Linear Quadratic Regulator based Seamless Transfer in Microgrids

Established 1911
Dibakar Das, Gurunath Gurrala and U J Shenoy; Department of Electrical Engineering, Indian Institute of Science
INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

1. Introduction

Concept of microgrid is becoming popular in the recent times:

1. Microgrid can operate in conjunction with the grid.
2. Can disconnect from the grid.

Advantages:

1. Lower distribution losses
2. Increased system reliability

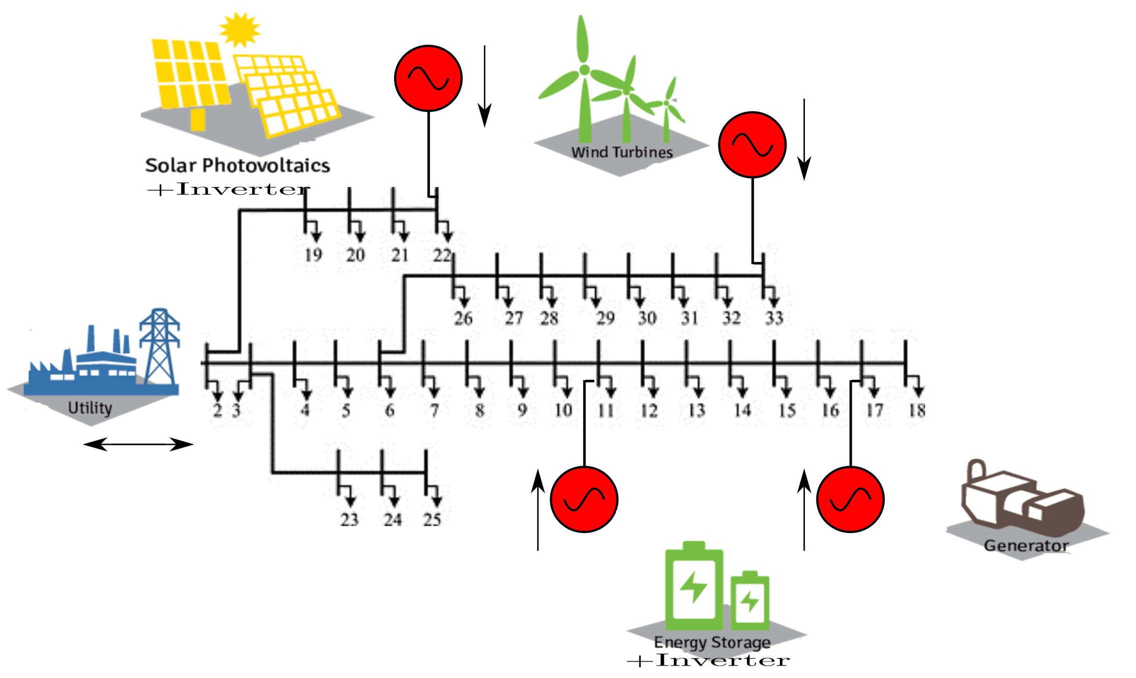

Figure 1: A Microgrid connected to the main grid.

2. Operating Modes

Grid is present:

- Grid maintains voltage and frequency. *DGs* operate to supply the P and Q as per reference.

Grid is absent:

- *DGs* share the load among them and maintain the voltage and frequency.

