Vector Control of Interlinking Converter for Droop Controlled Power Flow in AC-DC Hybrid Microgrids

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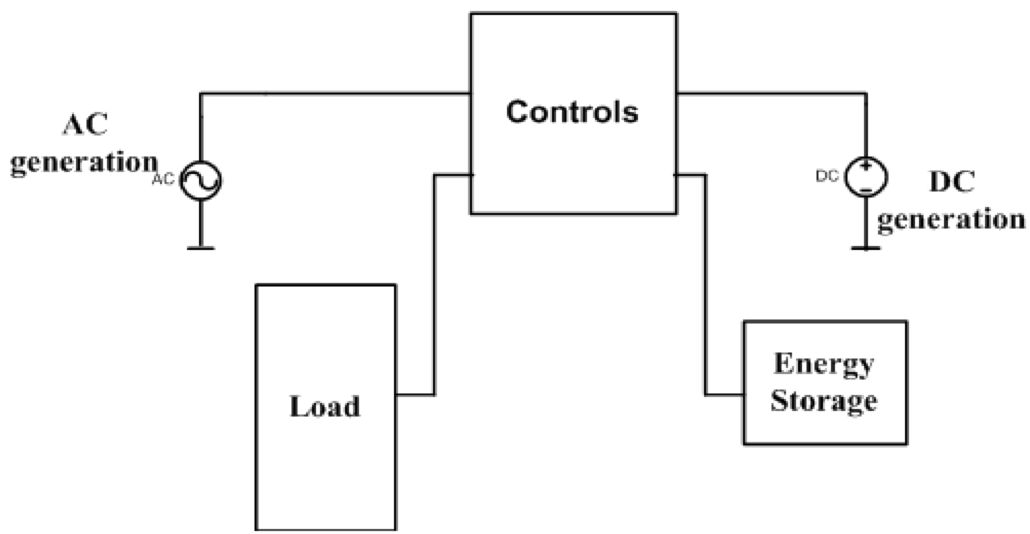
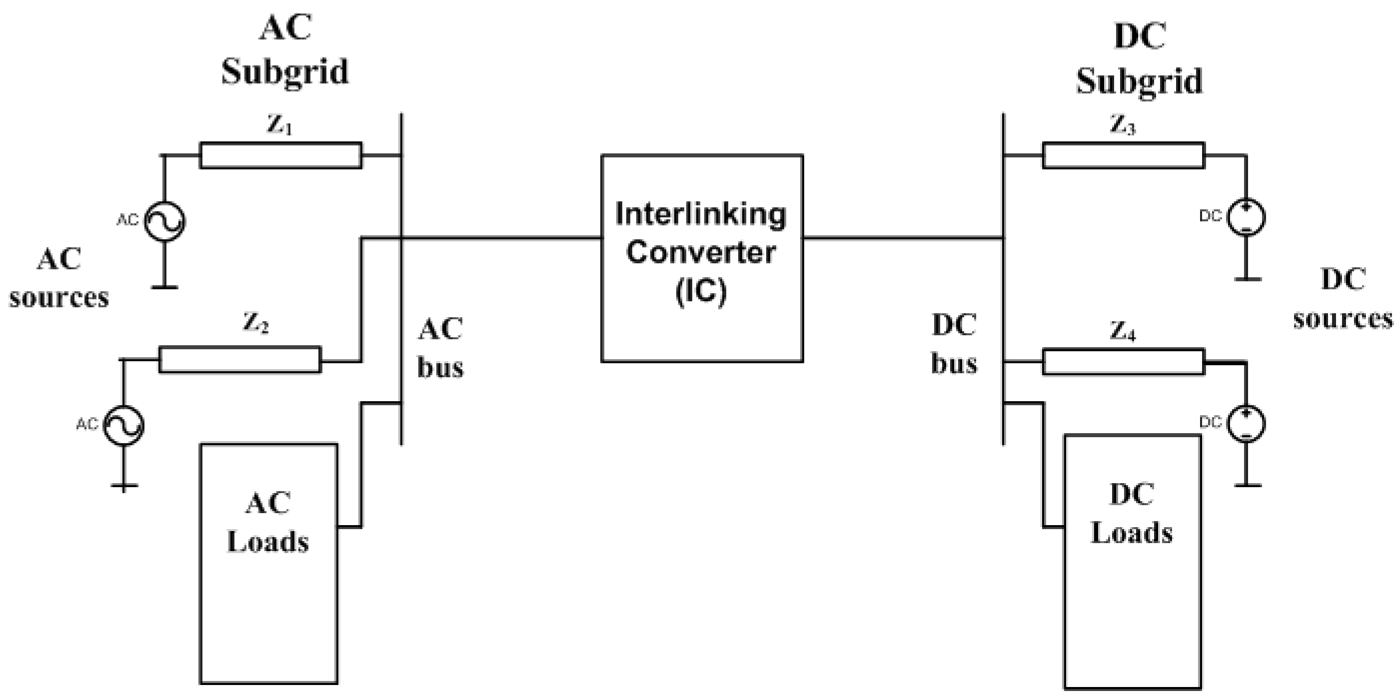
Introduction

