Microrredes Eléctricas

Tema 5 A
Secondary Control

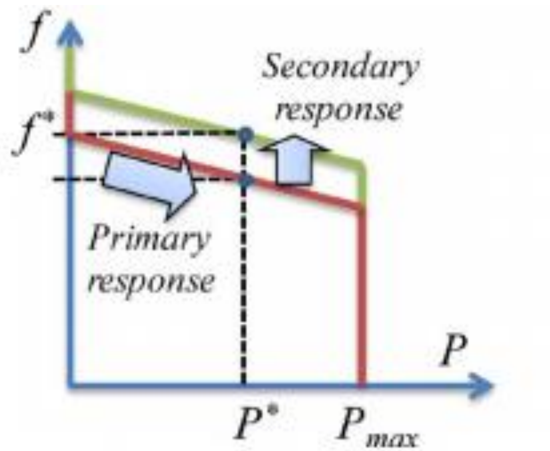
1. Secondary Control.
    1. Centralized Frequency and Voltage Restoration.
    2. Voltage Restoration in DC Microgrids.
    3. Distributed Restoration.

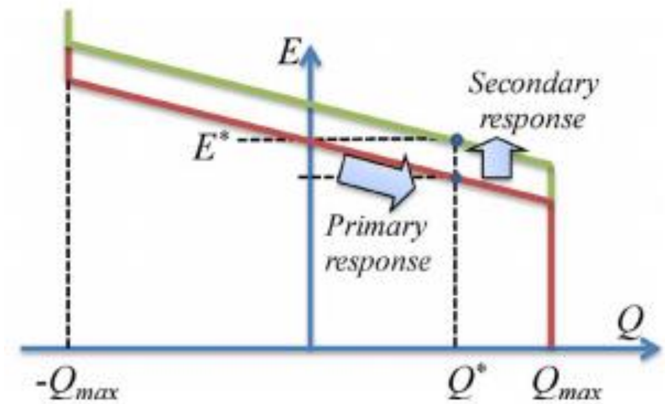
Secondary Control

1. Secondary Control

Due to the effect of Primary controllers on the power-sharing process, there are deviations in the voltage and frequency of the power system.

It is possible to restore the values of the frequency and voltage by adjusting the reference values without compromising the power-sharing.





J. C. Vasquez, J. M. Guerrero, J. Miret, M. Castilla and L. Garcia de Vicuna, "Hierarchical Control of Intelligent Microgrids," in *IEEE Industrial Electronics Magazine*, vol. 4, no. 4, pp. 23-29, Dec. 2010.

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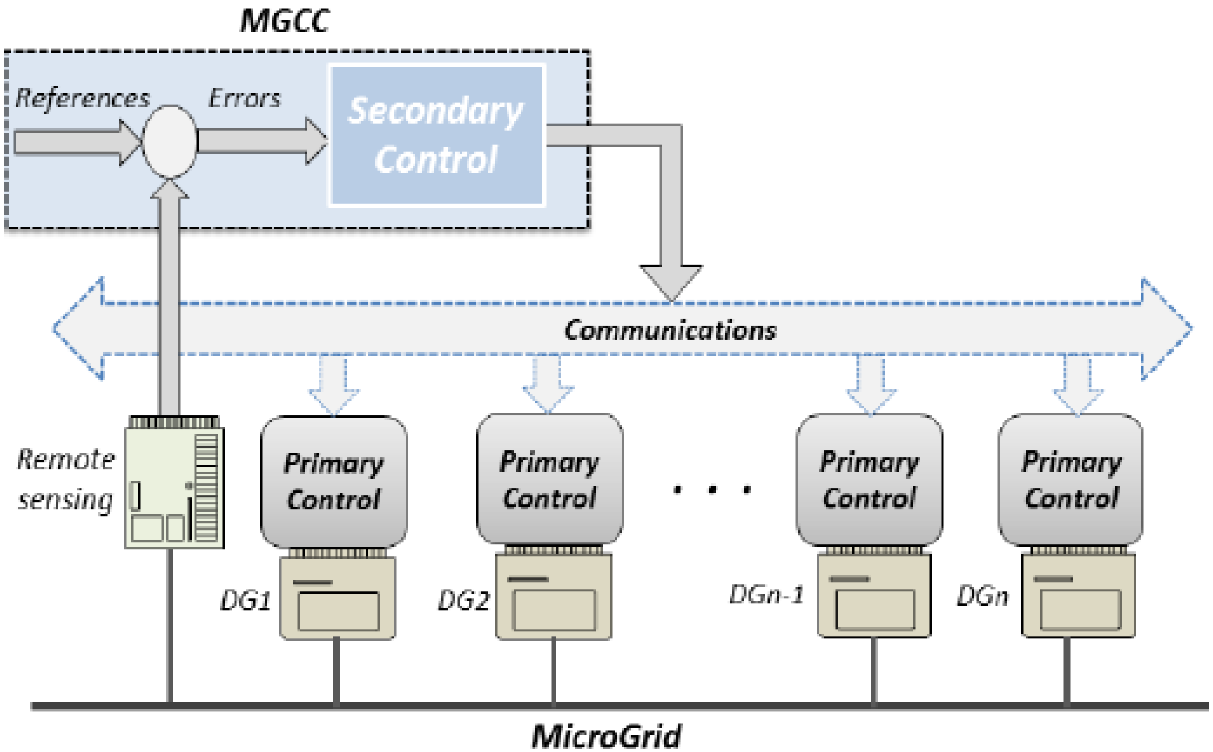
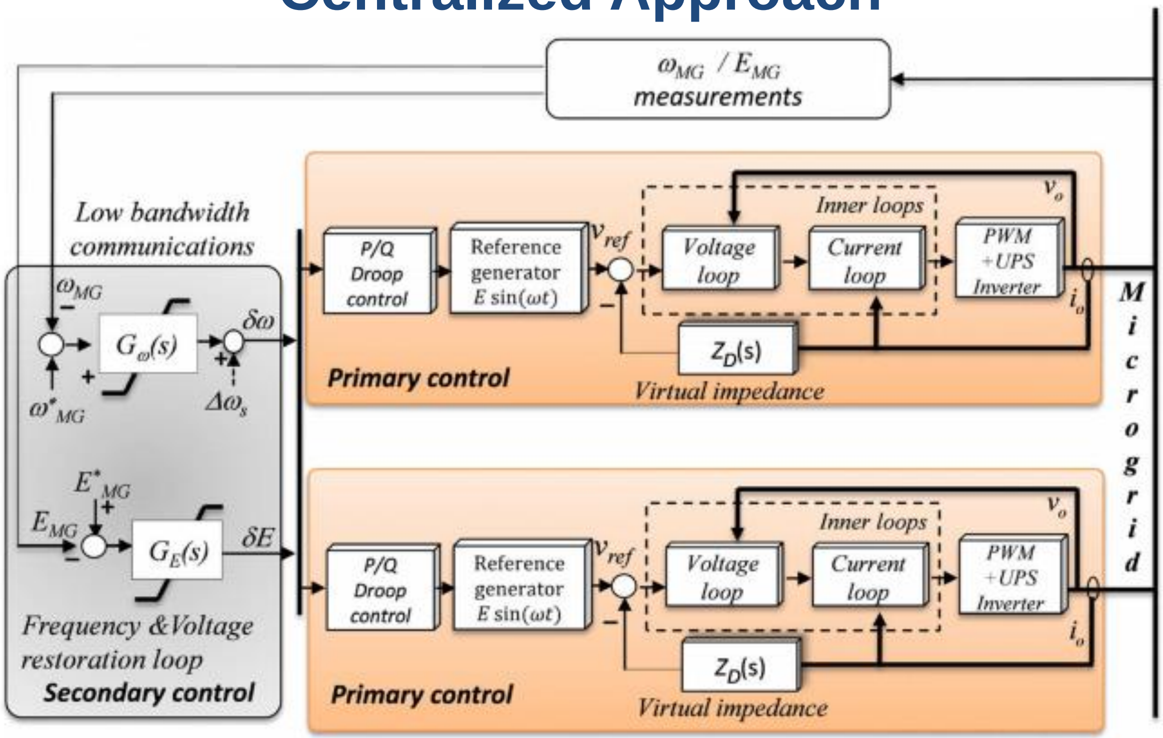
Centralized Approach



