About

Provide general information regarding the described model.

Model name	Residential Load
Author / organization	Luigi Pellegrino / RSE
Short description	The model describes the electrical behaviour of an aggregation of residential loads over a day. A pre-fixed load profile (typical for Italian residential loads) is implemented. The model considers constant power loads, hence a decrease in voltage causes an increase in current.
Present use / development status	Ready to use

Classification

Describe the context of the model regarding application (modelling domain, intended use) and technical details (modelling approach, model dynamics, model of computation, functional representation).

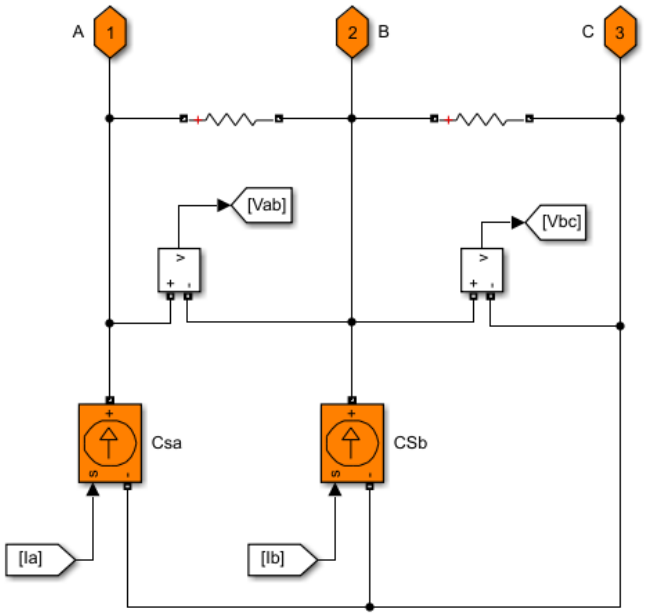
Domain	☐ electrical storage ☐ thermal storage ☐ energy conversion device ☒ other, please specify: Electrical Load
Intended application (including scale and resolution)	The model can be used for phasor simulations. The resolution of the aggregated load profile is 15 minutes. Lower timescales are allowed but imply a linearisation of the profile.
Modelling of spatial aspects *Explain the approach of how this model describes the spatial distribution of the system.*	☒ lumped (single device) ☐ discretized (single device) ☐ averaged (multiple devices) ☐ other, please specify:
	Details: The model does not provide the behaviour of single residential user but only the profile of the whole aggregate as a load profile at the secondary distribution substation.
Model dynamics *Explain how the model captures the dynamic behaviour of the system.*	☐ static ☒ quasi-static ☒ dynamic ☐ other, please specify:
	Details:

	The load is modelled with a AC current source that can be used for phasor simulation. To perform dynamic simulation current source input must be changed from phasor to continuous value.
Model of computation *Explain how the model captures the system's evolution with respect to time and/or external stimuli.*	☒ time-continuous ☐ discrete-event ☐ state machine ☐ other, please specify:
	Details:
Functional representation *Are the model functions explicit, i.e., of type y = f(x), or implicit, i.e., of type g(x,y) = 0?*	☒ explicit ☐ implicit ☐ other, please specify:
	Details:

Mathematical Model

This section provides information about the actual mathematical model by specifying variables, parameters and equations. Variables and parameters should be specified with type (Real, Integer, Boolean, String) and (physical) unit. In case the equations are too complex to be reproduced here, also a reference to a book or any other publication can be given.