- What is a Microgrid?
- Influencing factors leading for formation of hybrid microgrids



HYBRID MICROGRID



Example Hybrid AC-DC Microgrid

Droop Control Technique for Power Sharing

Droop equations used in case of conventional AC and DC sources

AC

$$\begin{cases} f_x{}^* = f'_x + m_x P_x \\ V_x{}^* = V'_x + n_x Q_x \end{cases}$$

DC

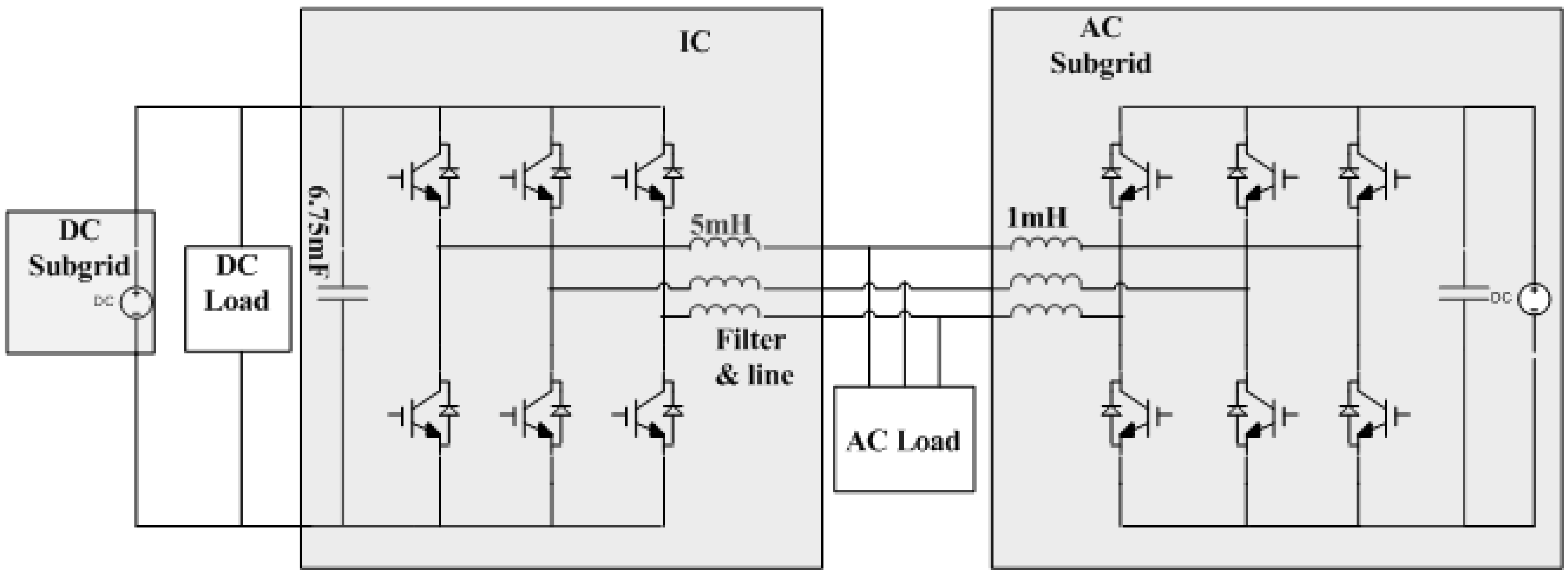
$$V_{d,y}{}^* = V'_{d,y} + v_x P_x$$

Perunitised Droop equations used for AC - DC hybrid microgrids

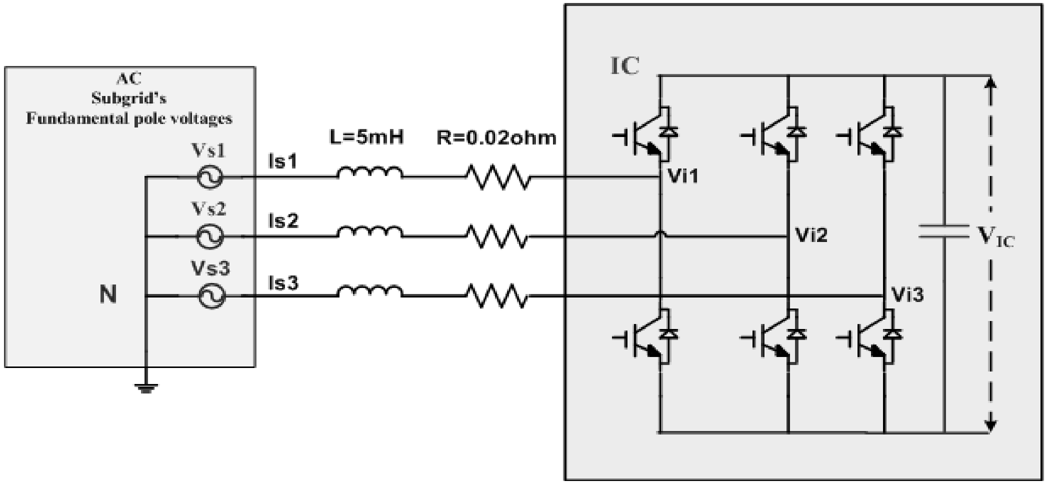
$$f_{pu} = \frac{f - 0.5(f_{max} + f_{min})}{0.5(f_{max} - f_{min})}$$

$$V_{pu} = \frac{V - 0.5(V_{max} + V_{min})}{0.5(V_{max} - V_{min})}$$