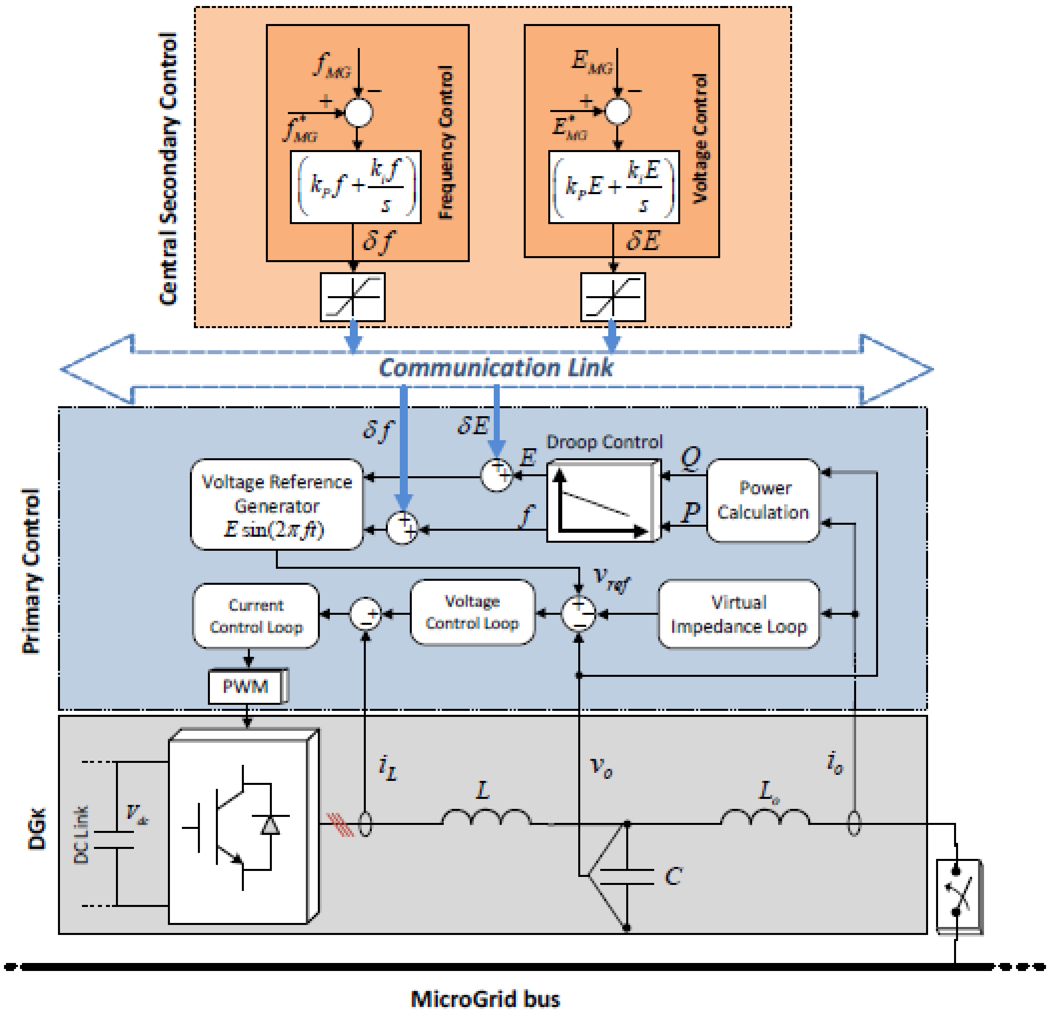
Centralized Approach



The frequency and amplitude levels in the microgrid ω and E are sensed and compared with the reference values for frequency and amplitude; the errors processed through compensators (δω and δE) are sent to all the units to restore the output voltage frequency and amplitude.