Input variables (name, type, unit, description)	Phase to ground voltages
Output variables (name, type, unit, description)	Phase currents
Parameters (name, type, unit, description)	Nominal power (P_n): this parameter is used to scale the load profile of the residential aggregation. Power factor (PF): this parameter determines the reactive power absorbed by the load. Timescale: this parameter changes the power setpoint variation.
Internal variables (name, type, unit, description)	-
Internal constants (name, type, unit, description)	Load profile ($L(t)$): residential aggregated load profile in p.u.
Model equations *Formulate or provide references to the model's governing equations*	Governing equations
	$$i(t) = \frac{2}{3} \cdot \frac{P_n \cdot L(t)}{v(t) \cdot PF}$$

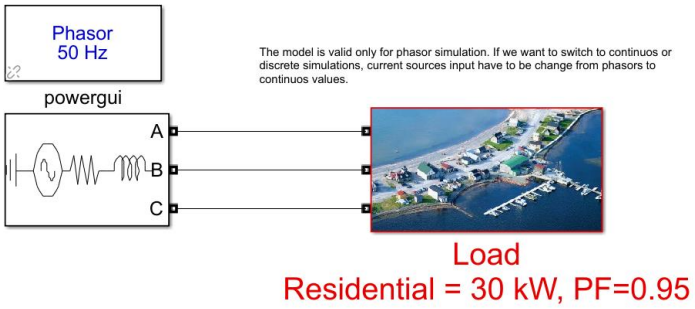
(describing the system state) and the constitutive equations (describing material properties)	Constitutive equations
Initial conditions	$L(t) = 0.68$ $\bar{\imath} = 10\ A$
Boundary conditions	-
Optional: graphical representation (schematic diagram, state transition diagram, etc.)	

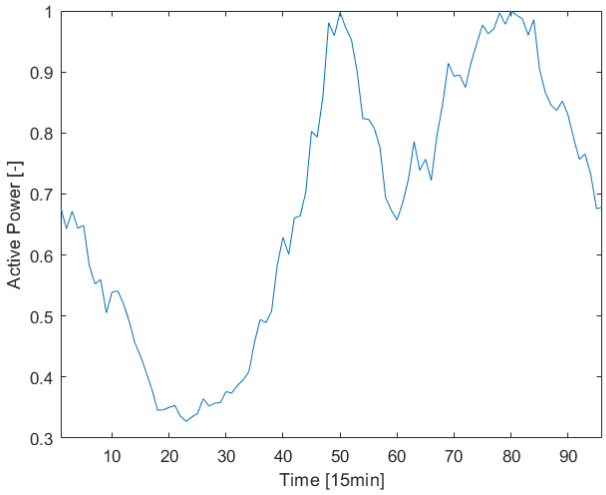
Testing

Please provide a (simple) test design for the purpose of component model characterization. This test should enable two different kinds of comparisons:

- ***model validation**: compare the behaviour of an implementation of the exact same model based on time-series data*
- ***model harmonization**: compare the behaviour of an implementation of a (supposedly) similar model with the same or comparable intrinsic or lower time resolution based on the comparison of key performance indicators*

Model Validation *Provide the description of a test setup (i.e., simulation) that enables others to validate their implementation of the same model. The results should be provided as time series.*	
Narrative *Provide a simple description of the test specification.*	The model is connected to a three-phase voltage generator emulating a LV network. Different voltage and frequency variation will be tested in order to validate the model response. To validate the model, the output current and the voltage measurement are used to calculate the active power output. If this power is equal to the load profile setpoint pre-fixed in the model, then the model is validated.
Test system configuration	The test system configuration includes the object under investigation, the residential aggregated load model, and a

Describe the test setup, including: *How long does the simulation run?* *Are there any other models required for this setup? If yes, provide a link to their description.* *Is a controller required for this setup (see also below)?*	voltage source with an internal impedance which represents the LV grid. The phasor simulation at 50 Hz is performed on 24 hours in order to evaluate the active and reactive power absorbed by the load. 
Inputs and parameters *Specify the (exogeneous) inputs of the model used in this test. Also specify the model parameters used in this test. If necessary, attach this information as dataset (SmILES data format).*	Voltage source parameters: • Phase to phase voltage: 400 V • Frequency: 50 Hz • Internal impedance: 8.9 + i5 mΩ Residential aggregated load profile setpoint.
Control function (optional) *Specify any additional control functions used for this test.*	-
Initial system state *Describe the initial state of the system.*	Phase currents = 10 A
Temporal resolution *Provide information regarding the temporal resolution of the test simulation, such as integrator step size, time resolution for event handling, etc.*	The model equations do not present differential equations; thus, the temporal resolution depends on the simulation configuration. Significant variations of the power profile are on a timescale of 15 minutes. Lower timescales imply linearization of the load profile.
Evolution of system state *Describe (textual and/or graphical) the expected qualitative behaviour of the component model in this simulation.*	The x-axis is expressed in 10^4 s. The figures show a simulation over one day. 