Simulated Hybrid Microgrid

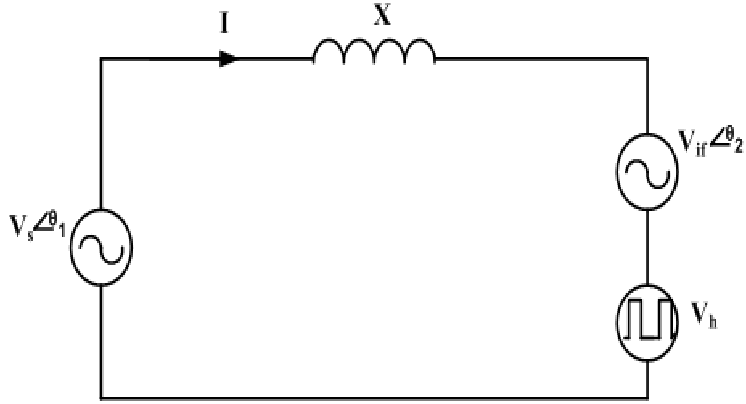


Vector Control Technique for Control of IC



IC connected to AC subgrid

Considering Lossless line



SLD of IC connected to AC subgrid

Applying KVL

$$V_{s1} = V_{i1} + L_s \frac{di_{s1}}{dt} + R_s i_{s1} \quad (1)$$

$$V_{s2} = V_{i2} + L_s \frac{di_{s2}}{dt} + R_s i_{s2} \quad (2)$$

$$V_{s3} = V_{i3} + L_s \frac{di_{s3}}{dt} + R_s i_{s3} \quad (3)$$

Transformation of abc to dqo

$$V_{sd} = V_{id} + L_s \frac{di_{sd}}{dt} - w_s L_s i_{sq} + R_s i_{sd} \quad (4)$$

$$V_{sq} = V_{iq} + L_s \frac{di_{sq}}{dt} - w_s L_s i_{sd} + R_s i_{sq} \quad (5)$$