1. Secondary Control

Centralized Approach

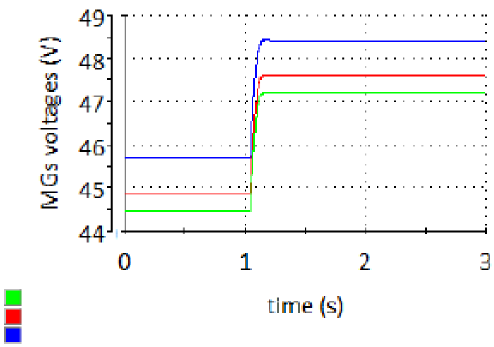


1. Secondary Control

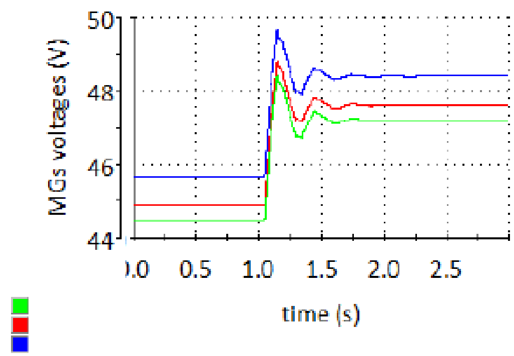
Centralized Approach

- **Advantages:**
  - Accurate control of the whole microgrid.
  - Simple Deployment.

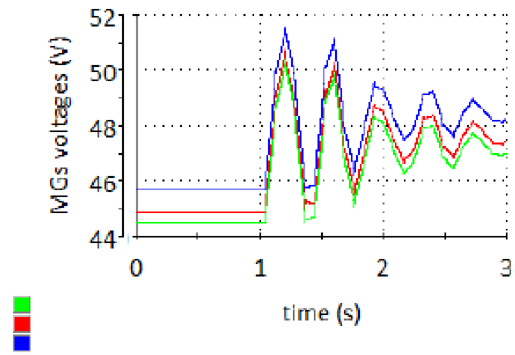
- **Drawbacks:**
  - Dependent on a communication Channel.
  - Single Point of Failure.
  - The Dynamic response may be affected by communication delays.v



(a) 20ms delay



(b) 50ms delay



(c) 20ms delay

Shafiee, Q., Dragicevic, T., Vasquez, J. C., & Guerrero, J. M. (2014). Hierarchical Control for Multiple DC Microgrids Clusters. I E E E Transactions on Energy Conversion, 29(4), 922-933 . 10.1109/TEC.2014.2362191

Centralized Approach

The secondary controller can be implemented by a PI controller. The dynamic response of the secondary controller should be slower than primary controllers.

$$\delta f = k_{pf}\,(f^*_{\mathrm{MG}} - f_{\mathrm{MG}}) + k_{if}\int (f^*_{\mathrm{MG}} - f_{\mathrm{MG}})\,dt + \Delta f_S$$

$$\delta E = k_{pE}\,(E^*_{\mathrm{MG}} - E_{\mathrm{MG}}) + k_{iE}\int (E^*_{\mathrm{MG}} - E_{\mathrm{MG}})\,dt$$

current controller	k_{pI}, k_{iI}	15, 50s^{-1}
voltage controller	k_{pV}, k_{iV}	0.1, 100s^{-1}
Secondary control proportional term	$k_{p\,sec}$	0.005
Secondary control integral term	$k_{i\,sec}$	0.5 s^{-1}

Shafiee, Q., Dragicevic, T., Vasquez, J. C., & Guerrero, J. M. (2014). Hierarchical Control for Multiple DC Microgrids Clusters. I E E E Transactions on Energy Conversion, 29(4), 922-933 . 10.1109/TEC.2014.2362191

The Control can be derived from the Linearized Model

1. $[\Delta i] = [Ys][\Delta e]$
3. $[\Delta S] = [Is][\Delta e] + [Es][\Delta i]$ Substituting 1 in 3.
4. $[\Delta S] = ([Is] + [Es][Ys])[\Delta e]$

6. $[\Delta \dot{X}] = [Ms][\Delta X] + [Cs][\Delta S]$
7. $[\Delta \dot{X}] = [Ms][\Delta X] + [Cs]([Is] + [Es][Ys])[\Delta e]$
8. $[\Delta \dot{X}] = ([Ms] + [Cs]([Is] + [Es][Ys])K_s)[\Delta X]$

- $[\Delta \dot{X}] = [A1][\Delta X]$

The Control can be derived from the Linearized Model

$$[\Delta \dot{X}] = \begin{bmatrix} \Delta\omega_1 \\ \Delta e_{d1} \\ \Delta e_{q1} \\ \Delta\omega_2 \\ \Delta e_{d2} \\ \Delta e_{q2} \end{bmatrix} \qquad \frac{Y(s)}{U(s)} = G(s)$$

