1. Document History

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| --- | --- | --- | --- |
| Date | Versions | Description | Author |
| 23-07-2021 | 0.1 | First draft version | Antonios Marinopoulos (JRC) |
| 13-10-2021 | 0.2 | Basic version of the model for simulations over short time intervals | Antonio De Paola (JRC) |

General description

* 1. System configuration identification

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| --- | --- |
| ID | Name |
| JRA1-EO-ST | JRA1 Electrical-Only system configuration - model for Short-Time simulations |

* 1. Short description of context

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| Context description |
| The system configuration described in this document has been developed as part of a reference setup for electrical only system simulations, performed in a Simulink/MATLAB environment. The goal of this reference setup is to become a benchmark for dynamic simulations over short time scales (up to tenths of seconds) of electrical distribution systems including loads, generators, DER (PV, wind, energy storage) and microgrids.  The level of detail, as well as the component models, have been specifically selected to perform simulations that account for a wide range of events such as faults, connection/disconnection of assets and microgrid islanding. |
| Key figures |
| * Distribution grid: MV grid equivalent (as a 20kV voltage source), MV/LV transformer (including OLTC), 6 LV lines and 6 circuit breakers operating at 420V. * 2 RL static loads (both drawing 10 kW of active power a 1kVAr of reactive power). * 1 synchronous generator (nominal power of 60 kVA). * 1 grid-following inverter (maximum active power of 50kW) * 1 asynchronous motor (nominal power of 160 kVA) * 1 interconnected microgrid, which includes:   - 1 grid-forming inverter  - 1 static R load (drawing 2 kW of active power) |
| Key words |
| * LV distribution network * Inverter connected DER * OLTC MV/LV transformer * Interconnected microgrid (can also operate autonomously in islanding mode) |

* 1. Climate

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| Climate conditions |
| N/A |

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| --- | --- | --- |
| Files attached | | |
| File ID | Description | Units |
|  |  |  |

* 1. Geographical features

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| --- |
| Geographical features |
| N/A |

1. System breakdown (SBD)

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1. Graphical representations of SC
   1. Network diagrams

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| **Overview** |

1. Element connections

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| --- | --- | --- | --- | --- |
| Name | ID | Type of exchange | Types of class connected | Comment |
| Control signal port | ControlPort | Interface for control signal |  |  |
| Electric power port | ElectricPort | Interface for electric power flow |  |  |

1. Elements description

Replicate the following table for every element in the SBD

|  |  |
| --- | --- |
| About | |
| ID in SBD | 1 |
| Level in SBD | 1 |
| Class name | LVDistributionGrid |
| Parent class | - |
| Contained in | JRA1-EO-ST |
| Description | Overall model of the considered distribution network, containing the different electrical components present at the LV level and the interconnection with the upstream MV grid. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | An electrical distribution network containing interconnected components, with the purpose of delivering electrical energy from the MV grid and from LV interconnected sources to the LV loads. |
| Physical characteristics | U\_LV\_n (float) – Nominal low voltage [V]  U\_MV\_n (float) – Nominal medium voltage [V]  f\_n (float) - Nominal frequency [Hz] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | Continuous type |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | - |
| ID in simulation | LVDG |
| Files attached |  |

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| --- | --- |
| About | |
| ID in SBD | 1.1 |
| Level in SBD | 2 |
| Class name | MVGrid |
| Parent class | - |
| Contained in | LVDG |
| Description | This element is used to represent the MV level of the electrical power system. It is modelled through a 3-phase voltage source in series with an RL branch, using the parameters of an equivalent MV electrical grid (CIGRE MV Benchmark model). |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | This element sets fixed values for voltage, frequency, and phase angle at the busbar to which it is connected. |
| Physical characteristics | U\_rms (float) – Nominal medium voltage [Volt]  Ph\_ang (float) – Phase angle of phase A [degrees]  f\_n (float) - Nominal frequency [Hz] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port (ElectricPort) - bus where the lowstream LV grid is connected (three phase) |
| ID in simulation | MVGrid |
| Files attached | *-* |

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| About | |
| ID in SBD | 1.2 |
| Level in SBD | 2 |
| Class name | LVLine |
| Parent class | - |
| Contained in | LVDG |
| Description | This element is used to model cables or overhead lines of a LV electric power system and is represented as a 3-phase series RL branch. |
| Number of elements in SC | 6 |
| Attributes | |
| Functionality | LV lines are used to connect two nodes/buses of a LV electric power system. |
| Physical characteristics | R (float) - Resistance [Ω]  L (float) – Inductance [H] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_a (ElectricPort) - connection with the bus on the sending end of the line (3-phase)  port\_b (ElectricPort) - connection with the bus on the receiving end of the line(3-phase) |
| ID in simulation | Line 1 – Line 6 |
| Files attached | - |