Real and Reactive power computation

$$\begin{cases} p = \frac{2}{3}\left(V_{sq} i_{sq} + V_{sd} i_{sd}\right) \\ q = \frac{2}{3}\left(V_{sq} i_{sd} \; - \; V_{sd} i_{sq}\right) \end{cases}$$

Consider $V_{sd} = 0$;

$$p = \frac{2}{3}\left(V_{sq} i_{sq}\right)$$

$$q = \frac{2}{3}\left(V_{sq} i_{sd}\right)$$

Now eqns. (4) and (5) become

$$0 = V_{id} + L_s \frac{di_{sd}}{dt} - w_s L_s i_{sq} + R_s i_{sd}$$

$$V_{sq} = V_{iq} + L_s \frac{di_{sq}}{dt} + w_s L_s i_{sd} + R_s i_{sq}$$

$$V_{id} = -(L_s \frac{di_{sd}}{dt} - w_s L_s i_{sq} + R_s i_{sd} \;)$$

$$V_{iq} = V_{sq} - (L_s \frac{di_{sq}}{dt} + w_s L_s i_{sd} + R_s i_{sq} \;)$$

$$V_{id} = G_{inv}.V_{id}^{*}$$

$$V_{iq} = G_{inv}.V_{iq}^{*}$$

$$V_{id} = -\left(L_s \frac{di_{sd}}{dt} - w_s L_s i_{sq} + R_s i_{sd}\right)$$

$$\Rightarrow V_{id} = \left(w_s L_s i_{sq}\right) - \left(L_s \frac{di_{sd}}{dt} + R_s i_{sd}\right)$$

$$\Rightarrow V_{id} = G\left(V_{dff} - V''_{id}\right),$$

$$Where\ GV_{dff} = w_s L_s i_{sq}\ \ and\ GV''_{id} = L_s \frac{di_{sd}}{dt} + R_s i_{sd}$$

$$\Rightarrow\ G.V^*_{id} = G(V_{dff} - V''_{id})$$

$$\boldsymbol{\Rightarrow V^*_{id} = V_{dff} - V''_{id}}$$

$$and, \qquad V_{iq} = V_{sq} - (L_s \frac{di_{sq}}{dt} + w_s L_s i_{sd} + R_s i_{sq})$$