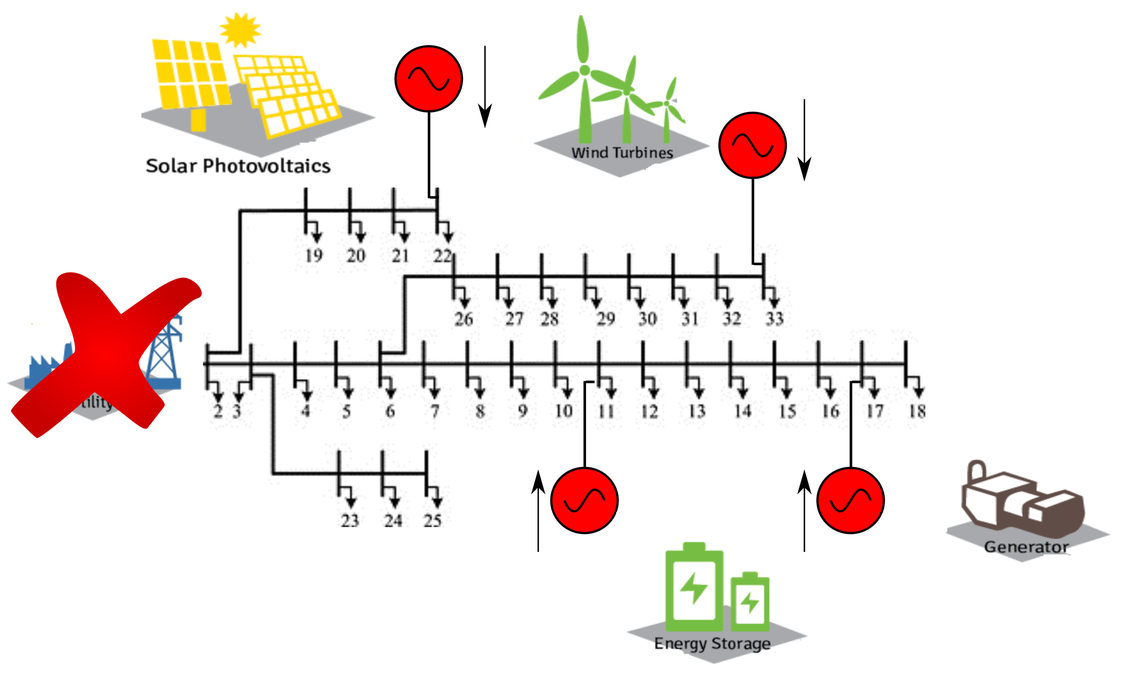

Figure 2: Microgrid in Islanded Mode.

3. Control with Grid

- *d-q* axis current control for constant power injection.

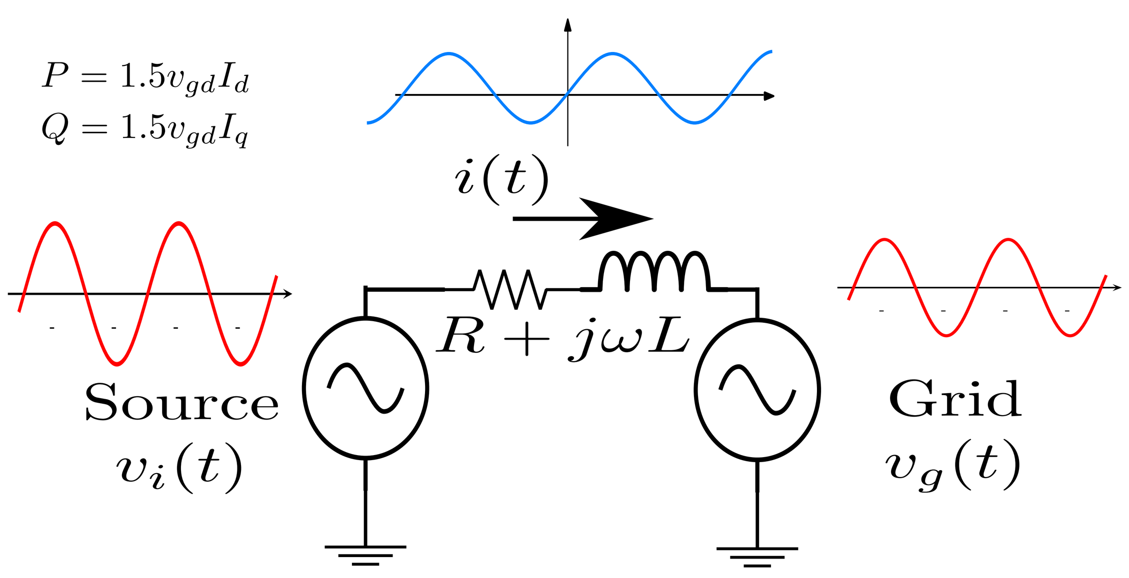

Figure 3: Control Scheme for a single *DG* source.

$$
\begin{aligned}
L_f\frac{di_a}{dt} + R_f i_a &= v_{ia} - v_{ga}\\
L_f\frac{di_b}{dt} + R_f i_b &= v_{ib} - v_{gb}\\
L_f\frac{di_c}{dt} + R_f i_c &= v_{ic} - v_{gc}
\end{aligned} \quad (1)
$$

4. Control without Grid

- Droop control Scheme for load sharing.

