Facoltà di Ingegneria Civile e Industriale

Dottorato di ricerca in Ingegneria Elettrica, dei Materiali e delle Nanotecnologie (EMNE)

Dottorato di Ricerca in Ingegneria Elettrica, dei Materiali e delle Nanotecnologie

Relazione annuale A.A.: 2020-2021	
Ciclo di Dottorato: XXXVI	**Curriculum: Ingegneria Elettrica**
Dottorando/a: Mohamed Elhag	**Supervisore: Prof. Giulio De Donato**

TITOLO DELLA RICERCA:

"**Control of Wide-bandgap semiconductor-based inverters for Grid-Connected renewable energy Systems".**

1. **Sintesi dell'attività di ricerca svolta**

- This project aims to design and analysis the performance, benefits, and application challenges of using Wide-bandgap semiconductor-based inverters in grid connected by using the commercially available wide bandgap Gallium Nitride (GaN) switches devices. Use of gallium nitride (GaN) as primary switches reduce switching losses to enable high-frequency operation, fast switching speed of WBG and achieve high efficiency performance for grid connected inverter.

- In addition, design, and analysis for propose primary control algorithms for three phases GaN inverter connected to the grid, with high performance current and power control such as Model Predictive Control (MPC), and microprocessor-based control required to catch the benefit of the high WBG switching speed.

- Then to investigate about the effect of the PLL on the dynamics on the primary control, active-reactive power control and current control in SRF.

- LCL and EMI filters are also required to reduce the effect of the harmonics and electromagnetic interference of the Wide-bandgap semiconductor grid connected inverter. Then to design proper LCL filter considering the effects of Wide-bandgap semiconductor switches.

- **Research carried out during the 1st year**

  During the first year, analytical models for discreet time domain have been obtained for L filter, connected to three phases grid in both stationary and synchronous reference frames. Also, the analytical models for the short circuit single phase LCL filter as shows bellow:

  - **Discrete time analytical model of the grid and L-filter in ($\alpha\beta$) reference frames:**

$$i_\alpha(Z) = \left[\frac{Z^{-1} \times \left(\frac{(1 - e^{-\frac{R}{L}T})}{R}\right)}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})}\right] \times u_\alpha + \left[\frac{\frac{Z^{-1} \times \left(\left(R \times e^{-\frac{R}{L}T}\right) - (R \times cos(wT) + wL \times sin(wT))\right)}{(R^2 + w^2L^2)}}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})}\right] \times e_\alpha + \left[\frac{\frac{Z^{-1} \times \left(\left(wL \times e^{-\frac{R}{L}T}\right) + (R \times sin(wT) - wL \times cos(wT))\right)}{(R^2 + w^2L^2)}}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})}\right] \times e_\beta$$

$$i_\beta(Z) = \left[\frac{Z^{-1} \times \left(\frac{(1 - e^{-\frac{R}{L}T})}{R}\right)}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})}\right] \times u_\beta - \left[\frac{\frac{Z^{-1} \times \left(\left(wL \times e^{-\frac{R}{L}T}\right) + (R \times sin(wT) - wL \times cos(wT))\right)}{(R^2 + w^2L^2)}}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})}\right] \times e_\alpha + \left[\frac{\frac{Z^{-1} \times \left(\left(R \times e^{-\frac{R}{L}T}\right) - (R \times cos(wT) + wL \times sin(wT))\right)}{(R^2 + w^2L^2)}}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})}\right] \times e_\beta$$

  - **Discrete time analytical model of the grid and L-filter in (dq) reference frames:**

$$\overrightarrow{i_{dq}}(z) = \left[\frac{(1 - z^{-1} \times e^{-\frac{R}{L}T} \times cos\,\omega T) - j(z^{-1} \times e^{-\frac{R}{L}T} \times sin\,\omega T)}{\left(1 - \left(2 \times z^{-1} \times e^{-\frac{R}{L}T} \times cos\,\omega T\right) + (z^{-2} \times e^{-\frac{2R}{L}T})\right)}\right]$$
$$\times \left[\left(\frac{z^{-1} \times (cos\,\omega T - j\,sin\,\omega T)}{R} \times \overrightarrow{u_{dq}}(z)\right) - \left(\frac{z^{-1} \times \tau \times e^{-\frac{R}{L}T} \times (cos\,\omega T - j\,sin\,\omega T)}{L} \times \overrightarrow{u_{dq}}(z)\right)\right.$$
$$\left. - \left(\frac{z^{-1} \times (R - j\omega L)}{(R^2 + \omega^2 L^2)} \times \overrightarrow{e_{dq}}(z)\right) + \left(\frac{z^{-1} \times (R - j\omega L) \times e^{-\frac{R}{L}T} \times (cos\,\omega T - j\,sin\,\omega T)}{(R^2 + \omega^2 L^2)} \times \overrightarrow{e_{dq}}(z)\right)\right]$$