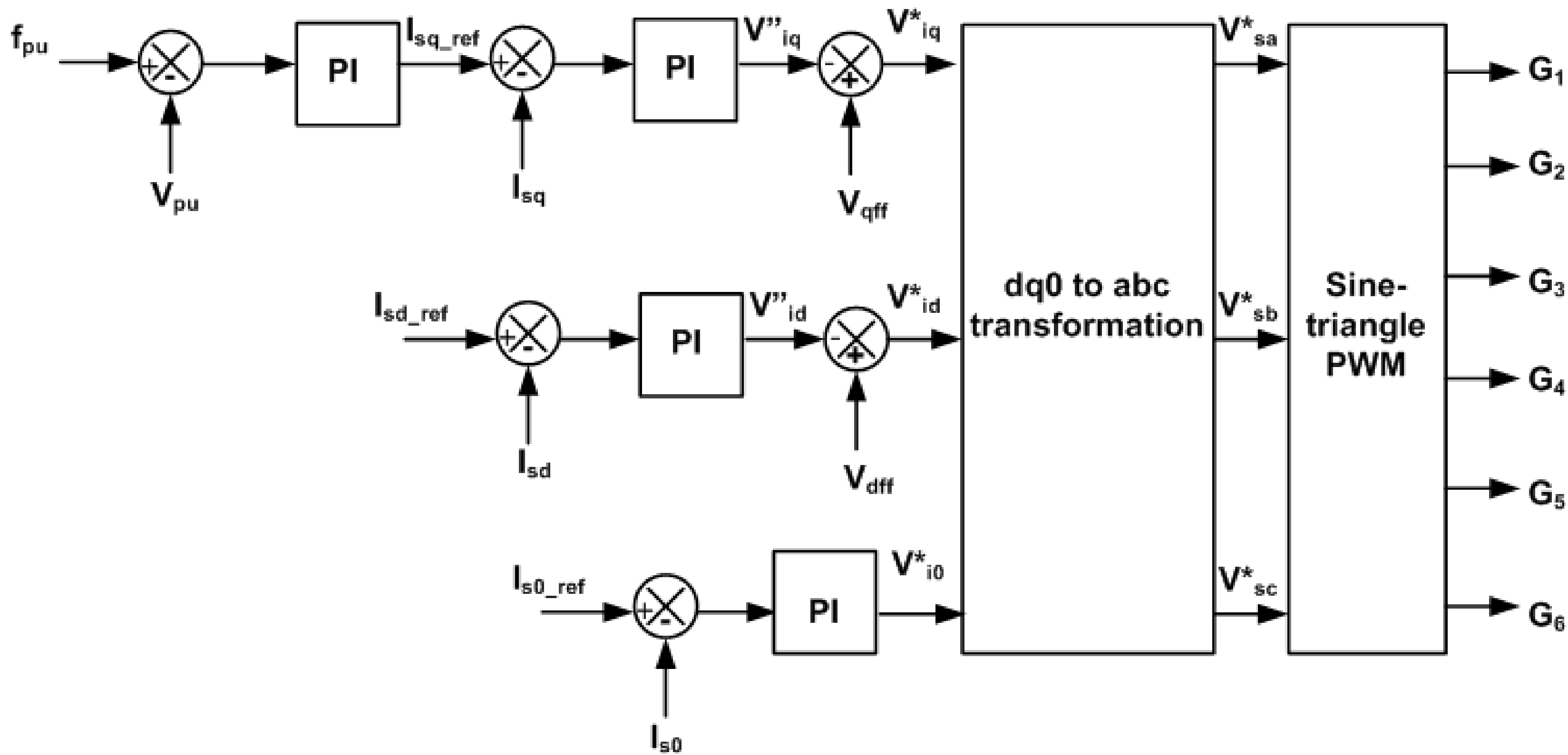
$$so\ similarly\ ,$$

$$\boldsymbol{V^*_{iq} = V_{qff} - V''_{iq}}$$

$$Where\ GV_{qff} = V_{sq} - w_s L_s i_{sd}\ \ and\ GV''_{iq} = L_s \frac{di_{sq}}{dt} + R_s i_{sq}$$