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| --- | --- |
| About | |
| ID in SBD | 1.3 |
| Level in SBD | 2 |
| Class name | LVBus |
| Parent class | - |
| Contained in | LVDG |
| Description | Graph node of the network diagram at which voltage and other electrical quantities are measured. It can correspond to physical busbars in substations. |
| Number of elements in SC | 10 |
| Attributes | |
| Functionality | The bus elements connect the different network components operating at the same voltage level. It also provides measurement of voltage, current, active and reactive power. |
| Physical characteristics | V\_rms (float) – Root-mean-square voltage [Volt]  Ph\_ang (float) – Phase voltage angle of phase A [degrees]  I\_rms (float) – Root-mean-square current [Ampere]  P\_act (float) – Active power [W], with positive sign if flowing in the direction of the associated Simulink diagram  Q\_react (float) – Reactive power [VAr], with positive sign if flowing in the direction of the associated Simulink diagram |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port (ElectricPort) - bus to which other electrical power system components can be connected. |
| ID in simulation | Bus 1 – Bus 10 |
| Files attached |  |

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| About | |
| ID in SBD | 1.4 |
| Level in SBD | 2 |
| Class name | LVCircuitBreaker |
| Parent class | - |
| Contained in | LVDG |
| Description | Three-phase component of the electrical power system that can open/close in order to disconnect/connect the network components connected to its two terminals. |
| Number of elements in SC | 6 |
| Attributes | |
| Functionality | A three-phase circuit breaker (CB) can be normally open (NO) or normally closed (NC). It can then close (for a NO) or open (for a NC) at either a predefined time or following an external triggering signal. The CB can open/close any or all of its three phases. |
| Physical characteristics | t\_s (float) – switching time [t]  R\_on (float) – breaker resistance [Ω]  R\_s (float) – snubber resistance [Ω]  C\_s (float) – snubber capacitance [F] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_a (ElectricPort) -  port\_b (ElectricPort) -  Representation of the two distinct terminals of the circuit breaker, to which the relevant sections of the LV network are connected |
| ID in simulation | Three Phase LV Breaker 1-6 |
| Files attached |  |

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| --- | --- |
| About | |
| ID in SBD | 1.5 |
| Level in SBD | 2 |
| Class name | OLTC\_trafo |
| Parent class | - |
| Contained in | LVDG |
| Description | A three-phase two-winding transformer model that transfers electrical energy between the MV and LV sections of the network. The component includes also an On-Load Tap Changer (OLTC) and the respective controls. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The transformer (Yg/Delta1) connects the voltage level of the node at the primary side (the feeding MV grid) to the voltage level of the node at the secondary side (LV distribution grid). The three-phase primary multi-tap winding is modeled with three Variable-Ratio Transformer blocks.  The OLTC is controlled by the secondary voltage using a feedback control loop and adapts the voltage ratio between the primary and secondary side, so that the secondary voltage is kept between an upper and a lower boundary.  The transformer voltage ratio V\_2/V\_1 is given by:  V\_2/V\_1= 1/ (1+TapPosition\*Δ\_U)  Tap position 0 corresponds to nominal voltage ratio.  When the 'Voltage regulator' is 'on', the signal applied at the 'Vm' input is monitored and the voltage regulator asks for a tap change if:  abs(Vm-V\_ref)>db/2, during a time t > del. |
| Physical characteristics | Transformer  P\_nom (float) – nominal apparent power [VA]  F\_nom (float) – nominal frequency [Hz]  V\_1 (float) – winding 1 (Yg) rated ph-ph rms [V]  R\_1 (float) – winding 1 (Yg) resistance [pu]  X\_1 (float) – winding 1 (Yg) reactance [pu]  V\_2 (float) – winding 2 (D1) rated ph-ph rms [V]  R\_2 (float) – winding 2 (D1) resistance [pu]  X\_2 (float) – winding 2 (D1) reactance [pu]  R\_m (float) – magnetization branch resistance [pu]  L\_m (float) – magnetization branch inductance [pu]  OLTC  Δ\_U (float) – voltage step per tap [pu]  min\_tap (float) – minimum tap position  max\_tap (float) – maximum tap position  init\_tap (float) – initial tap position  t\_tap (float) – tap selection time [s]  Voltage Regulator (if selected)  V\_ref – reference voltage [pu]  db (float) – voltage dead band [pu]  del (float) – time delay [s]  v\_tap (float) – voltage per tap [%]  shift (float) – transformer phase shift angle [°] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_1 (ElectricPort) - connection of the primary side (MV) of the transformer  port\_2 (ElectricPort) - connection of the secondary side (LV) of the transformer |
| ID in simulation | Three-Phase Tap Changer Transformer |
| Files attached |  |

