Academic year 2019-2020

Group work of course ELEC0029

Information about the power system and the use of ARTERE

1. The power system

The 28-bus system shown in Figure 1 is to be considered.

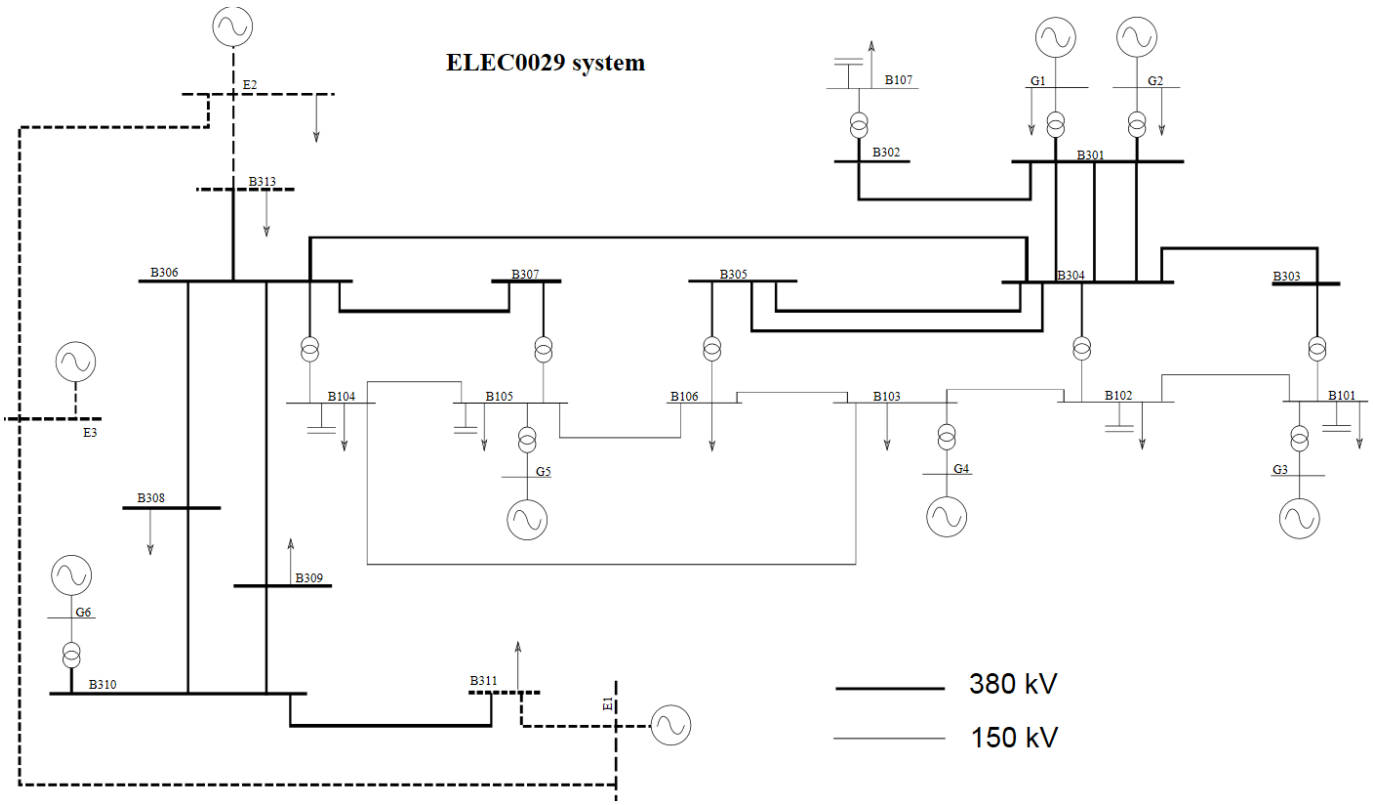

Figure 1. One-line diagram

The transmission lines shown with dashed line in that figure, as well as generators E1, E2 and E3 make up an equivalent replacing the external system seen from buses B311 and B313. The thermal limits of those equivalent lines and the reactive power of those equivalent generators do not need to be checked; hence, they have been given very large values in the data file.

For the same reason, their tripping is not considered in N-1 security analysis (see Sections 3 and 5).

Thus, lines B310-B311 and B306-B313 play the role of tie-lines interconnecting the "internal" system (shown with solid lines) with the external equivalent (shown with dashed lines).

