Title: Economic Model Predictive Control for DC Microgrids

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Object under Investigation (*OuI*)

- Droop Control
- MPC (Model Predictive Control)
- Estimator

Function(s) under Investigation (*FuI*)

- *Droop control:* voltage stabilization
- *Estimator:* partial estimation of Gbus
- *MPC:* unify the second and third layers of the hierarchical control scheme

Domain under Investigation (*DuI*)

- Control
- Environment
- DC Microgrid

Test Objectives

The test results are expected to be satisfactory as simulated. The effectiveness of E-MPC (Economic Model Predictive Control) and PPS-MPC (Primary Power Sharing Model Predictive Control) is expected to be corroborated in their ability to integrate secondary and tertiary control stages within the hierarchical control framework designed for isolated DC microgrids. This integration aims to preserve the different control objectives of each stage, encompassing the maintenance of control variables and the execution of optimal power dispatch operations.

Purpose of Investigation *(PoI)*

Verification of E-MPC (Economic Model Predictive Control) and PPS-MPC (Proportional Power Sharing Model Predictive Control), guaranteeing the voltage at the power injection nodes within the established limits

System under Test (*SuT*)

The testing system is divided into two experiments, each comprising three progressive stages that build upon one another.

- The first stage entails the implementation of a DC microgrid with a primary control stage utilizing droop controls (see *Figure 1*).
- In the second stage, a partial Gbus estimator is introduced (see *Figure 2*).
- The third stage involves incorporating model predictive control into the preceding step, which conforms to a hierarchical control scheme encompassing secondary and tertiary layers (see *Figure 3*).

The first experiment consists of implementing the DC microgrid using hardware-in-the-loop (HIL), which is presented in *Figure 4*. This microgrid will be replaced in the DC Microgrid blocks of the stages presented in Figures 1-3.

The second experiment consists of implementing part of the DC microgrid using hardware-in-the-loop (HIL) and replacing a resistive load, connected to the 7 node. *Figure 5*. This microgrid will be replaced in the "DC Microgrid" blocks of the stages presented in Figures 1-3.

Functions under Test (*FuT*)

HIL (Figure 4)

- *DC Microgrid of Figure 4 implemented in hardware in the loop.*
- *Measurement of power and voltage at the nodes where power is injected, in addition to the power available from the primary resource.*

P-HIL (Figure 5)

- Internal control for DC converters, which allows to bring their voltage to a specified reference.
- Mixing of HIL with real components for a DC microgrid.
- Measurement of power and voltage at the nodes where power is injected; in addition to the power available from the primary resource.

Target metrics (*TM*)

- Power measurement at the power injection nodes of each of the converters
- Measurement of the voltage at the power injection nodes of each of the converters.
- Plant factor of each of the converters.

Compare the experimental results with those obtained in the simulation using SIMULINK and MATLAB software.

Test criteria *(TCR)*

- (STAGE 1 - Figure 1)
  - Voltage stabilization at nodes where power injection is available.
- (STAGE 2 – Figure 2)
  - Estimation of loads within Gbus
- (STAGE 2 – Figure 3)
  - Voltages at the power injection nodes within established limits (0.9*Vnom < Vk < 1.1*Vnom)
  - Optimal Power Sharing with:
    - Economic criteria
    - Proportional Power sharing balance between DC converters

Quality attributes *(QA)*

- Voltage at the converter nodes between 0.9 and 1.1 of the nominal value.
- For the case of PPS-MPC, plant factor of the converters with 90% similarity.
- For the case of EMPC, an economic dispatch of the converters, in which the cost is the optimum.

Variability attributes *(VA)*

In the case of HIL and P-HIL experiments, the parameters of the available power of the primary resource must be varied, as well as the resistive loads connected to the microgrid, including the real load (Load 3) in the case of P-HIL.

