Centralised Control Algorithms for Smart Grid Operation

Jialeng Guo
Project No. 34, Supervisor: Dr Petros Aristidou
School of Electronic and Electrical Engineering
UNIVERSITY OF LEEDS

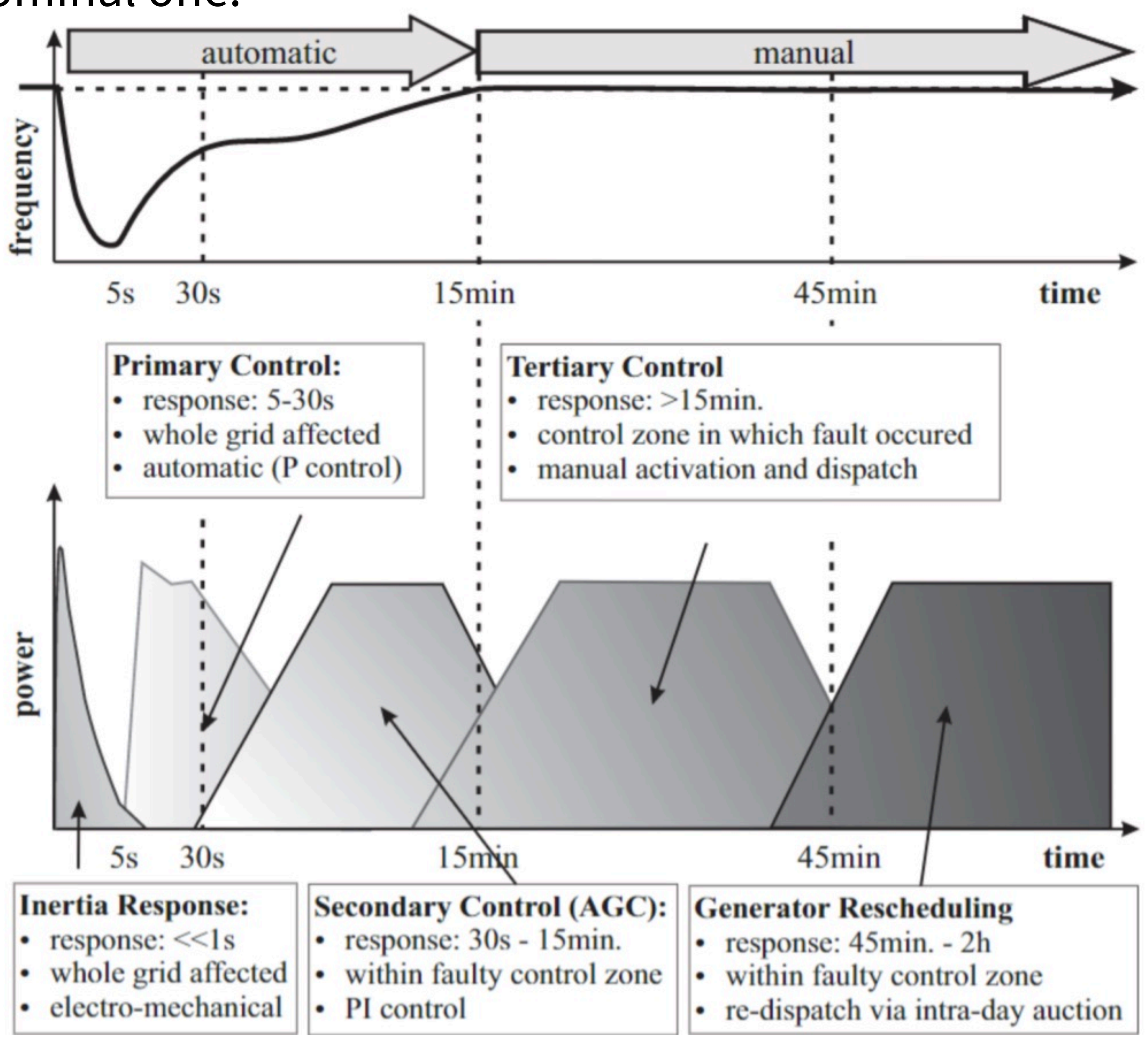
Motivations

1. The energy crisis and the climate issues are getting worse;
2. Power interruptions, like Northeast blackout of 2003, are happening;
3. Clean energy sources are causing more unstable power grids.