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| About | |
| ID in SBD | 2 |
| Level in SBD | 1 |
| Class name | Assets |
| Parent class | - |
| Contained in | JRA1-EO |
| Description | This is a collection of elements representing electrical components that can be connected to the LV electrical distribution grid. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The different electrical components can produce, consume, or convert electrical energy. |
| Physical characteristics | - |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | - |
| ID in simulation | Assets |
| Files attached | - |

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| About | |
| ID in SBD | 2.1 |
| Level in SBD | 2 |
| Class name | RLStaticLoad |
| Parent class | - |
| Contained in | Assets |
| Description | Component of the electrical power system that consumes electric power. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The component represents a load with constant resistance and inductance (series RL). |
| Physical characteristics | Conf (text) – type of 3-ph configuration [Yg, Yn, Y, D]  V\_n (float) – nominal ph-ph rms voltage [V]  f\_n (float) – nominal frequency [Hz]  P (float) – active power [W]  Q\_L (float) – inductive reactive power [VAr]  Q\_c (float) – capacitive reactive power [VAr]  L\_type (text) – load type for load flow simulation [constant Z, PQ, I] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port (ElectricPort) -– connection to the LV network |
| ID in simulation | RLStatic |
| Files attached |  |

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| About | |
| ID in SBD | 2.2 |
| Level in SBD | 2 |
| Class name | SynchronousGenerator |
| Parent class | - |
| Contained in | Assets |
| Description | Component of the electrical power system that generates electric power. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The synchronous generator is modelled with a 3-phase synchronous machine model in the dq rotor reference frame. The stator windings are connected in wye to an internal neutral point. |
| Physical characteristics | P\_n (float) – nominal power [VA]  V\_n (float) – line to line rms voltage [V]  f\_n (float) – frequency [Hz]  Xd, Xd’, Xd’’, Xq, Xq’’, Xl (float) – reactances [pu]  Td’, Td’’, Tq’’ (float) – d and q time constants (open or close circuits) [s]  Rs (float) – stator resistance [pu]  H (float) – inertia coefficient [s]  F (float) – friction factor [pu]  p (float) – number of pole pairs  Initial conditions  dw (float) – speed deviation Δω [%]  th (float) – electrical angle of rotor Θe [deg]  i\_a, i\_b, i\_c – line current magnitude [pu]  ph\_a, ph\_b, ph\_c – line phase angles [deg]  V\_f (float) – field voltage [pu]  No-load saturation curve parameters  Magnetic saturation of the stator and rotor iron is modeled by a piecewise linear relationship specifying points on the no-load saturation curve. The first row of this matrix contains the values of field currents. The second row contains values of corresponding terminal voltages.  i\_fd (float) – field current [pu]  v\_t (float) – terminal voltage [pu] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_1 (ElectricPort) - connection to the LV grid (three phase terminal of the generator)  port\_2 (ControlPort) –control signal of the field voltage V\_f from the excitation system block.  port\_3 (ControlPort) - control signal of the mechanical power P\_m .  port\_4 (ControlPort) – provides relevant measurement signals. |
| ID in simulation | SynGen |
| Files attached |  |

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| About | |
| ID in SBD | 2.3 |
| Level in SBD | 2 |
| Class name | GridFollowingInverter |
| Parent class | - |
| Contained in | Assets |
| Description | Component that converts direct current into alternating current. In the present benchmark network, it is implicitly assumed that the DC energy source of the inverter corresponds to a renewable generator. |
| Number of elements in SC |  |
| Attributes | |
| Functionality | The grid following inverter is modelled as a VSI Converter (Voltage Source Inverter), which outputs an AC voltage from a DC voltage source. The AC voltage signal follows the frequency of the grid. |
| Physical characteristics | P\_max (float) – maximum active power [W]  Q\_max (float) – maximum reactive power [VAr]  V\_dc (float) – DC bus voltage [V[  f\_s (float) – switching frequency [Hz]  L\_f (float) – filter inductance [H]  L\_out (float) – output inductance [H]  C\_f (float) – filter capacitance [F] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_1 (ElectricPort) - connection to the LV grid (three phase terminal of the converter)  port\_2 (ControlPort) – control signal of the active power reference.  port\_3 (ControlPort) - control signal of the reactive power reference.  port\_4 (ControlPort) – connection to the PI controller triggering signal is connected.  port\_5 (ControlPort) – voltage and current signal for the grid and the DC bus.  port\_6 (ControlPort) – saturation control signal. |
| ID in simulation | InvGrFollow |
| Files attached |  |