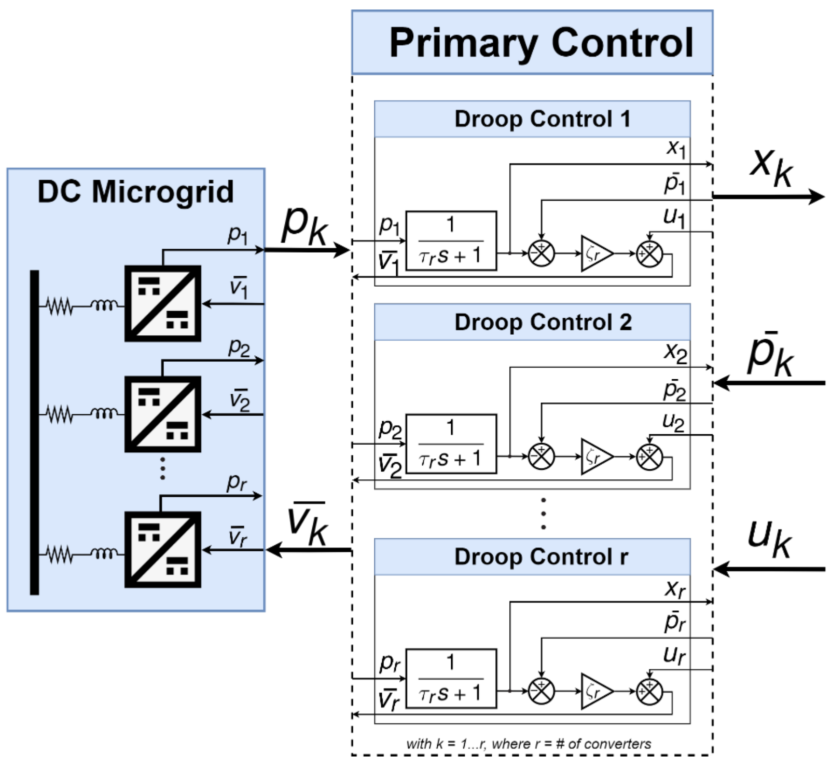

Figure 1. Stage 1

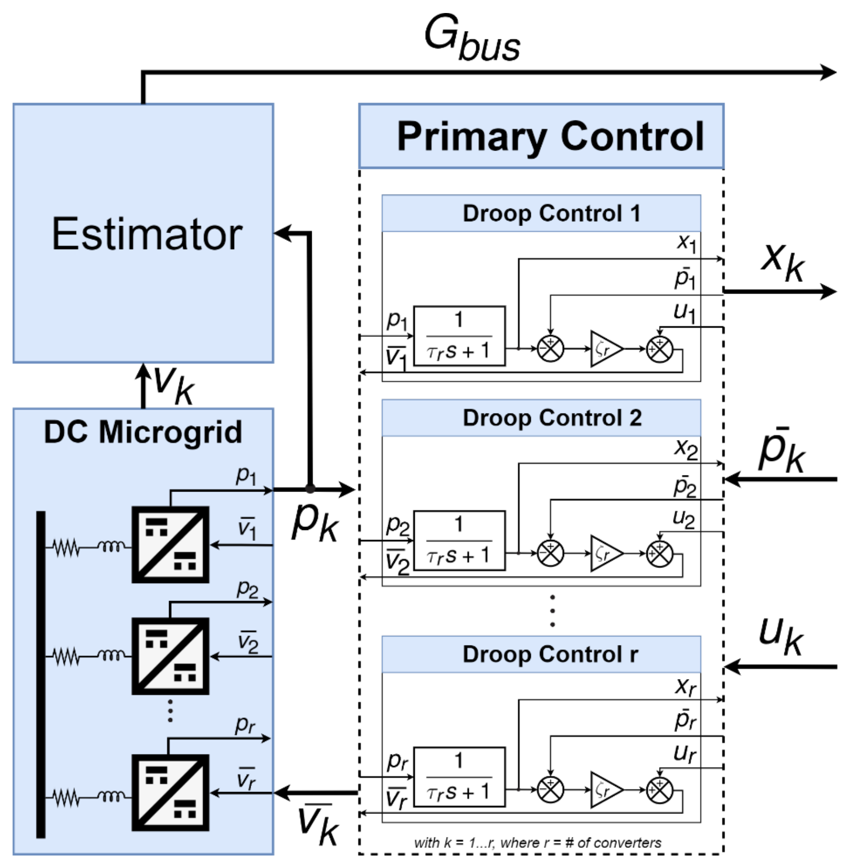

Figure 2. Stage 2