Centralised Control Algorithms

- **Secondary Frequency Control (SFC):**

1. Primary Frequency Control (PFC) aims to restore the active power balance in the grid;
2. After PFC balances the active power (takes 5s~30s), there will be a lower or higher steady-state frequency in the system;
3. SFC aims to restore the frequency in the grid to the nominal one.



- **PI control:**

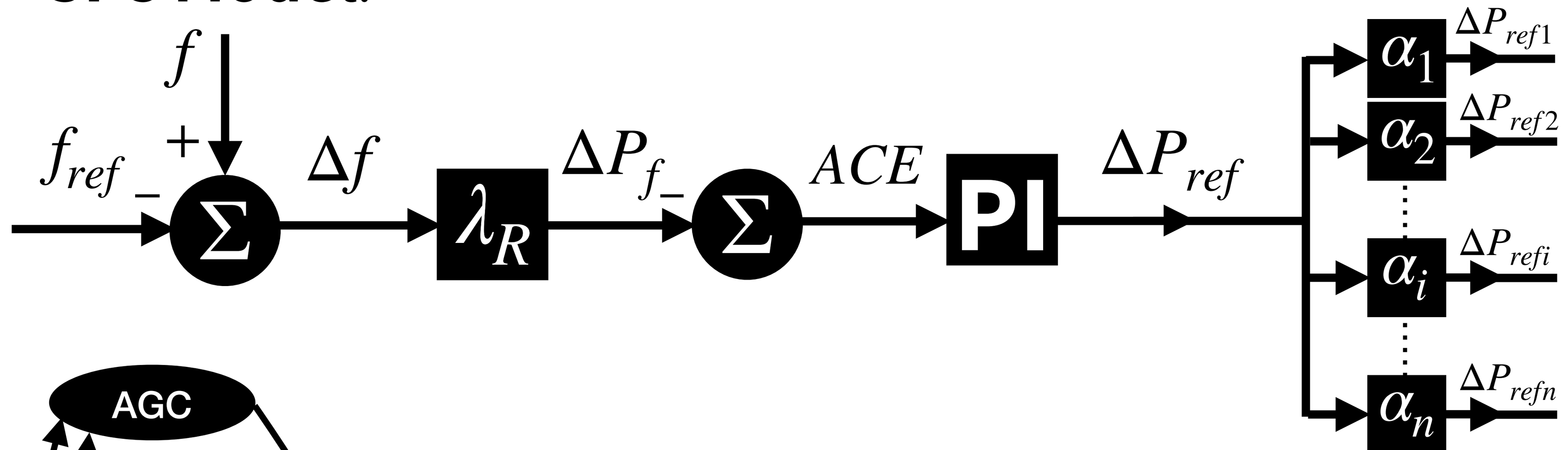
$$u(t) = k_p e(t) + k_i \int_0^t e(\tau) d\tau$$

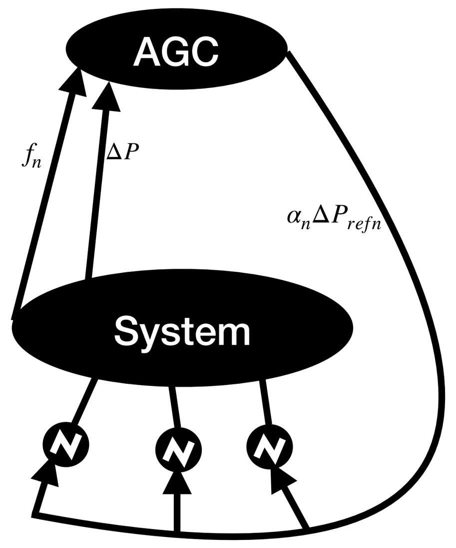
Objectives

1. Build a communication layer on top of an existing Smart Grid simulator and design a centralised controller for stabilising the frequency in the system;
2. Implement a standard SFC controller in Python with RAMSES;
3. Analyse the impacts of time delay and the impacts of emergency situation to the stability of control.