The Transfer Matrix Can be obtained from

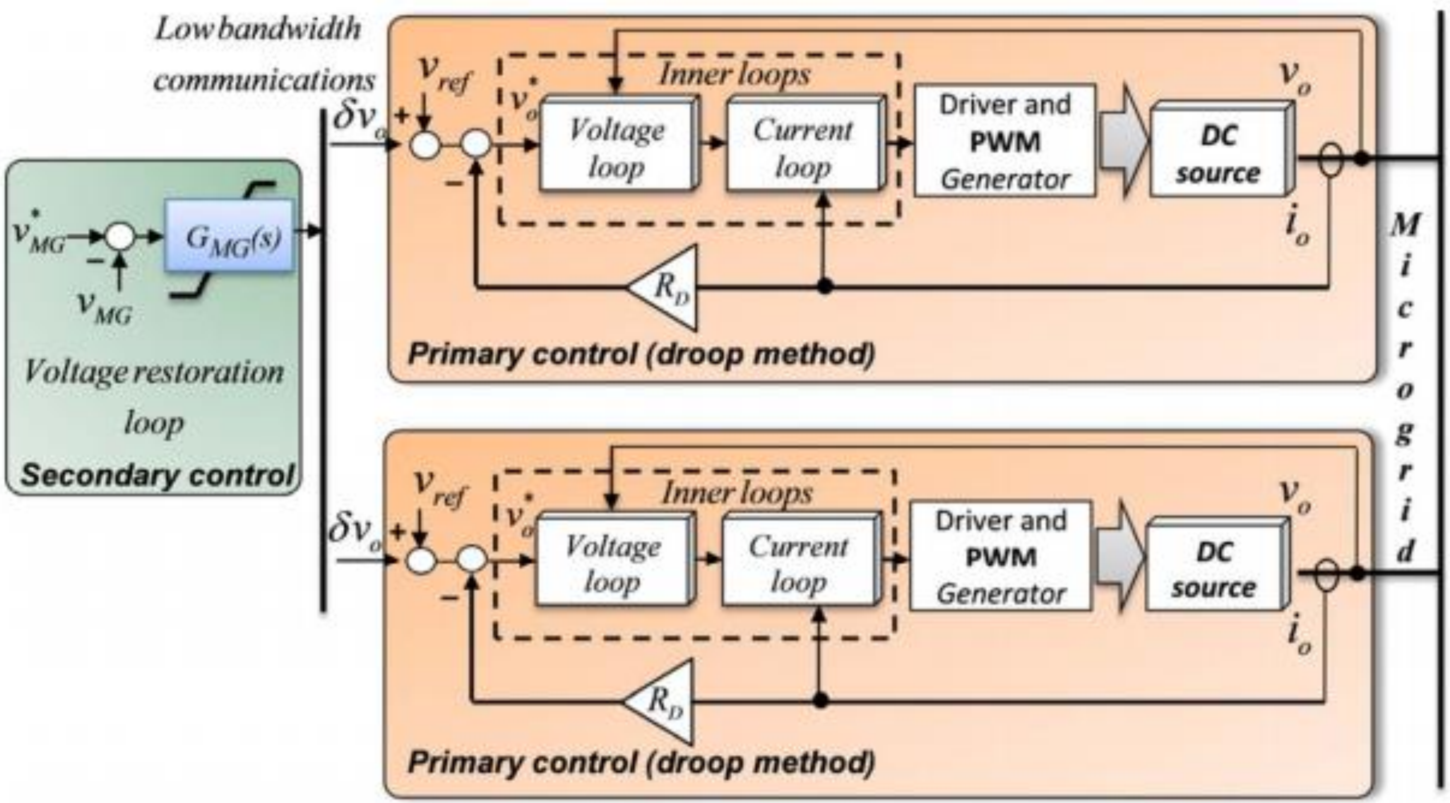
$$\frac{Y(s)}{U(s)} = G(s) = C(S*I - A)^{-1} * B$$

1. Secondary Control

The Control can be derived from
the Previously designed controllers

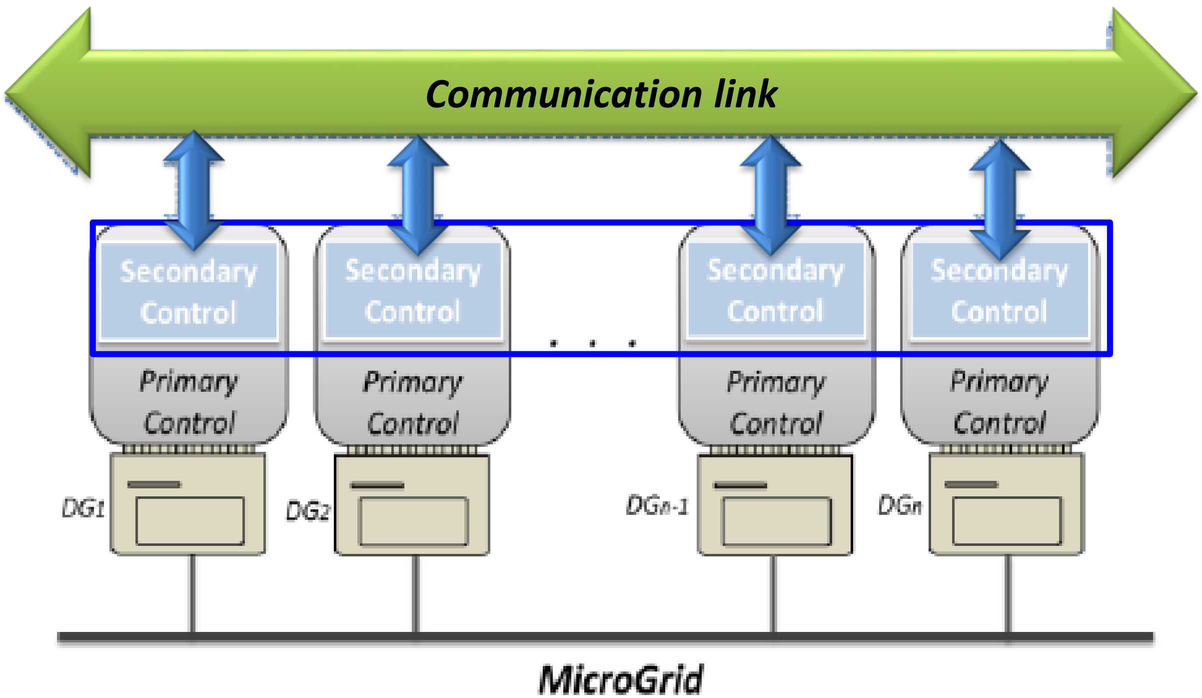
Control System	Bandwidth
Current Control	ω_0
Voltage Control	$\omega_0/10$
Primary Control	$\omega_0/100$
Secundary Control	$\omega_0/1000$
Tertiary Control	$\omega_0/10000$

