1. Document History

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

General description

1.1 System configuration identification

ID	Name
JRA1-EO-LT	JRA1 electrical only system configuration

1.2 Short description of context

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 long time scales (hours or days) of electrical distribution systems including loads, generators and DER (PV, wind, energy storage). The level of detail, as well as the component models, have been specifically selected to perform simulations and test various functionalities, such as coordinated voltage control, power sharing among DERs and OLTC functionality of the grid transformer.
Key figures
• Distribution grid: MV grid equivalent (as a 20kV voltage source), MV/LV transformer (including OLTC), 6 LV lines and 5 circuit breakers operating at 420V. • 1 RL static loads (drawing 10 kW of active power a 1kVAr of reactive power). • 1 residential load (nominal power of 30 kW, with a 0.95 power factor). • 1 photo-voltaic farm (with peak production of 10.5 kW) • 1 storage device (with rated capacity of 75 kWh and rated power of 15 kW)
Key words
• LV distribution network • Inverter connected DER • OLTC MV/LV transformer • Storage device • Residential loads

1.3 Climate

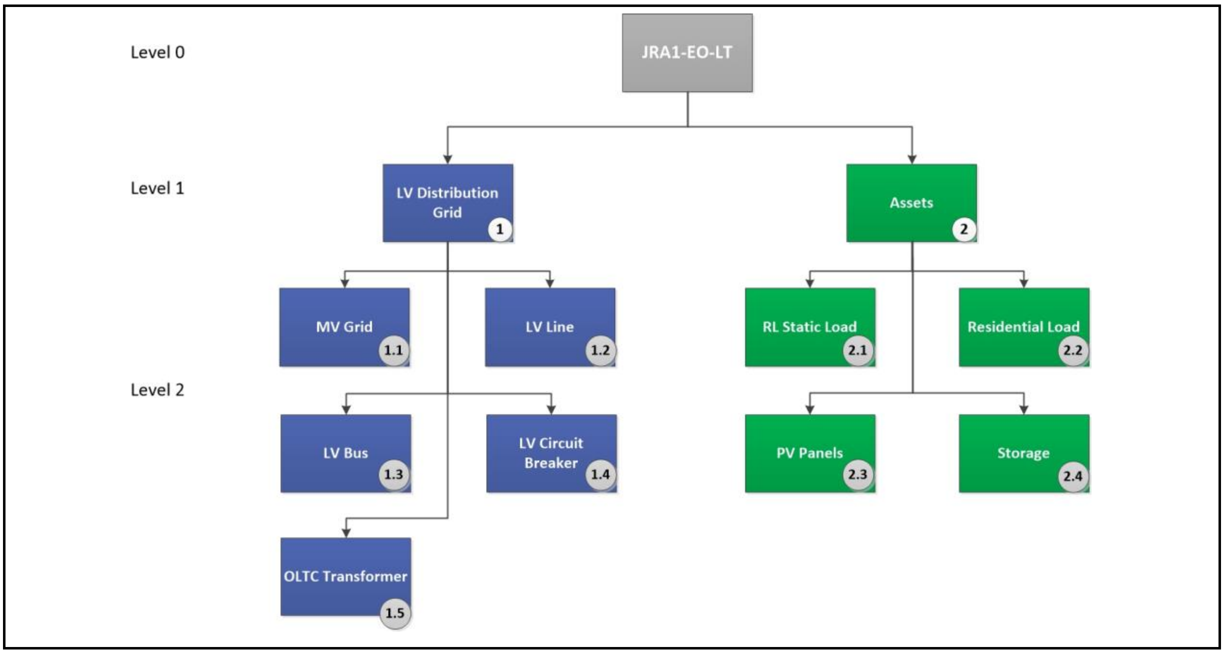
Climate conditions
N/A

Files attached		
File ID	Description	Units

1.4 Geographical features

Geographical features
N/A

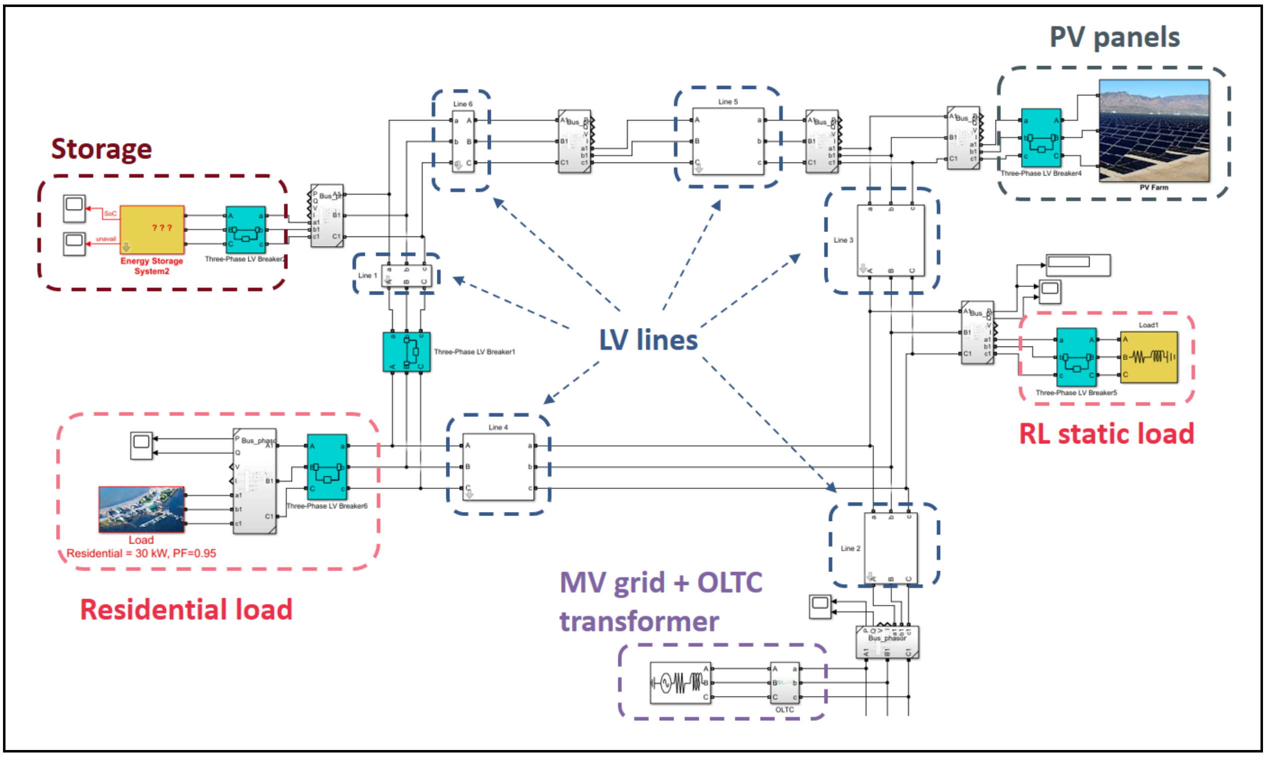
2. System breakdown (SBD)



3. Graphical representations of SC

3.1 Network diagrams

Overview



4. Element connections

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		

5. 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
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	

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	-

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	-

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	7
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 7
Files attached	

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	5
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 1-5

Files attached	

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	<u>Transformer</u> 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]