Models

- **SFC Model**:





- **Other models**:

1. Ramp rate analysis model;
2. Deadband control model;
3. 3D Triangle Surface plot model;
4. Six other analysis models.

Methodology and Analysis

- **Tune parameters**:

1. Find the margin/borderline of kp and ki;
2. Use bisection method;
3. Step of kp and ki is from big to small (accuracy is from low to high).

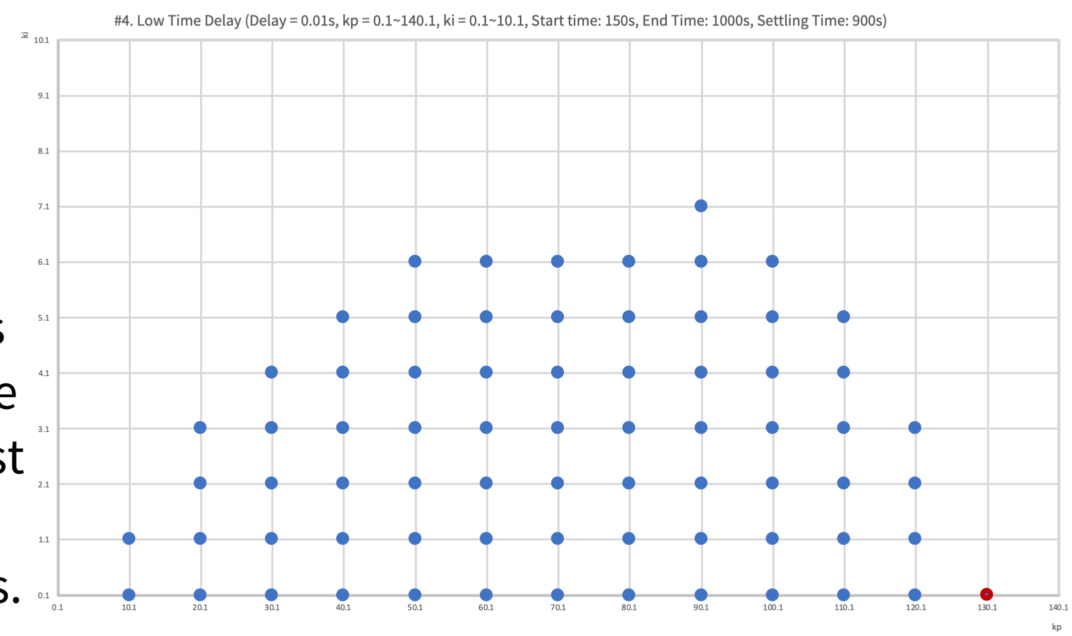
- **Analyse simulation results:**

1. Original data set -> MATLAB graph + EXCEL spreadsheet: using MATLAB find the acceptable results;
2. EXCEL spreadsheet -> Python analytical algorithms -> MATLAB graph: using Python to collect the data we need and using MATLAB to plot a suitable 3D triangle surface diagram.

