Model Description

This model represents an active distribution grid with high penetration of distributed generation (DG). The model was initially developed as part of the IDE4L (Ideal Grid for All) project, financed by the European Commission [1]. It can be used to study dynamics of active distribution grids under several test scenarios.

The modelled grid is a 79-bus multi-phase unbalanced network including components of 10 different types, each with electrical and mechanical parts, various controllers and protection systems, to emulate the behavior of an active distribution grid. Details of the component models and the grid structure are explained in [2]. As shown in the figure below, the modelled grid includes four different voltage levels: HV (220 kV), MV (36 kV), LV (6.6 kV), and residential LV (0.4 kV).

1. *HV section:*

   The HV section is a 6-bus network adopted from [3] with 50 MW wind farm generation added.

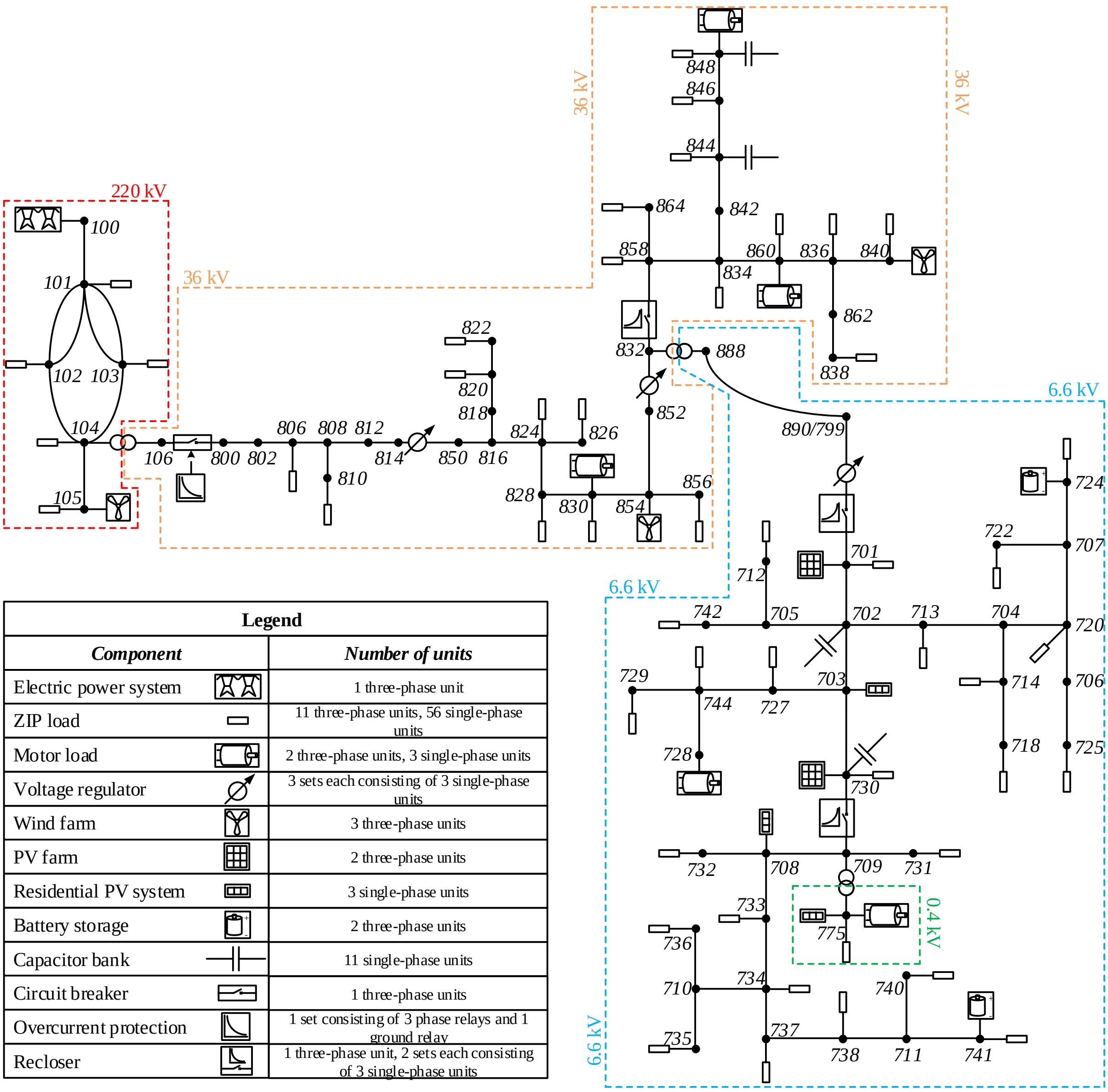
2. *MV section:*

   The MV section is based on the IEEE 34 bus test feeder with the main difference being that three constant power loads (total of 110 kVA) are replaced by motor load models to incorporate motor loads dynamics, and two 1.5 MW wind farms are added to the middle and end of the feeder [4]. In addition, a circuit breaker supervised by an overcurrent protection relay and a three-phase recloser are added to the beginning and middle of the MV feeder, respectively.

