Hydrogen Electrolyser participation in Automatic Generation Control using Model Predictive Control

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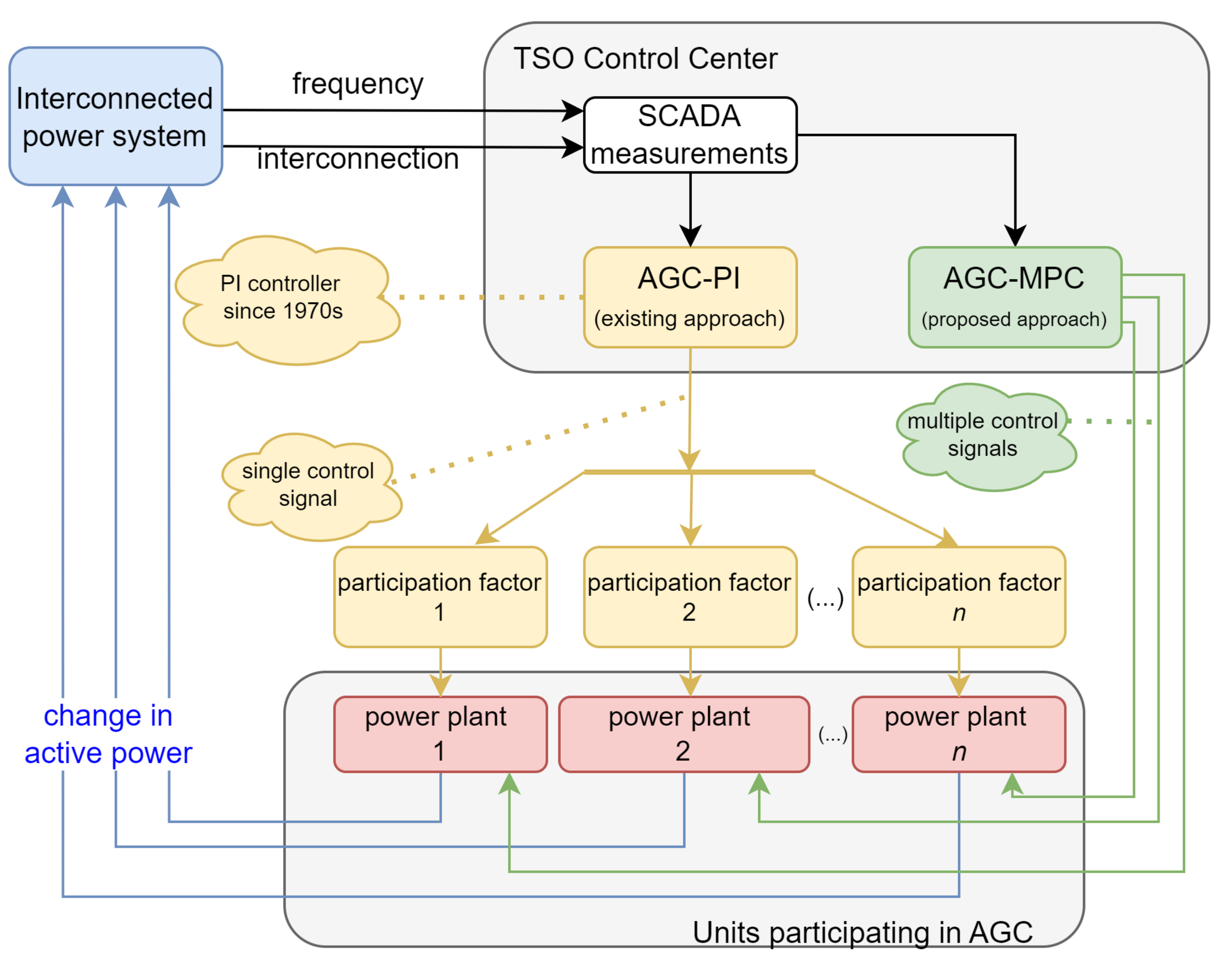
1. PROBLEM FORMULATION

In power systems, Automatic Generation Control (AGC) has been successfully employed in every control area, guaranteeing a stable frequency on the whole synchronous area. Traditionally, a proportional-integral (PI) controller is employed for AGC. A single control signal (via Area Control Error) is distributed among participating units.