$$
\begin{aligned}
\omega &= \omega_0 - k_{pd}(P - P_r)\\
V &= V_0 - k_{qd}(Q - Q_r)
\end{aligned} \quad (2)
$$

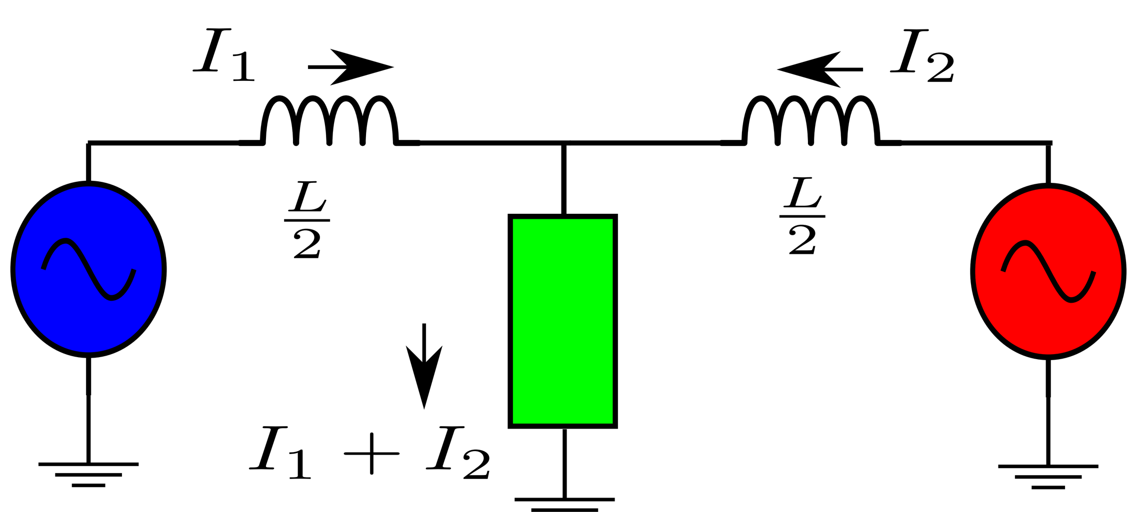

Figure 4: Droop control with 2 *DGs*.

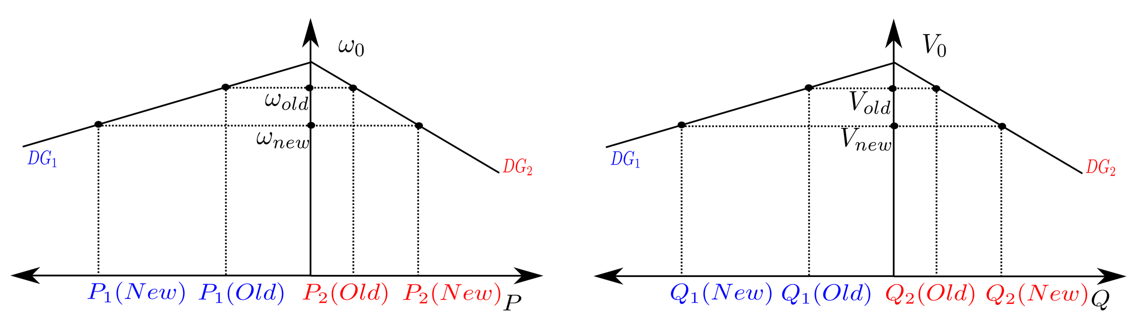

Figure 5: Droop control for *DG* source.

5. Challenge

Control Challenge:

- Controllers should produce well matched output at the instant of transition.