3. *LV and residential LV sections:*

   The LV and residential LV sections are based on the IEEE 37 bus test feeder. The following differences are made: two constant power loads (total of 150 kVA) are replaced by motor load models; two PV farm models (total of 1.05 MW), three residential PV system models (total of 0.77 MW), and two battery storage models (total of 325 Ah) are added to the feeder [4]; and two sets of single-phase reclosers are added to this section.

In order to comply with real-time simulation constraints, the model was implemented in three subsystems each partitioned into SSN groups so that parallel computations can be performed using the ARTEMiS-SSN solver. More details on the real-time simulation setup of the model can be found in [5].



Legend	
Component	*Number of units*
Electric power system	1 three-phase unit
ZIP load	11 three-phase units, 56 single-phase units
Motor load	2 three-phase units, 3 single-phase units
Voltage regulator	3 sets each consisting of 3 single-phase units
Wind farm	3 three-phase units
PV farm	2 three-phase units
Residential PV system	3 single-phase units
Battery storage	2 three-phase units
Capacitor bank	11 single-phase units
Circuit breaker	1 three-phase units
Overcurrent protection	1 set consisting of 3 phase relays and 1 ground relay
Recloser	1 three-phase unit, 2 sets each consisting of 3 single-phase units

Demonstration

Once the model starts running, two auxiliary ideal voltage sources, connected at nodes 104 and 890/799, automatically disconnect after the first 10 seconds of simulation. The voltage sources are used at the simulation startup to help the grid model to reach to a stable operating point.

Because all motor loads (total of 260 kVA) switch on at t = 30 s, it is recommended to apply any change or disturbance to the model after the first 50 seconds of simulation so that the grid reaches a relatively steady state operating point. Additional changes/disturbances can be applied through the console.

The console consists of two separate panels: “Monitoring” and “Control”. In the monitoring panel, it is possible to observe different component and grid variables, such as: grid voltage and frequency, power generation of DGs, tap changer operation of voltage regulators, status of protective devices, speed and current of motors, and the total load served by each section of the grid. Note that, next to each scope, there is a “constant variable” block that serves as a selector for choosing the node or the unit of interest for monitoring. More details can be found in the monitoring panel.

In the control panel, it is possible to control the wind speed, solar irradiation, and the charge/discharge rate of battery storage in different sections of the grid. In addition, it is possible to trigger a fault, located in the MV section at node 858, with predetermined duration and firing angle. Moreover, the control panel makes it possible to perform load shedding separately on each section. More details can be found in the control panel.

Notes

1. The model runs under **RT-Lab v11**, **ARTEMiS v7.0.2** and **MATLAB 2011b**.
2. The subsystem "Measurements" analyses the measurements (calculates P, Q, etc) and sends the selected signals to the console. It does not contain any part of the grid model
3. Note: Before running the model (both in offline and real-time), please build the S-function by:

   Under "SS_MVGrid" subsystem ==> under "Single-Phase Voltage Regulator" ==> double click on the 'SSN OLTC xfo' block and press 'Generate internal S-function code' button

   (Real-time only: Generated C-code files will need to be downloaded to target also)

Reference

[1] EU-FP7 IDE4L project official website at http://www.ide4l.eu

[2] H. Hooshyar, F. Mahmood, L. Vanfretti, M. Baudette, “Specification, implementation, and hardware-in-the-loop real-time simulation of an active distribution grid,” *Elsevier Sustainable Energy, Grids and Networks (SEGAN)*, vol. 3, pp. 36-51, September 2015.

[3] R. Billinton, S. Kumar, N. Chowdhury, K. Chu, K. Debnath, L. Goel, E. Khan, P. Kos, G. Nourbakhsh, J. Oteng-Adjei, “A reliability test system for educational purposes-basic data”, *IEEE Transactions on Power Systems*, vol. 4, no. 3, pp. 1238-1244, Aug. 1989.

[4] Available online at http://www.ewh.ieee.org/soc/pes/dsacom/testfeeders/index.html

[5] H. Hooshyar, L. Vanfretti, C. Dufour, “Delay-free parallelization for real-time simulation of a large active distribution grid model”, in *Proc. IEEE IECON*, Florence, Italy, October 23-27, 2016.