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| --- | --- |
| About | |
| ID in SBD | 2.4 |
| Level in SBD | 2 |
| Class name | AsynchronousMotor |
| Parent class | - |
| Contained in | Assets |
| Description | Component of the electrical power system that consumes electrical power, transforming electrical energy to mechanical. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The asynchronous motor is modelled with a three-phase asynchronous machine (squirrel cage) in a selectable dq reference frame (rotor). Stator and rotor windings are connected in wye to an internal neutral point. The shaft mechanical torque is an input to the model. |
| Physical characteristics | P\_n (float) – nominal power [VA]  V\_n (float) – line to line rms voltage [V]  f\_n (float) – frequency [Hz]  Rs (float) – stator resistance [Ω]  Lls (float) – stator inductance [H]  Rr’ (float) – rotor resistance [Ω]  Llr’ (float) – rotor inductance [H]  Lm (float) – mutual inductance [H]  J (float) – inertia coefficient [kg.m^2]  F (float) – friction factor [N.m.s]  p (float) – number of pole pairs  Initial conditions  s (float) – slip [%]  th (float) – electrical angle Θe [deg]  i\_a, i\_b, i\_c – stator current magnitude [A]  ph\_a, ph\_b, ph\_c – stator phase angles [deg]  V\_f (float) – field voltage [pu]  No-load saturation curve parameters  Magnetic saturation of the stator and rotor iron is modeled by a piecewise linear relationship specifying points of the no-load saturation curve. The first row of this matrix contains the values of stator currents. The second row contains values of corresponding terminal voltages.  i (float) – stator rms current [A]  v (float) – line to line terminal rms voltage [V] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_1 (ElectricPort) - connection of the motor to the grid (three phase terminal of the motor)  port\_2 (ControlPort) – control signal of the mechanical torque Tm. |
| ID in simulation | SynMot |
| Files attached |  |

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| About | |
| ID in SBD | 3 |
| Level in SBD | 1 |
| Class name | Microgrid |
| Parent class | - |
| Contained in | JRA1-EO |
| Description | Group of energy sources and loads that has the capability to either operate synchronously with the interconnected grid or autonomously in islanded mode. In this model, the microgrid is composed by a grid-forming inverter and by a resistive load. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The electrical microgrid, containing a grid-forming inverter and a resistive load, is connected to the main LV distribution grid through a common point of coupling. The microgrid can operate in interconnected and autonomous (grid islanding) mode. In the latter case, the local load is fed by the renewable energy source that is assumed to be powering the grid forming inverter. |
| Physical characteristics | U\_n (float) – nominal voltage [V]  f\_n (float) - nominal frequency [Hz] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | Continuous type |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | - |
| ID in simulation | MG |
| Files attached |  |

|  |  |
| --- | --- |
| About | |
| ID in SBD | 3.1 |
| Level in SBD | 2 |
| Class name | RStaticLoad |
| Parent class | - |
| Contained in | MG |
| Description | Component of the electrical power system that consumes electric power. |
| Number of elements in SC | 1 |
| Attributes | |
| Functionality | The component represents a resistive load with constant impedance (R type). |
| Physical characteristics | Conf (text) – type of 3-ph configuration [Yg, Yn, Y, D]  V\_n (float) – nominal ph-ph rms voltage [V]  f\_n (float) – nominal frequency [Hz]  P (float) – active power [W]  Q\_L (float) – inductive reactive power [VAr]  Q\_c (float) – capacitive reactive power [VAr]  L\_type (text) – load type for load flow simulation [constant Z, PQ, I] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port (ElectricPort) -– connection of the component to the microgrid |
| ID in simulation | RStatic |
| Files attached |  |

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| --- | --- |
| About | |
| ID in SBD | 3.2 |
| Level in SBD | 2 |
| Class name | GridFormingInverter |
| Parent class | - |
| Contained in | MG |
| Description | Component that converts direct current into alternating current. In the present benchmark network, it is implicitly assumed that the DC energy source of the inverter corresponds to a renewable generator. |
| Number of elements in SC |  |
| Attributes | |
| Functionality | The grid forming inverter is modelled using a Universal 3-arm Bridge with ideal switches, fed by a constant DC source, in series with an RL and a shunt capacitor. The bridge is driven by a PWM signal created by an appropriate voltage controller. The inverter is able to independently set up and maintain the network frequency at its nominal value (50Hz), without the need for a reference grid voltage. |
| Physical characteristics | Universal Bridge  Rs (float) – snubber resistance [Ω]  Cs (float) – snubber capacitance [F]  Ron (float) – internal resistance [Ω]  Ideal DC Voltage source  V (float) – voltage amplitude [V]  Three-phase series RL branch  R (float) – resistance [Ω]  L (float) – inductance [H]  Three-phase series C branch  C (float) – capacitance [F] |
| Surroundings | - |
| Quality | - |
| Support | - |
| Operation type | - |
| Economical features | - |
| Legal constraints | - |
| Instances characterization | |
| Interfaces | port\_1 (ElectricPort) - Connection of the converter to the grid (three phase terminal of the converter) |
| ID in simulation | InvGrForm |
| Files attached |  |