Centralized Approach
DC Microgrids



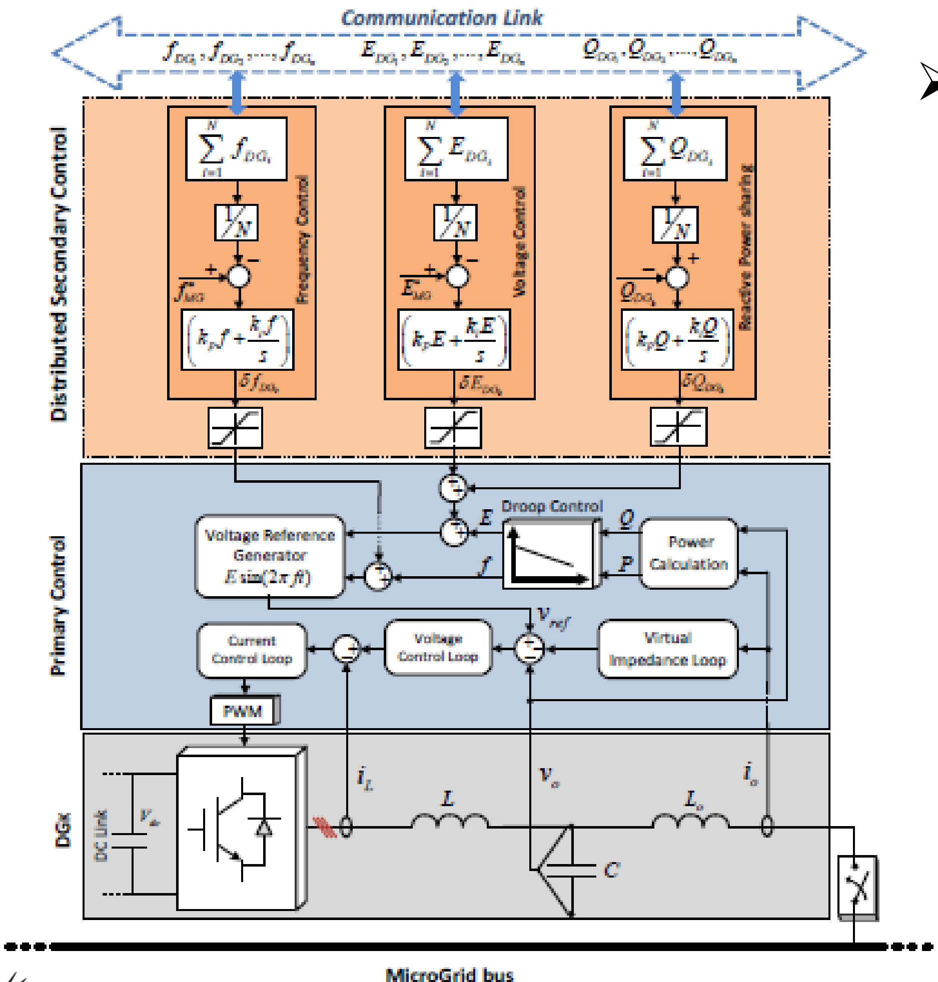
J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuna and M. Castilla, "Hierarchical Control of Droop-Controlled AC and DC Microgrids—A General Approach Toward Standardization," in *IEEE Transactions on Industrial Electronics*, vol. 58, no. 1, pp. 158-172, Jan. 2011.

Distributed Approach



Microgrid Research Group Aalborg University, Denmark

Distributed Approach

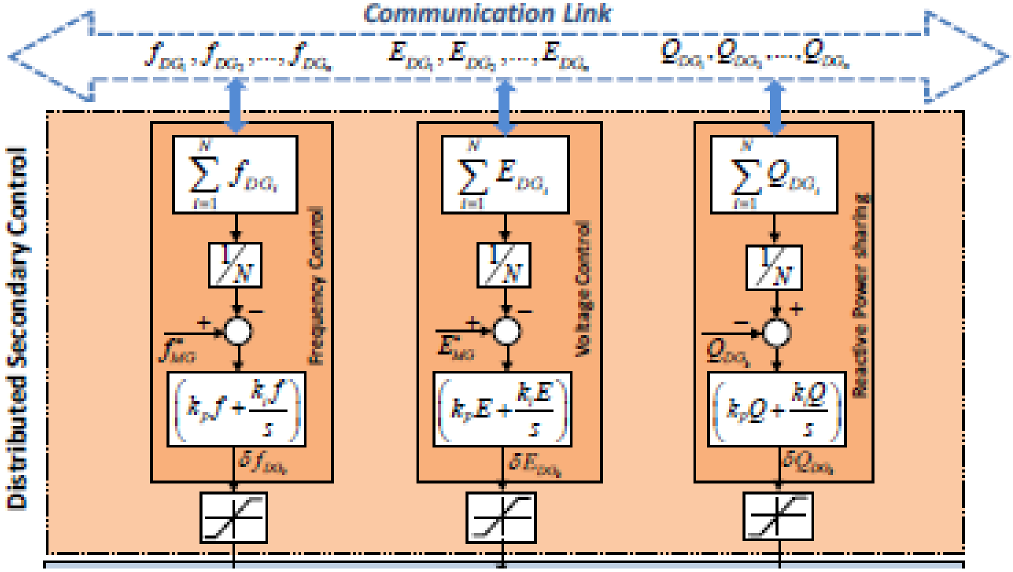


- **Averaging Method:**
  The local measurement of each DER is shared with all the interconnected DGs by means of a deddicated communication channel.