V_{dff} and V_{qff} are feed forward terms

Control block of IC

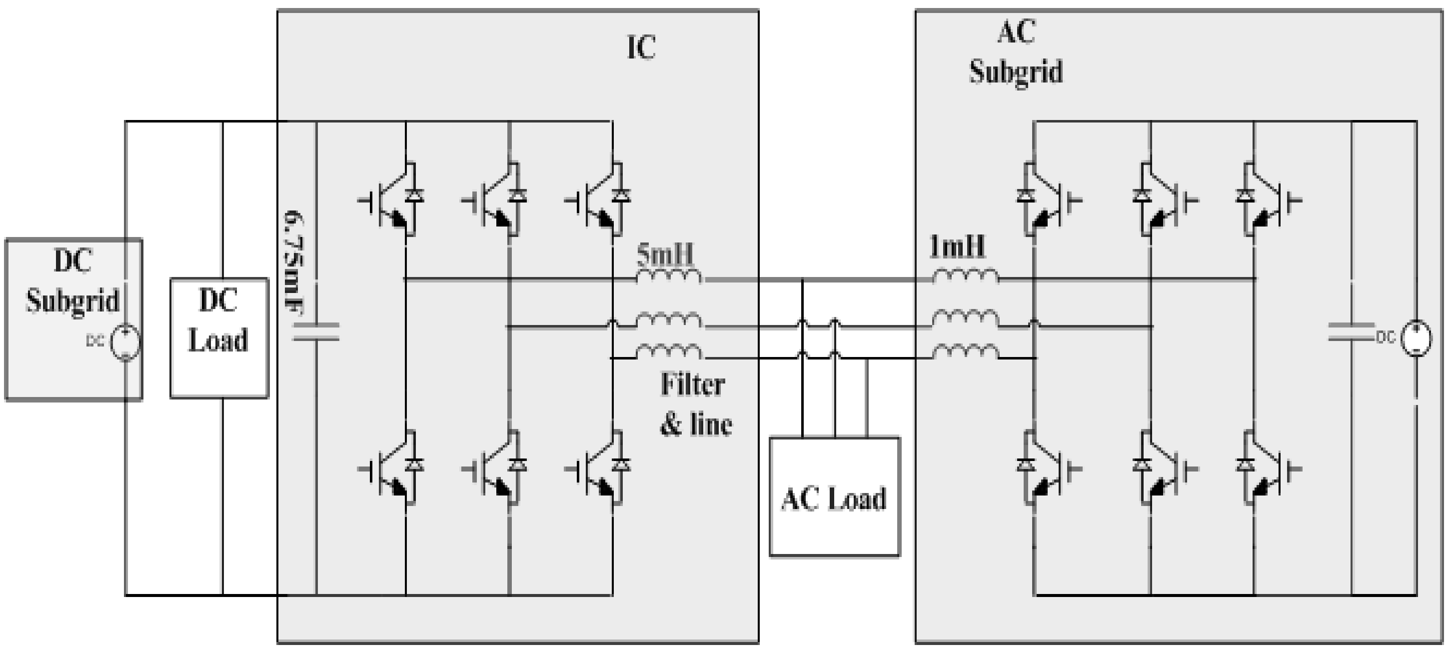


System Specifications

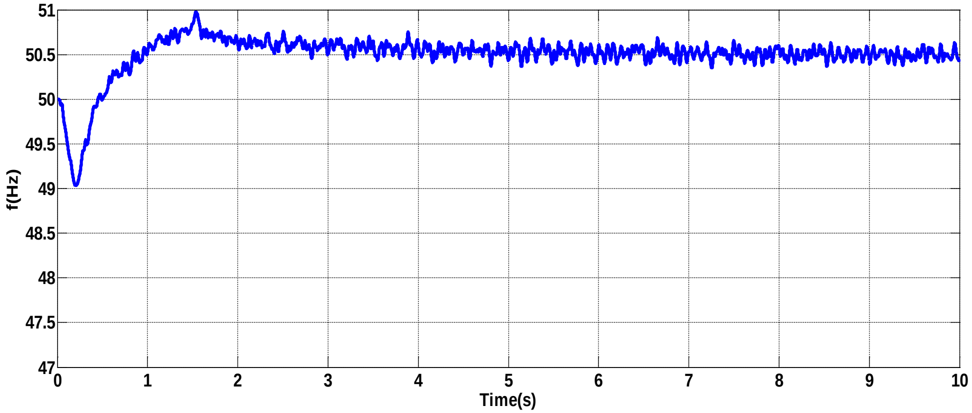
Parameters	Values
f_{min}	49Hz
f_{max}	51Hz
V_{max}	615V
V_{min}	595V
L	5mH
R	0.002 Ohm
C (IC)	6.75mF