Results (Nordic Power System)

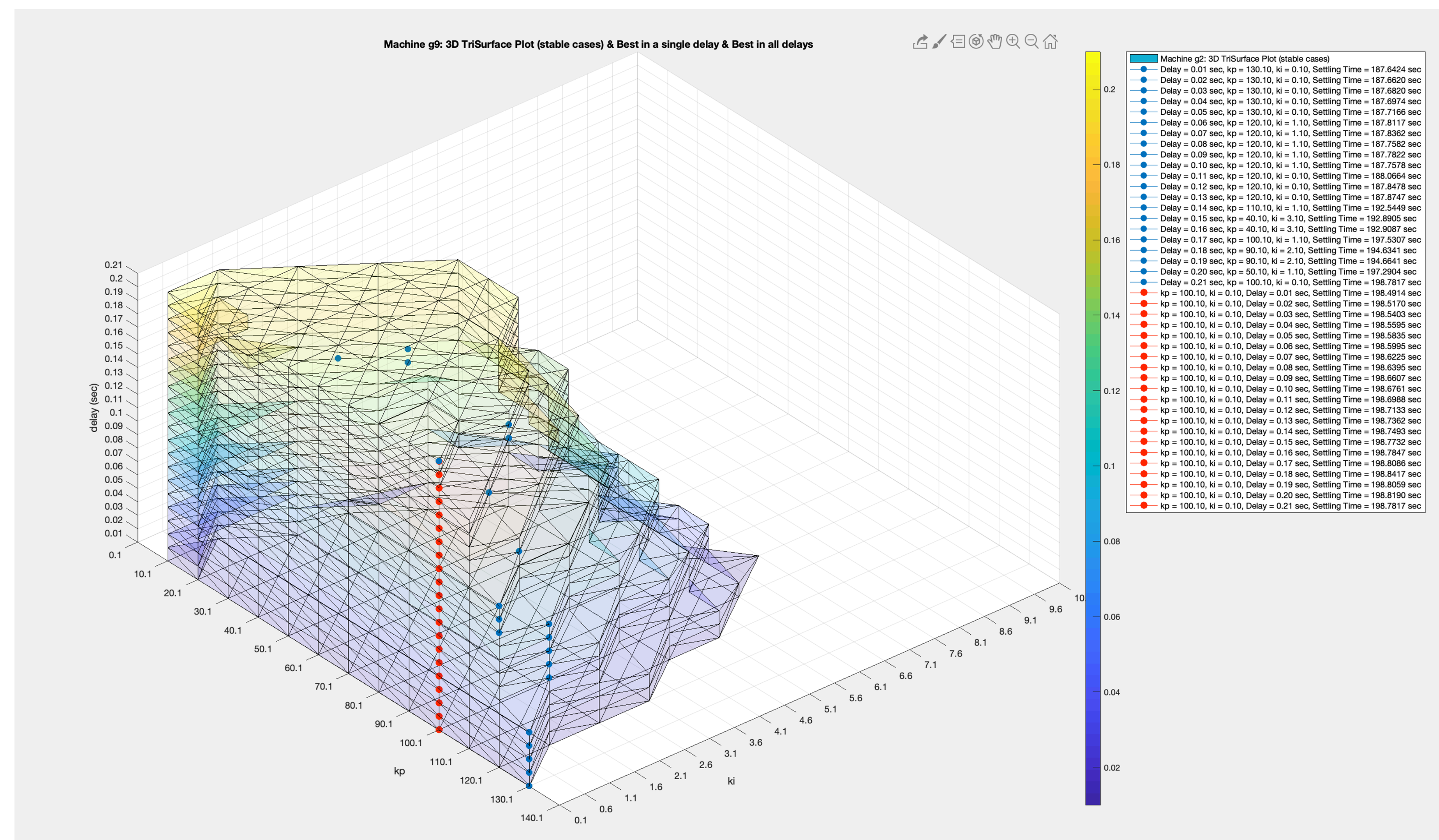
- **Low time delay:**

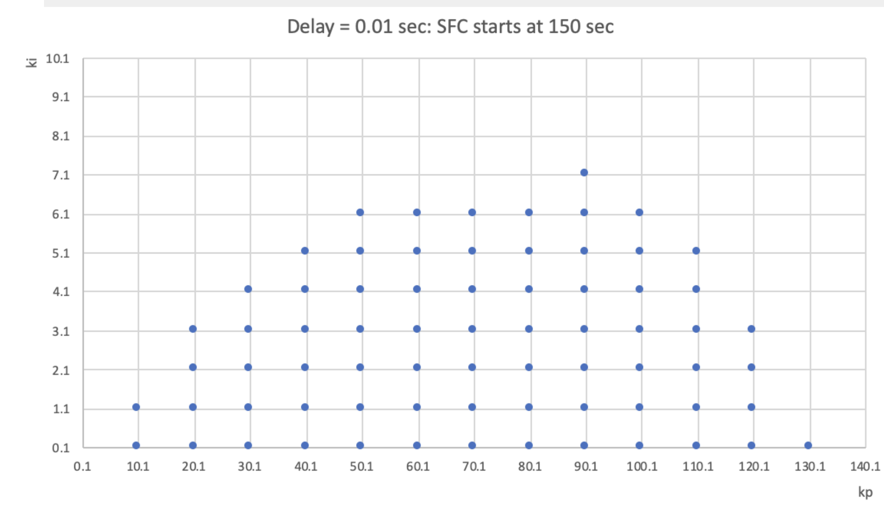
1. The limit/borderline/ margin of kp and ki is shown;
2. The fastest controller's parameters contain the biggest kp and smallest ki among all the acceptable parameters.

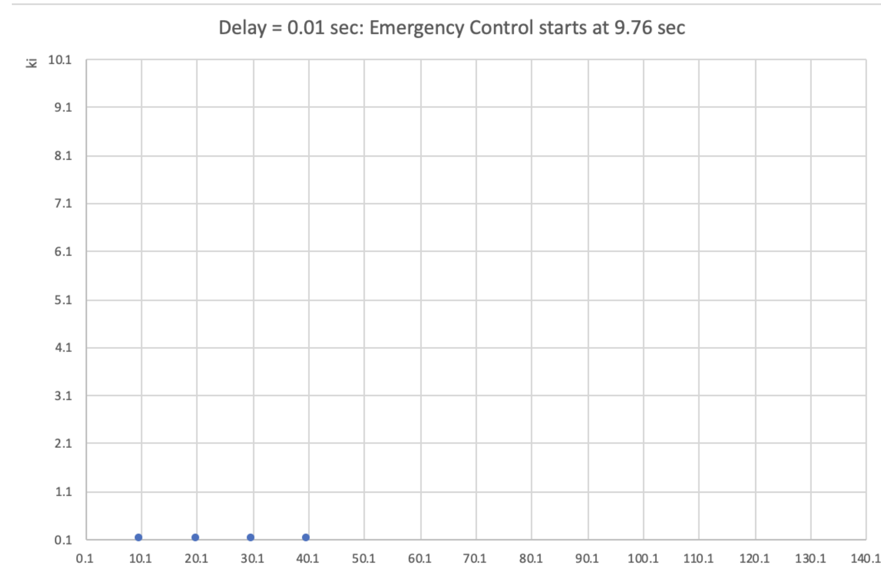


- **Different time delays:**

1. Acceptable kp and ki are shrunk together;
2. Time delay will disturb the stability of controller.







- **Emergency Control:**

1. The stability of the controller increases —— less acceptable parameters can be tuned;
2. Parameters are shrunk faster than the worst time delay situations we can imagine.

Bibliography

B. Kirby and M. Milligan, "Method and case study for estimating the ramping capability of a control area or balancing authority and implications for moderate or high wind penetration: Preprint," pp. 3,7, 2005.

S. K. Pandey, S. R. Mohanty, and N. Kishor, "A literature survey on load–frequency control for conventional and distribution generation power systems," *Renewable and Sustainable Energy Reviews*, vol. 25, pp. 318–334, 2013.