  Therefore, a common measured value is obtained by averanging the whole information

  $\bar{X}$

Distributed Approach



$$\partial f = K_p(f^* - \bar{f}) + K_i \int (f^* - \bar{f})\, dt$$

$$\bar{f} = \frac{\sum_{i=1}^{N} f_{DG}}{N}$$

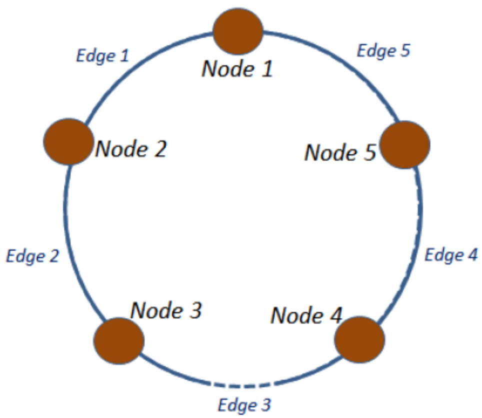
Where N is the number of Interconnected DGs

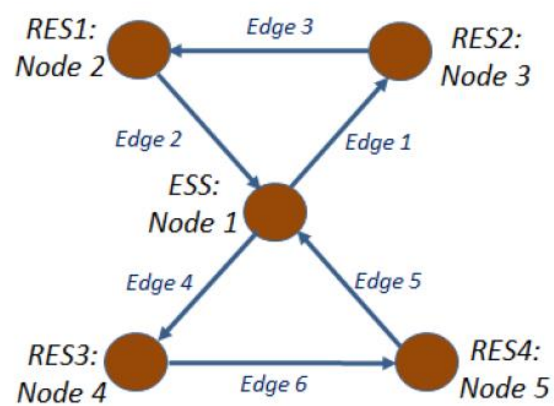
This Strategy is particularly usseful for reducing the error in the reactive power sharing

Distributed Approach
Consensus Algorithm

A consensus algorithm is a process in computer science used to achieve agreement on a single data value among distributed processes or systems.

This Strategy is also rely on a communication channel. However, it does not require a dedicated communication between all the distributed units





Secondary Coordinated Control of Islanded Microgrids Based on Consensus Algorithms. /Dan Wu, Tomislav Dragicevic, Juan C. Vasquez, Josep M. Guerrero, Yajuan Guan. In:IEEE Energy Conversion Congress and Exposition (ECCE), 2014.

Distributed Approach
Consensus Algorithm

The Algorithm is based on the following equation

$$\dot{x_i}(t) = C \sum_{j \in N_i} a_{ij}(x_j(t) - x_i(t))$$

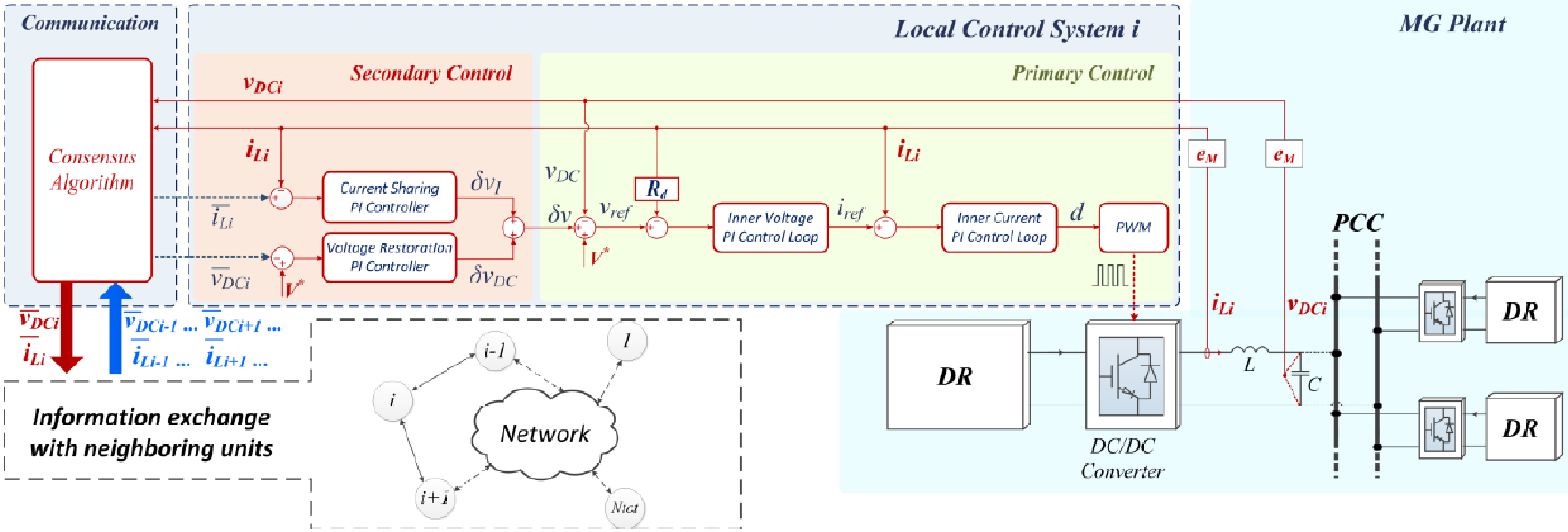
$$\Delta x_i(k) = C \sum_{j \in N_i} a_{ij}(x_j(k) - x_i(k))$$