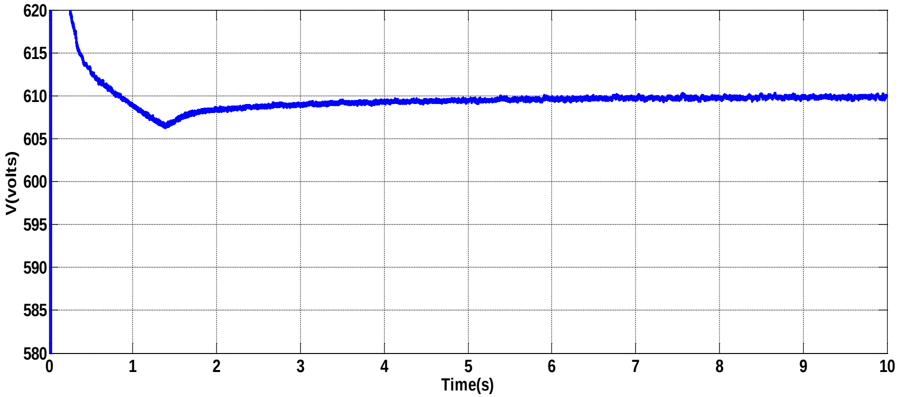
Case Studies

- Case1: DC Load = 5kW, AC Load = 0
- Case2: DC Load =10kW, AC Load = 0

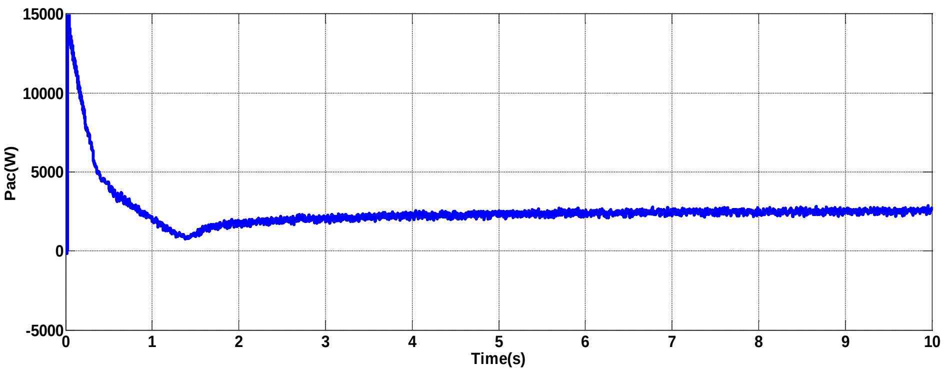


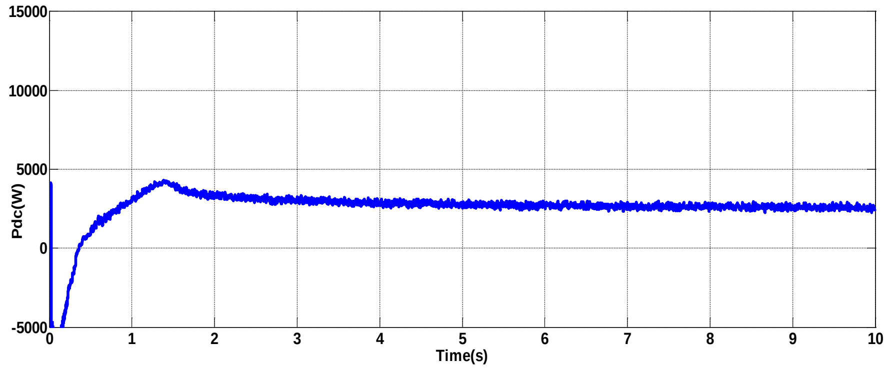
Simulation Results - Case1





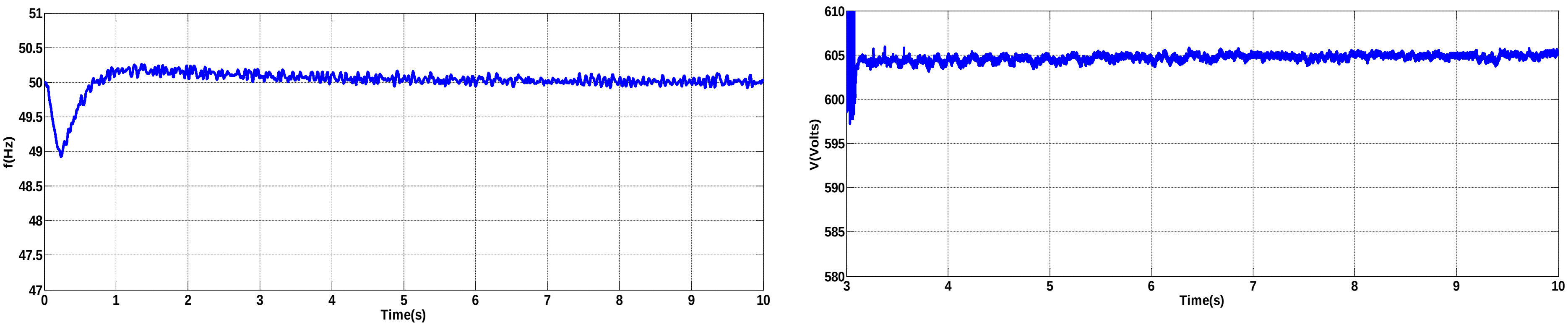
Frequency of AC bus and Voltage of DC bus for Case1: DC Load = 5kW, AC Load = 0