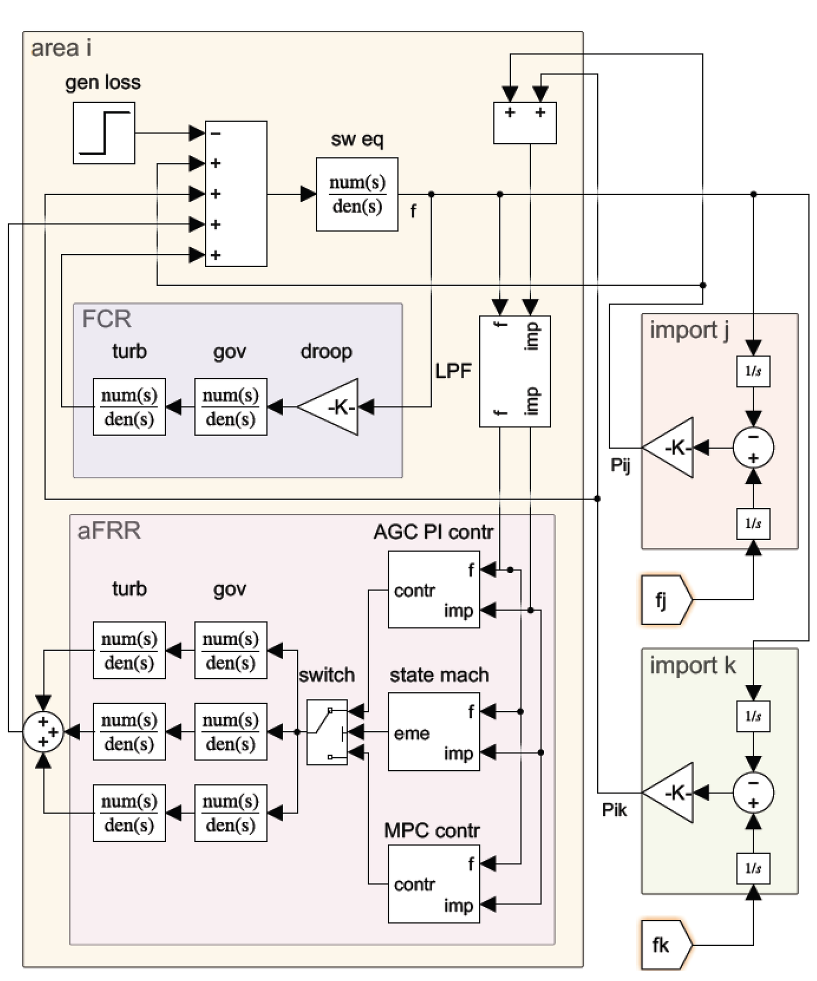
While the AGC-PI remains a straightforward approach for keeping the frequency on the 50 Hz, it is also true that such controller exploits the participating power plants equally and regardless of their ramping capability. As such, fast ramping units such as Hydrogen Electrolysers (HEs) are not fully exploited. Particularly, after a contingency, it is in the interest of the TSO of the control area to recover fast, by exploiting adequately fast resources.

In this work, Model Predictive Control (MPC) is used for the AGC problem. The fundamental difference between both controllers is that MPC generates multiple control signals, one for each participating unit. It is also proposed that such control mechanism is used only when following a generation loss in which an emergency mode is activated.



2. METHODOLOGY

A simulation platform was developed in MATLAB-Simulink. Below, one control area is shown in detail. The Frequency Containment Reserve and automatic Frequency Restoration Reserve have been decoupled, in line with the existing markets in Central Europe. A three-area system is implemented.



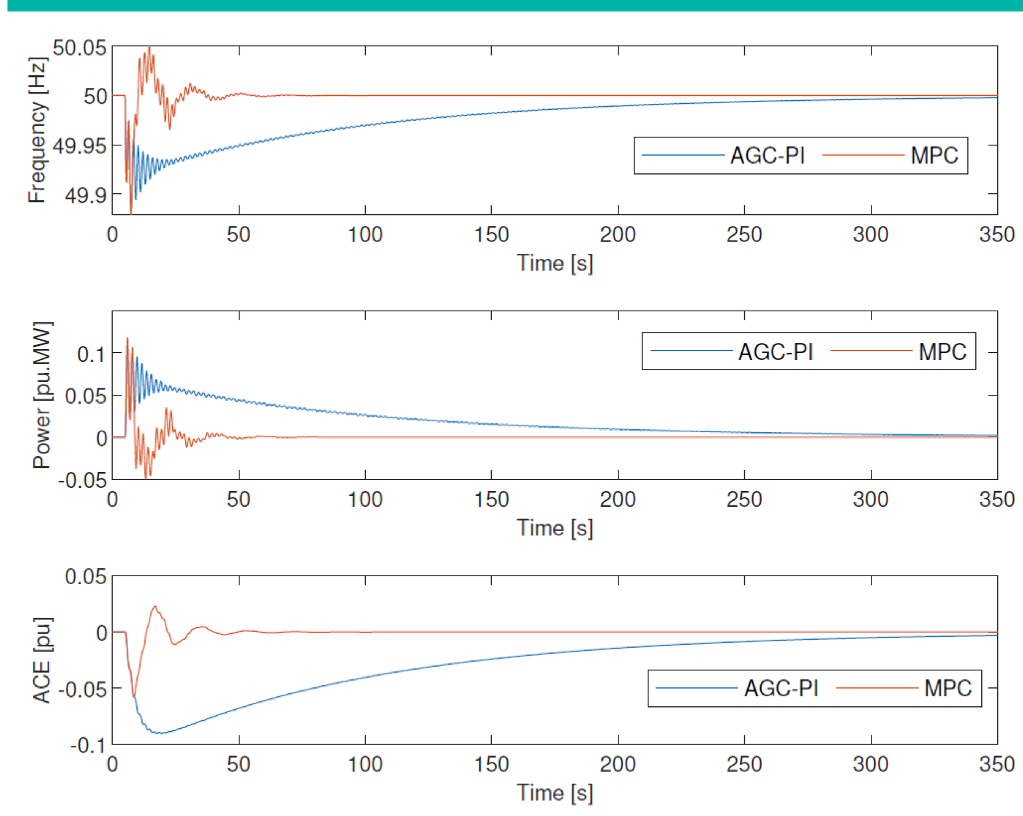
A finite state machine was created to detect the contingency (when both frequency and interconnection flows are below a threshold). Low-pass filters (LPF) are employed to smooth the measurements of frequency and interconnection flows.