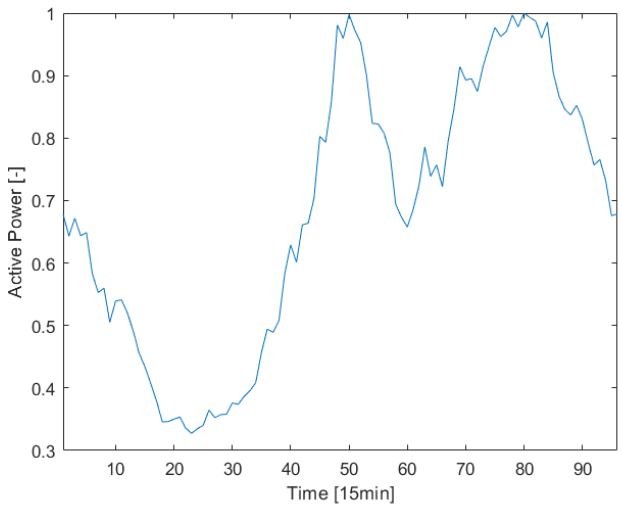
	OLTC Δ_U (float) – voltage step per tap [pu] min_tap (float) – minimum tap position max_tap (float) – maximum tap position init_tap (float) – initial tap position t_tap (float) – tap selection time [s] Voltage Regulator (if selected) V_ref – reference voltage [pu] db (float) – voltage dead band [pu] 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	

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	-

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	

About	
ID in SBD	2.2
Level in SBD	2
Class name	ResidentialLoad
Parent class	-
Contained in	Assets
Description	Component of the electrical network that consumes electrical power/energy from the grid.
Number of elements in SC	1
Attributes	
Functionality	The component represents an aggregation of the (active and reactive) power consumption of several residential consumers. The user defines a nominal power and a power factor, as well as the timestep used for the consumption data. The load (consumption) profile is expressed in p.u. with respect to the nominal power via a vector, with a length fitting the timestep used. The pre-fixed load profile is depicted in the following figure: 

	The aggregated load is modelled using controlled AC current sources, injecting current based on the consumption profile.
Physical characteristics	P_nom (float) – nominal power [kW] pf (float) – power factor t_step (float) – timestep [minutes]
Surroundings	-
Quality	-
Support	-
Operation type	The current model can be used for phasor simulation. For continuous or discrete simulations, current sources input have to be change from phasors to continuous values.
Economical features	-
Legal constraints	-
Instances characterization	
Interfaces	port (ElectricPort) — bus to which other electrical components can be connected
ID in simulation	ResLoad
Files attached	

About	
ID in SBD	2.3
Level in SBD	2
Class name	PVPanels
Parent class	-
Contained in	Assets
Description	Small plant for photo-voltaic generation
Number of elements in SC	1
Attributes	
Functionality	The component provides electric power to the grid according to a set irradiance profile, accounting for partial shading phenomena. The aggregated generation is modelled using controlled AC current sources, injecting current based on the prescribed generation profile.
Physical characteristics	Vab, Vbc, Vac (floats) - Line voltage at the PV terminals [V] Ia, Ib, Ic (floats) - current at the PV terminals [A]
Surroundings	-
Quality	-

Support	-
Operation type	-
Economical features	-
Legal constraints	-
Instances characterization	
Interfaces	port_1 (ElectricPort) - Connection to the LV grid
ID in simulation	PVPlant
Files attached	

About	
ID in SBD	2.4
Level in SBD	2
Class name	Storage
Parent class	-
Contained in	Assets
Description	Component that absorbs energy from the grid and is able to inject it back at a later time.
Number of elements in SC	
Attributes	
Functionality	The electrical operation of the component is modelled using controlled AC current sources, injecting currents based on the prescribed charge/discharge profile. Such profile is determined by the storage controller, which also generates the signals necessary to update the internal State-of-Charge (SoC) of the device.
Physical characteristics	P_r (float) – Rated power [kW] C_r (float) – Rated capacity [kWh] SoC0 (float) - Initial State of Charge [p.u.] eff (float) – Storage round-trip efficiency [p.u.] Pmax (float) - maximum power allowed from the grid [kW] Igain (float) - Regulator integrator gain Soc_min, Soc_max (floats) - Minimum and maximum allowed value of SoC [p.u.] Pn (float) - Maximum charging power during night-time [kW]
Surroundings	-
Quality	-
Support	-
Operation type	-
Economical features	-

Legal constraints	-
Instances characterization	
Interfaces	port_1 (ElectricPort) - Connection to the LV network
ID in simulation	Storage
Files attached	