NICHOLAS

In configuration A the generators 1 and 2 feeds load 1 and load 2 while the generator 3 feeds load 3 and 4.

Our aim is to set up a primary/secondary power frequency control to have a ramp electric power variation of 5MW over 10s whit a normalised frequency error that never exceed a magnitude of 0.05 and vanishes in 15 min at most.

To have the secondary control contributions proportional to the generators nominal power we set beta1=1/3, beta2=2/4 and beta3=1 because whit this set of constants we obtain that the sum of the betas of each subgrid is equal to 1.

For the first subgrid control scheme we used a PI regulator.

through the specifications we obtained a suitable omega c and built a transfer function that cut the 0db with a slope equal to minus 1. by arranging the poles and zeros of the latter we searched for the optimal phase margin and finally, equaling it with the L(s) of the real block diagram we obtained the primary and secondary control parameters kp and ks.

obtained a PI that satisfied the required parameters we implemented the function on modelica. at this point, to make the regulator more performing, we adjusted the values ​​of Kp and Ks and in this way we obtained the desired error.

for subgrid 2 the use of a PI would have satisfied the parameters but presented error oscillations with large amplitude.

we therefore chose to use a PID and thanks to this we were able to modify the dominant pole of the ideal L(S).

by carrying out the same procedure carried out for subgrid A, taking into account the presence of a pole and a zero inside the primary control, we obtain the desired values ​​of kp and ks.

similarly to subgrid 1 we implemented on modelica and adjusted parameters including Ks, Kp and pole position, preserving phase margin, to obtain optimal frequency error.

PIETRO

After achieving the Primary and Secondary control objective described by my colleagues, we addressed the tertiary control problem.

Tertiary Control purpose is to minimise the energy production cost with respect to the needed power and its time constant is in the order of 30 minutes. Since needed power depends on the future consumption, it can't be computed deterministically so a forecast based on a statistical analysis is needed in order to achieve this control.

Once obtained the forecast, it is solved the constrained optimisation problem. The constraints concern the minimum and maximum power that each generator can supply and assure that the required power by the grid is met (if feasible).

In the following the tertiary control problem for our grid in both configuration A and B is discussed. Note that the same load request data given for the grid simulation were used as load request forecast in the optimisation problem.

**CONFIGURATION A**

Configuration A is composed of two sub-grids, the former links generator 1 and generator 2 to loads 1 and 2 while the latter links generator 3 to loads 3 and 4.

The objective function aims to minimise the energy production cost for the first generators pool, hence generator 3 will not be considered.

Three constraints must be met in this case, the first two provide actuation feasibility by prescribing that both generated power by each generator have value between zero and their respective rated power, the third constraint ensures that the loads power request is met.

The optimisation problem is then solved by means of Lagrange Multipliers method with Karush-Kuhn-Tucker Conditions in wxMaxima environment.

In the table are shown the numerical results of the non-linear programming problem.

**CONFIGURATION B**

In configuration B there is a unique generators pool that supplies all the loads.

The objective function aims to minimise the energy production cost for the entire pool of generators.

The problem is very similar to the one already discussed in configuration A.

In this case four constraints must be met, the first three provide actuation feasibility by prescribing that all generated power by each generator have value between zero and their respective rated power, the fourth constraint ensures that the loads power request is met.

Also in this case the optimisation problem is then solved by means of Lagrange Multipliers method with Karush-Kuhn-Tucker Conditions in wxMaxima environment.

In the table are shown the numerical results of the non-linear programming problem.

ELEONORA

In configuration B, the three generators and the four loads form a unque grid. Our objective was to establish a primary/secondary/tertiary power/frequency control mechanism that maintains a normalized frequency error δω below 0.05 and vanishes within a maximum of 15 minutes.

Generators G1 and G3 had to equally handle 80% of the load, so we assigned a beta coefficient of 0.4 to G1 and G3, while G2 received the remaining 0.2. In order to control the system, we employed PID regulators, which enabled us to construct a loop transfer function consisting of three zeros and five poles, with two of the poles being integrators and the remaining three corresponding to the generators ones.

We first selected the cutoff frequency in order to meet the speed requirement and positioned one zero to neglect the slowest pole. Then, by looking at the bode diagram, we identified two suitable zeros that provided a significantly high phase margin, enhancing system stability and robustness.

From these values we were able to find kp1,kp2,kp3 and ks parameters by analitical calculation. Subsequently, we validated the model in Modelica and made slight adjustments to the parameters to enhance its performance. As a result, we achieved a favorable outcome that satisfied all the specifications. However, it exhibited minor oscillations.

By repositioning the poles, we successfully mitigated these oscillations, resulting in a highly satisfactory final result that adhered to all the problem's constraints without exhibiting any significant oscillation.

BERNA

The main idea behind the switching configuration regards the possibility to change the setup while simulation is running.

The only feasible way we thought to allow this change is the use of switches because they keep the model cleaner and tidy.

Note that the switch-block in Modelica needs a boolean reference, for this reason we introduced the use of a boolean-expression as an overall manager for all the switches.

This manager boolean-expresion block is called ‘total’.

The expression is time varying and allows the boolean output to be modified during the simulation.

A true ‘total’ value means that the configuration B has been selected while a false ‘total’ value means that configuration A is the choice.

All the switches, on the other hand, need another boolean-expression block as reference. The expression of these blocks are the output of ‘total’ block manager. This allows to set an unique expression where all the switches inherit the reference for the chosen configuration.

The overall scheme contains both configurations strictly connected, there are no duplicate generators.

Both controllers dynamics feed each switch but these allow only the chosen control variable to enter the generators dynamics.

The other tricky situation regards the inertias and the electrical power demand since in the configuration A generator1 and generator2 feed both load1 and load2 and generator3 feeds load3 and load4 while in configuration B one has all generators forming unique grid that feeds all four loads.

For this reason it is necessary to add other switches to chose to which pool of loads the generators have to provide power.

These switches, if the relative configuration is not active, bring the output to zero.

Finally, the simulation output has to be seen with the overlap of both configuration outputs to appreciate the performances during the switch action.