The MPC controller incorporates system knowledge using a linear-time invariant model.

It was found that if the controller is only reestablishing the interconnection flows it reacts faster than if controlling both the frequency and interconnection. Three machines (fast, medium and slow) are modelled for the aFRR.

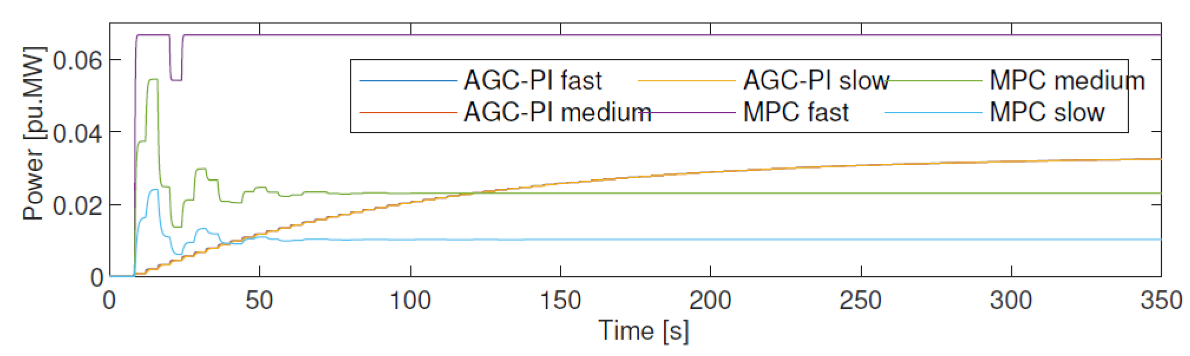
3. MAIN RESULTS

In the figure below, the top plot refers to the frequency, the middle one to the interconnection flow and the bottom one the Area Control Error. From the top one, it can be observed that frequency recovers much faster in the MPC case than in the AGC-PI.



In fact, the frequency overshoots, or goes higher than, 50 Hz, which is undesirable. Future work should tune the MPC in a smoother way, to avoid overshooting. Likewise, it can be seen that the interconnection flows are quickly reestablished. Considering the desirable frequency band as 50 Hz ± 50 mHz, the AGC-PI settles in 52 seconds whereas the MPC settles in less than 15 seconds.

Regarding the response of the fast, medium and slow resources, the difference is revealing. The fast resource (HE) is fully exploited after a very short period of time as seen in the figure below. The AGC-PI exploits all the resources at virtually the same time.



4. Conclusions and Future Work

MPC has been successfully applied to the AGC problem. The fundamental differences in the AGC-PI and AGC-MPC are the following: (1) while the AGC-PI generates one control signal using only frequency and interconnection measurements, the MPC requires a full model containing knowledge about the power system and participating units, which the transmission system operators do, (2) the MPC is used in emergency only and has a single objective of reestablishing the interconnection values, (3) the MPC generates one control signal per participating unit whereas the AGC generates a single control signal which is then divided among participants.

Future work may include the use of time delays in the plant model. Smoother control to avoid overshooting may also be investigated. Further plant-model mismatch such as different inertia and load damping constants should be part of future work, to investigate the robustness of the model in the presence of bad estimates from the TSO's SCADA system. Future work should also tune the MPC in a smoother way, to avoid overshooting.

5. Publications

1. Conference paper:
   "Hydrogen Electrolyser participation in Automatic Generation Control using Model Predictive Control" – presented in 7th International Conference on Smart Energy Systems and Technologies (SEST 2024), 10-12 September, Torino, Italy
2. Journal paper:
   Currently under preparation for submission to Sustainable Energy Grids and Networks (SEGAN)

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