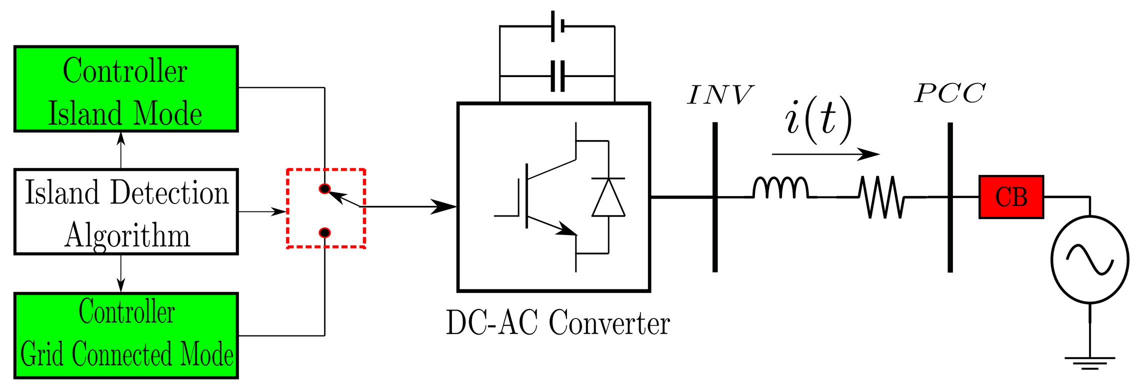

Figure 6: Concept of Seamless Transfer

6. Proposed Method

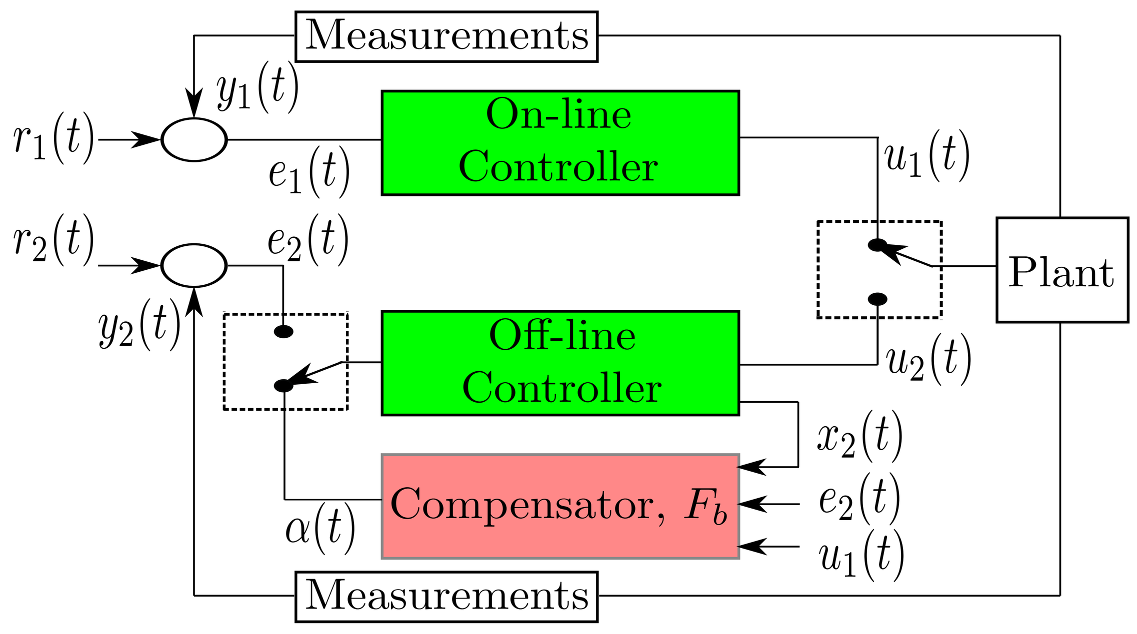

Figure 7: Proposed LQR Scheme.

- The feedback compensator minimizes error between output of two controllers.

7. LQR Formulation

- Minimization of a cost function is desired.

$$
\begin{aligned}
J = \frac{1}{2}\int_0^\infty &(u_2 - u_1)^T Q (u_2 - u_1)\\
&+ (e_2 - \alpha)^T R (e_2 - \alpha)dt
\end{aligned} \quad (3)
$$

- Subject to the constraint

$$
\begin{aligned}
\dot{x}_2(t) &= Ax_2(t) + B\alpha(t)\\
u_2(t) &= Cx_2(t) + D\alpha(t)
\end{aligned} \quad (4)
$$

8. LQR Solution

$$
\alpha = F_b \begin{bmatrix} x_2 & u_1 & e_2 \end{bmatrix}^T \quad (5)
$$

1. Formulate the State Space Model of the off-line controller and solve the problem for a given choice of Q and R matrices.
2. Implement the controller with the available signals x_2, u_1, e_2.