2. The provided files

The following files are provided:

- `lf_*.dat` : the data of the power flow computation to be performed with ARTERE

- `pt.svg` : file for ARTERE to display on the one-line diagram a selection of active power generations, loads and flows, as well as the bus voltage phase angles
- `qv.svg` : similar file to display a selection of reactive power generations, loads and flows, as well as the bus voltage magnitudes in kV
- `qvpu.svg` : similar file to display a selection of reactive power generations, loads and flows, as well as the bus voltage magnitudes in per unit
- `incid.txt` : file describing the list of incidents to consider in the N-1 security analysis (see Sections 3 and 5).

3. Complementary information and data

Here are some complementary information and data not included in the `lf_*.dat` file (which relates to the power flow computation itself).

The nominal frequency of the system is 50 Hz.

The stator resistances of all machines are neglected. The nominal power of each turbine corresponds to the maximum power it can produce; the latter is specified in the `lf_*.dat` file.

E1 and E2 participate in primary frequency control with an equivalent frequency droop. E3 acts as a synchronous condenser (with a zero active power generation) to support voltages in the external system.

An equivalent subtransient reactance is specified for these three generators in the short-circuit calculation.

When simulating incidents, the sensitivity of loads to frequency is neglected.

The system is considered:

- to operate « in security N » (or to be « N-secure ») if :
  - the voltages at buses *with loads* are in the [0.95 1.10] pu interval, and
  - the currents in all branches are lower than their nominal values, specified in the `lf_*.dat` file[1];
- to operate « in security N-1 » (or to be « N-1 secure ») if, after each incident of the list specified in the file `incid.txt`:
  - the voltages at all buses *with loads* are in the [0.93 1.10] pu interval, and
  - the currents in all branches are lower than their nominal values, specified in the `lf_*.dat` file.

The incidents involved in N-1 security analysis involve the loss of one branch or one generator (hence, the name “N-1”). They are the most probable ones. They are also referred to as *contingencies*.

4. Compensation of active power imbalances

By default, ARTERE compensates any active power imbalance with the generator attached to the slack bus.

[1] More precisely, the `lf_*.dat` file gives the nominal apparent power of the lines

This is not acceptable when simulating contingencies that result in significant power imbalances, such as the outage of (large) generators. Hence, *before* simulating such incidents, it must be specified to ARTERE how to adjust the active power productions of the other generators. In this work, the generation adjustment must reflect the primary frequency control performed by speed governors.

To this purpose:

1. define a "zone" including the buses of the generators to be adjusted. Such a zone is already pre-defined in the `lf_*.dat` file through "BUSPART" records. Its name is "PRIM". The participation factors "PARTP" must be set to values reflecting the primary frequency control. The "PARTQ" fields of the BUSPART records will not be used; they can be left to the default values specified in the file;
2. specify ARTERE to use those participation factors. To this purpose, use the command "`Rescheduling – take participations from zone`" and provide the name ("PRIM") of the zone *before* simulating the incidents.

As indicated in the user guide, ARTERE adjusts the active power generations, according to the participation factors, *before it computes the post-disturbance bus voltages*, assuming that the *active power losses will not vary*. The active power generations are *not* corrected after the new losses are known.

Note that, when adjusting the active powers of generators, ARTERE obeys the minimum and maximum values specified in the TURLIM records.

5. Modification of the system operating point and contingency analysis

Modifications of the operating point can be simulated using the command `modify – data and rerun`. Alternatively, the data file can be modified but, in this case, the generation rescheduling explained in Section 4 has to be performed by the user, since the first run of ARTERE uses the slack bus to balance the active powers.

The successively applied modifications are *cumulated*. Hence, do not forget to *reset the system to its initial state*, if appropriate. This is performed by executing the command `Modify – reset to initial situation`. This resets the bus voltages to their values computed after loading the data file(s).

N-1 security can be performed by ARTERE automatically by executing the command `Contingency – analysis`. Do not forget to first specify how the active power generations have to be rescheduled, as explained in Section 4.

6. MATLAB scripts generated by ARTERE

The command "`matlab – generate SIMULINK initialisation files`" produces a file named `ini.m` which defines a structure named `opt` (see ARTERE user guide) as well as the bus admittance matrix `Y0`. This matrix, of dimensions 28 x 28 for the system to be studied, involves *the network only* (lines, cables, transformers, shunt compensation elements) and not the *machines* nor the *loads*.

The bus voltage magnitudes and phase angles are displayed in the `opt` structure with more digits than in the "listing" display or on the one-line diagrams.