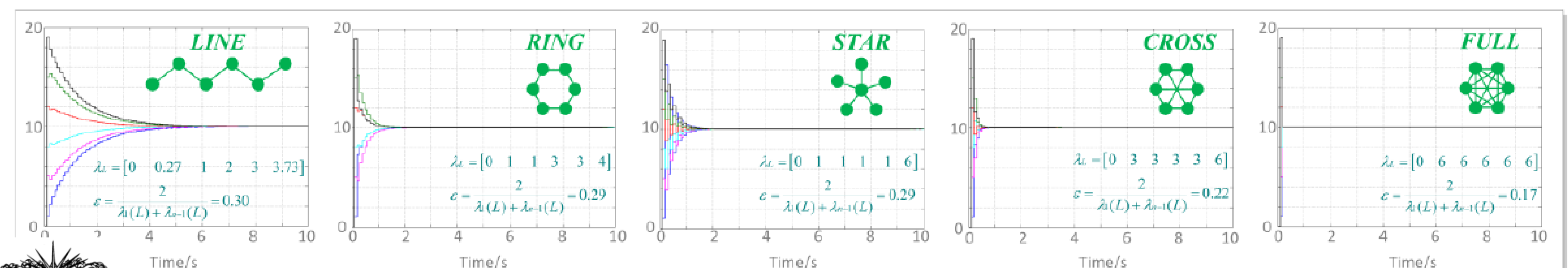
- C *is the constant edge weight used for tuning the algorithm.*
- a *is indicates the connection status between node i and node j, =0 if the nodes i and j are not linked.*
- N *is the number of neighbors connected to the each node.*

$$x_i(k+1) = x_i(k) + C \sum_{j \in N_i} a_{ij}(x_j(k) - x_i(k))$$

1. Secondary Control

Distributed Approach
Consensus Algorithm



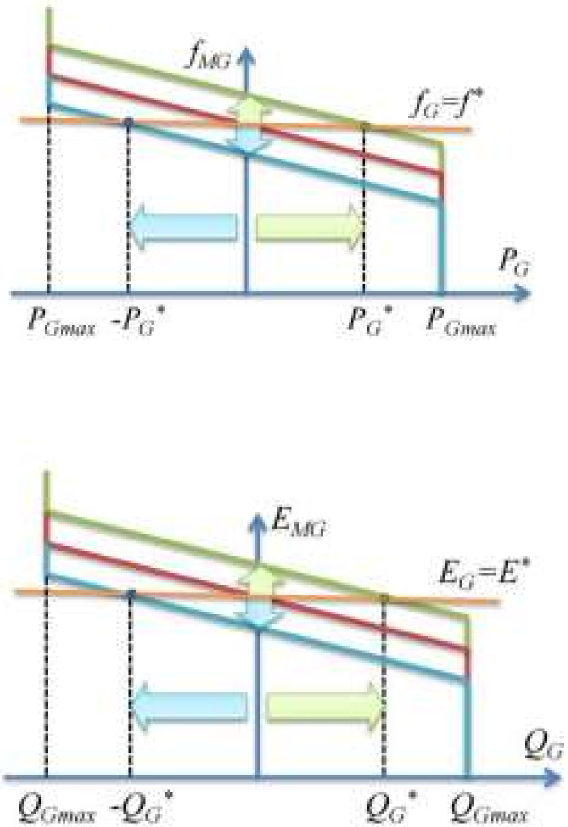


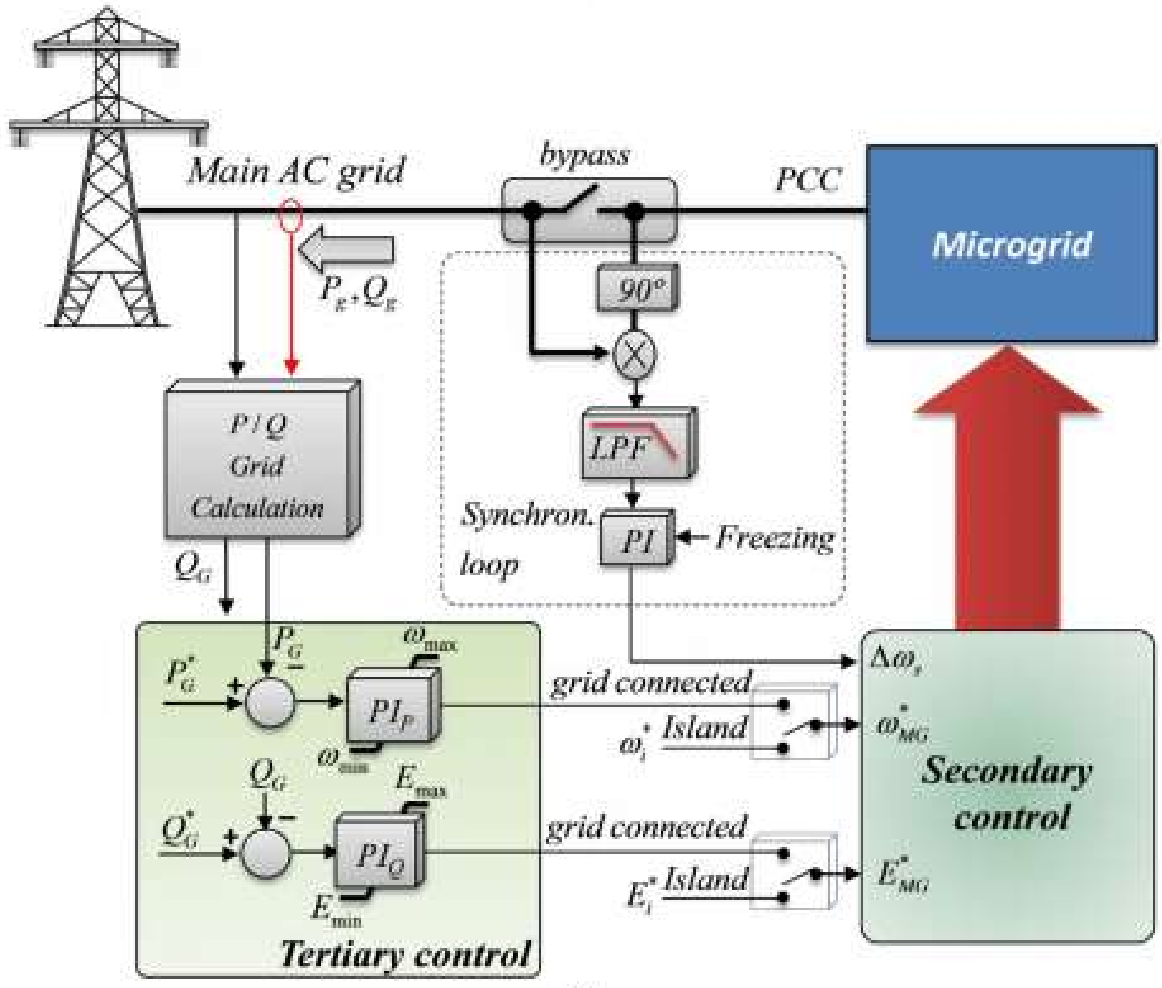
Modeling and Sensitivity Study of Consensus Algorithm Based Distributed Hierarchical Control for DC Microgrids / Meng, Lexuan; Dragicevic, Tomislav; Roldan Perez, Javier; Quintero, Juan Carlos Vasquez; Guerrero, Josep M. In:I E E E Transactions on Smart Grid, 2015.