9. Results-Islanding Scenario

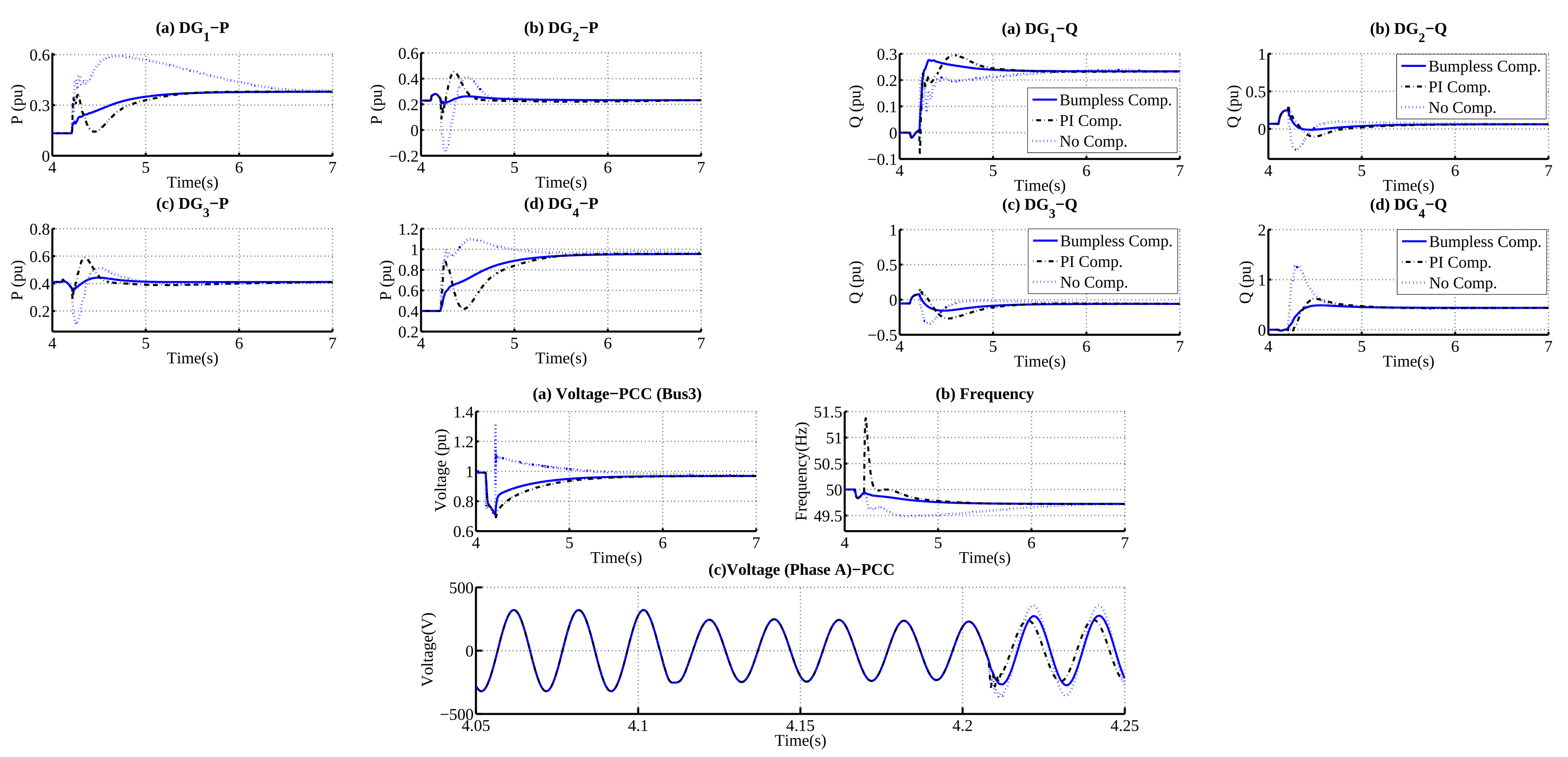

Figure 8: (i)*DG* Active powers (LHS), (ii) *DG* Active powers (RHS), (iii) *PCC* voltage and frequency (Bottom) (Solid Blue: LQR, Dash Black: Li et. al., Dash Blue: No comp). Grid disconnected at t=4.1s islanding command issued at t=4.23s.

10. Conclusion

- Seamless transfer in microgrids is a major challenge.
- A novel LQR based seamless transfer scheme for microgrids is proposed.

11. References

[1] D. Das, G. Gurrala, and U J Shenoy, Linear quadratic regulator based bumpless transfer in microgrids, IEEE Trans. on Smart Grid, June 2016.