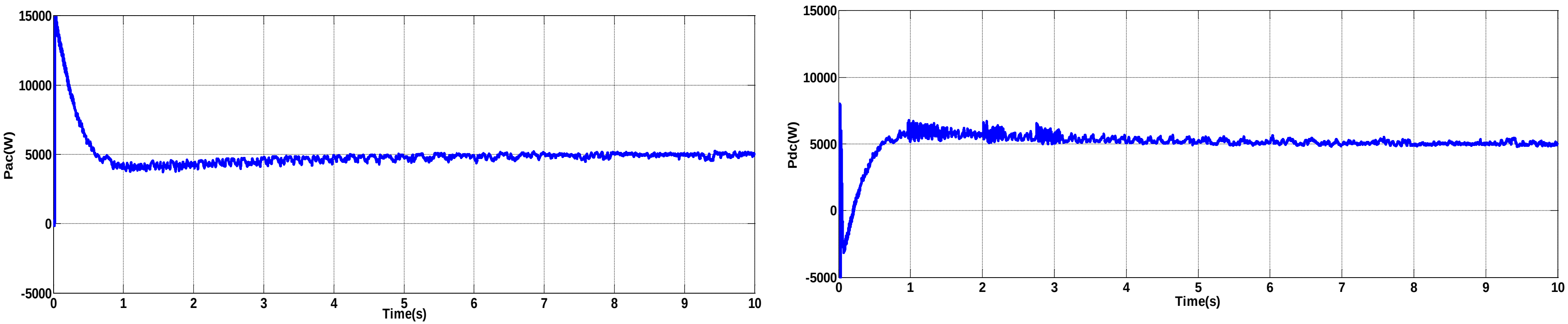


Power supplied by AC and DC subgrids for Case1: DC Load = 5kW, AC Load = 0

Simulation Results – Case2



Frequency of AC bus and Voltage of DC bus for Case2: DC Load = 10kW, AC Load = 0



Power supplied by AC and DC subgrids for Case2: DC Load = 10kW, AC Load = 0

Conclusions

- IC is controlled using vector control technique
- Controlled power sharing within the hybrid microgrid is obtained using droop control technique ensuring proportional power sharing

References

[1] X. Liu, P. Wang, and P. C. Loh, “A Hybrid AC/DC Microgrid and Its Coordination Control,” *IEEE Transactions on Smart Grid*, vol. 2, no. 2, (2013), pp. 278-286.

[2] C. Wang, X. Li, L. Guo and Y. W. Li, “ A Nonlinear-Disturbance-Observer-Based DC-Bus Voltage Control for a Hybrid AC/DC Microgrid, ” *IEEE Transactions on Power Electronics*, vol. 29, no. 11, (2014), pp. 6162-6177.

[3] P. C. Loh, D. Li, Y. K. Chai and F. Blaabjerg, “Autonomous Operation of Hybrid Microgrid with AC and DC Subgrids,” *IEEE Transactions on Power Electron*, vol. 28, no. 5, (2013), pp. 2214-2223.

[4] J S SIVA PRASAD, TUSHAR BHAVSAR, RAJESH GHOSH and G NARAYANAN, “Vector Control of Three Phase AC/DC Front End Converter,” *Sadhana*, vol 33. , October, 2008,pp 591-613.

THANK YOU