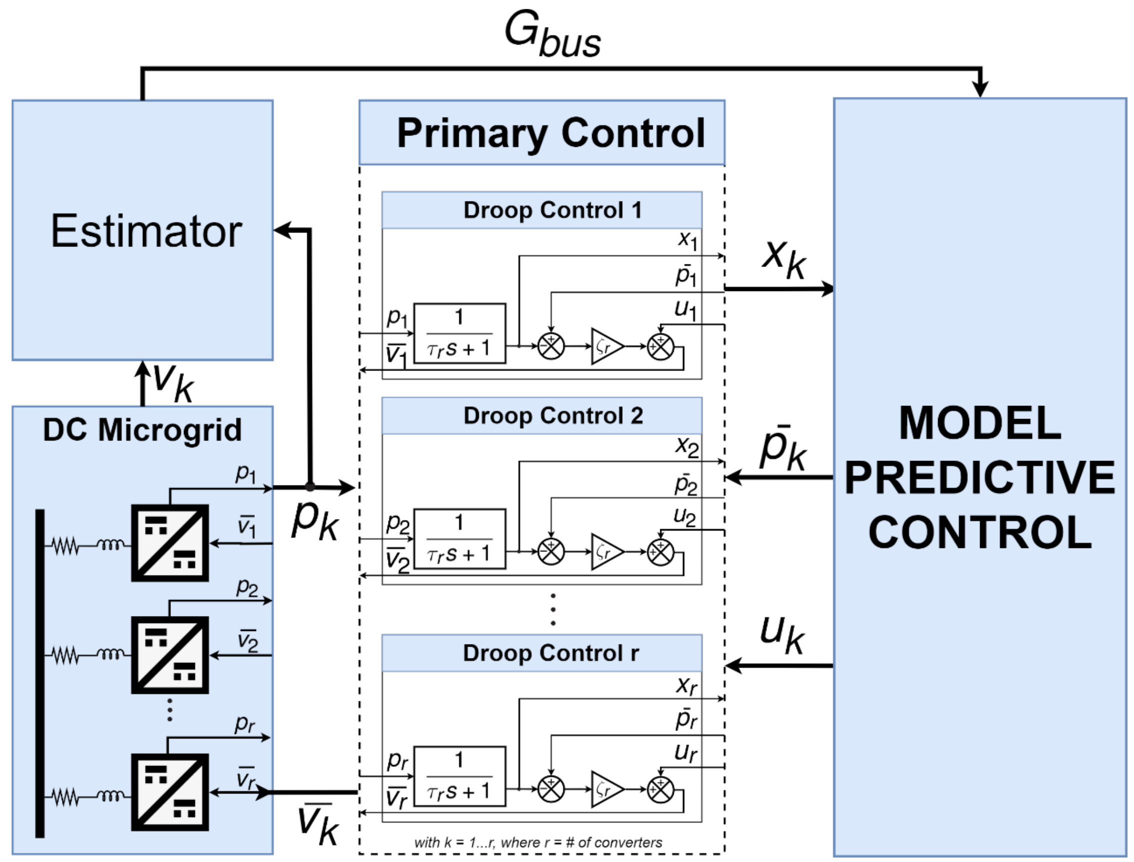

Figure 3. Stage 3

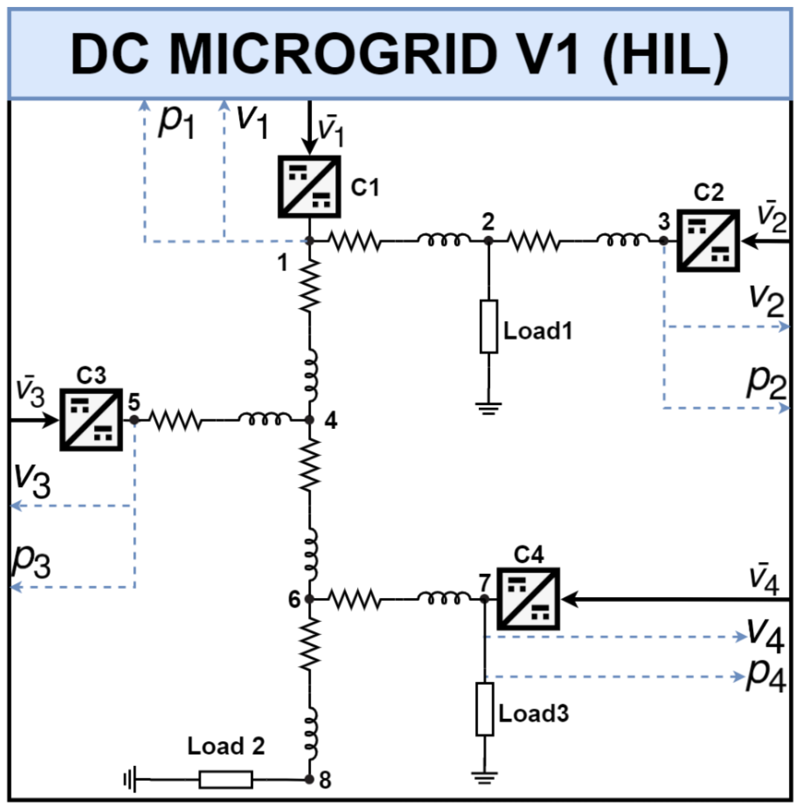