	Several tests with different voltage and frequency values have been performed. The active and reactive power profile are always the same. Only the output current profile changes as function of the voltage.
Expected results *Provide a quantitative description of the expected simulation output based on time series. This information must be comprehensive enough for someone else to validate his/her own implementation of this model. If necessary, attach this information as dataset (SmILES data format).*	The expected result of the model is the power profile set as model parameter times the nominal power. The following figure shows the load profile use as parameter.  This profile is exactly the same (with different amplitude) of the one provided by the model.

Model harmonization *Provide information that enables others to compare the behaviour of similar models with this model. The results should be provided as KPIs, targeting a time resolution that is lower than that of the model itself. For instance, if the intrinsic time resolution of the model is seconds, then the provided KPI should measure a significant attribute of the modelled system on an hourly or daily basis.*	
Narrative *Provide a simple description of the test specification.*	The model is developed for being used with different timescales expressed in seconds.
Test system configuration *Describe the test setup, including:* *How long does the simulation run?* *Are there any other models required for this setup? If yes, provide a link to their description.* *Is a controller required for this setup (see also below)?*	
Inputs and parameters *Specify the (exogeneous) inputs of the model used in this test. Also specify the model parameters used in*	

this test. If necessary, attach this information as dataset (SmILES data format).	
Control function (optional) *Specify any additional control functions used for this test.*	
Initial system state *Describe the initial state of the system.*	
Temporal resolution *Provide information regarding the temporal resolution of the test simulation, such as integrator step size, time resolution for event handling, etc.*	
Evolution of system state *Describe (textual and/or graphical) the expected qualitative behaviour of the component model in this simulation.*	
Expected results *Provide a quantitative description of the expected simulation output based on key performance indicators. This information must be comprehensive enough for someone else to validate his/her own implementation of this model. If necessary, attach this information as dataset (SmILES data format).*	

Sensitivity analysis (optional) *Provide additional information that enables others to validate their implementation of the same model. The goal is to understand how different sources of uncertainty in the component model input affect the model's output.*	
Narrative *Provide a simple description of the test specification.*	As already stated, the output of the model (phase current) depends on the voltage input by the governing equation as well as by the model parameters.
Test system configuration *Describe the test setup, including:* *How long does the simulation run?*	

Are there any other models required for this setup? If yes, provide a link to their description. *Is a controller required for this setup (see also below)?*	
Source of uncertainty *Specify the source of uncertainty for this specific sensitivity analysis.*	
Inputs and parameters *Specify the (exogeneous) inputs of the model used in this test. Also specify the model parameters used in this test. If necessary, attach this information as dataset (SmILES data format).*	
Control function (optional) *Specify any additional control functions used for this test.*	
Initial system state *Describe the initial state of the system.*	
Temporal resolution *Provide information regarding the temporal resolution of the test simulation, such as integrator step size, time resolution for event handling, etc.*	
Evolution of system state *Describe (textual and/or graphical) the expected qualitative behaviour of the component model in this simulation.*	
Expected results *Provide a quantitative description of the expected simulation output. This information must be comprehensive enough for someone else to validate his/her own implementation of this model. If necessary, attach this information as dataset (SmILES data format).*	

Additional Information

Provide any other additional information here.

Reference implementation	-
Similar / related models	-
Related publications	-
Intellectual property concerns (if applicable)	-