444 343555
Fax +39 0444 343509
www.bdfdigital.com