Figure 4. DC Microgrid Version 1 (Experiment 1)

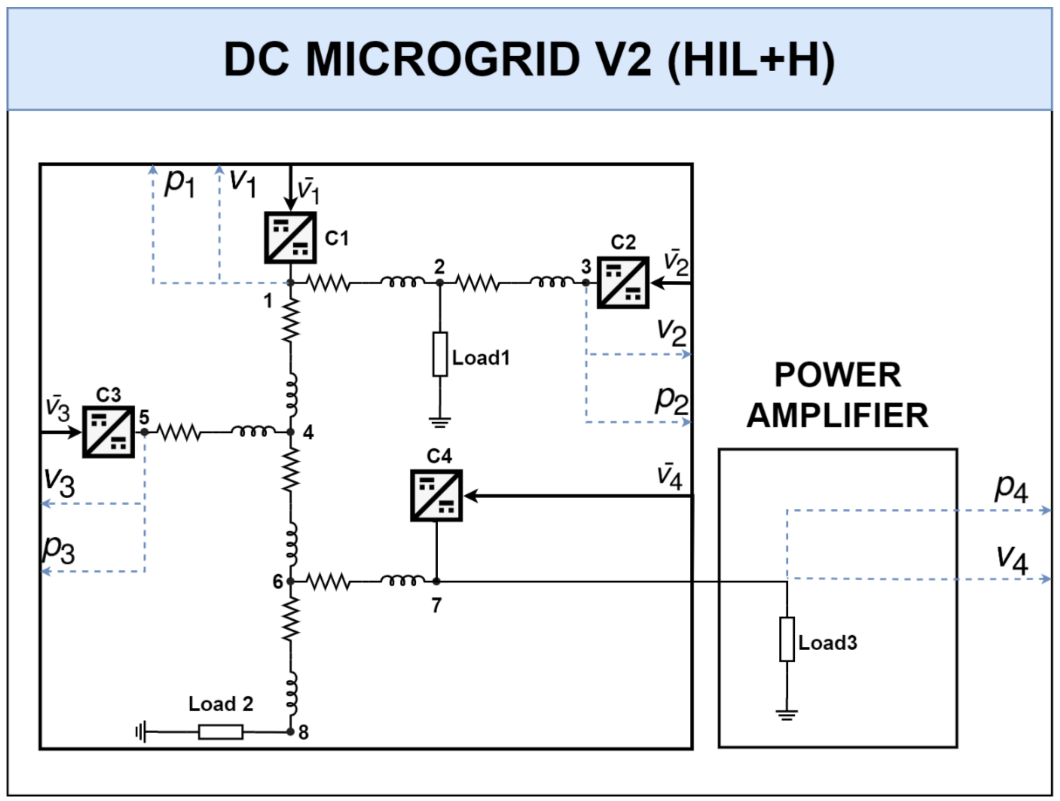

Figure 5. DC Microgrid Version 2 (Experiment 2)