Tema 5 B
Tertiary Control

1. Tertiary Control.
    1. AC Micrograds
    2. DC Microgrids.

1. Tertiary Control





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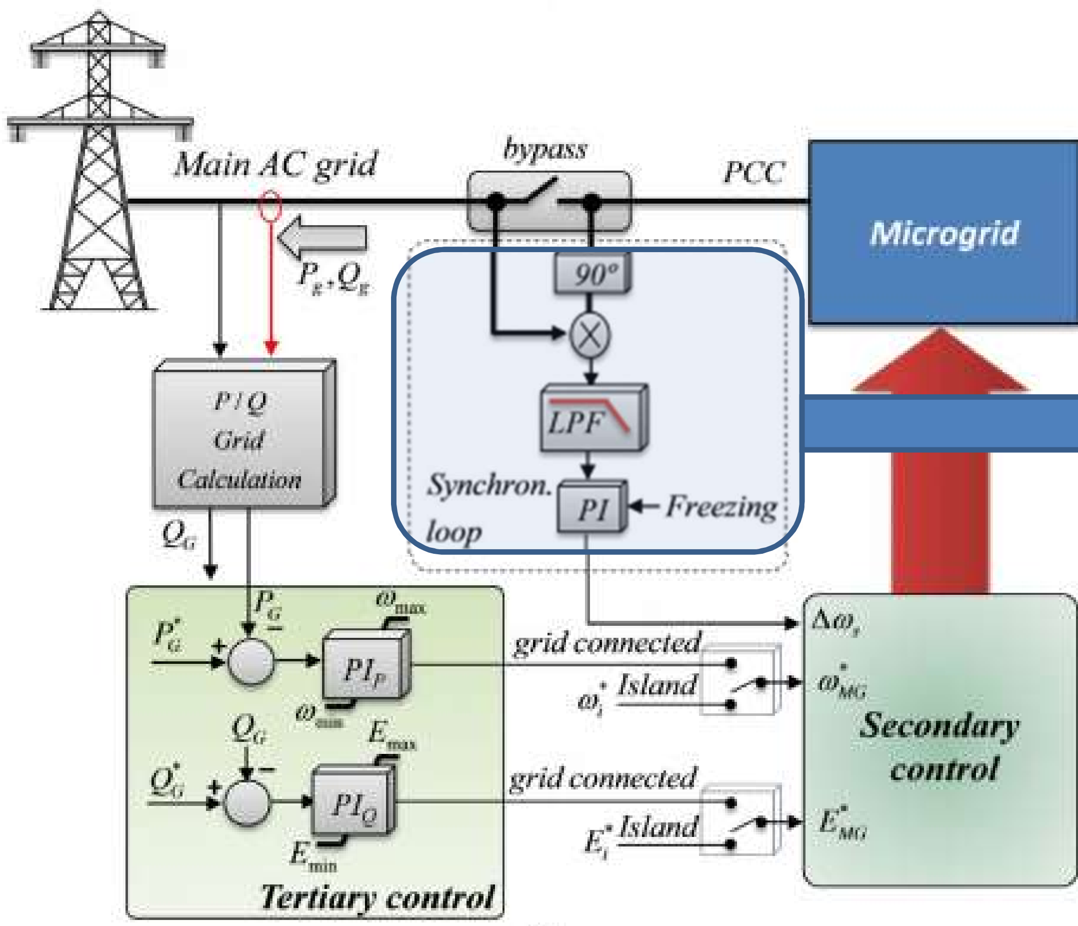
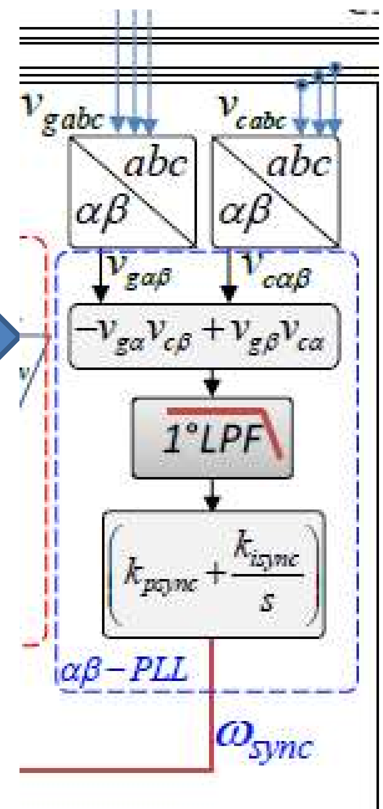
1. Tertiary Control

Synchronization is required before grid connection





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1. Tertiary Control