➢ **<u>Discrete time analytical model of the single phase LCL-filter by using Thevenin theorem:</u>**

$$\mathbf{i}(Z) = \left[\frac{Z^{-1} \times \left(\frac{(1-e^{-\frac{R}{L}T})}{R} \right)}{(1 - Z^{-1} \times e^{-\frac{R}{L}T})} \right] \times U$$

2. Seminari, Corsi, Workshop e Scuole:

- ME746: Dynamics of Controlled Systems.
- ME547 Design of Computer Control Systems.
- Discrete- Time Signal Processing.
- Digital Control in Power Electronics.
- PSIM Training - Single Phase and Three-Phase Inverters Control.

3. Partecipazione a Congressi Nazionali e Internazionali:

- European PhD School: Power Electronics, Electrical Machines, Energy Control and Power Systems.

Allegati (Figure e tabelle):

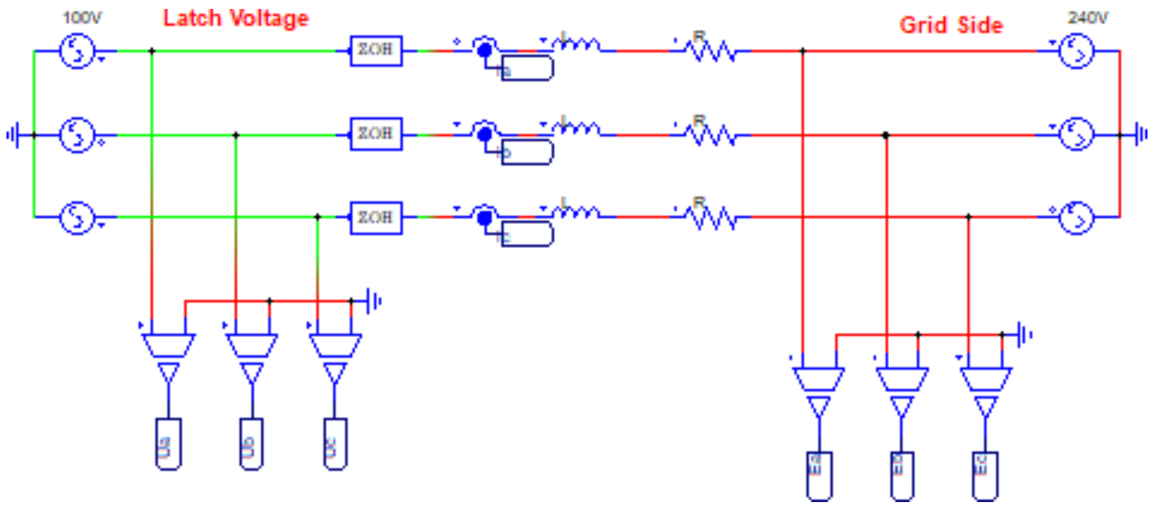

Fig (1): PSIM simulation for three phases L filter connected to grid.

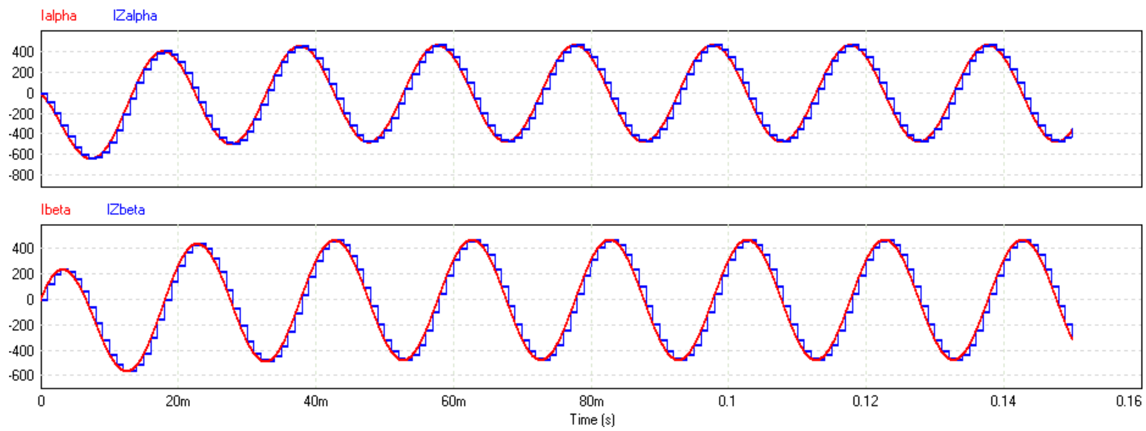

Fig (2): Actual and discrete current in $\alpha\beta$ reference frame.

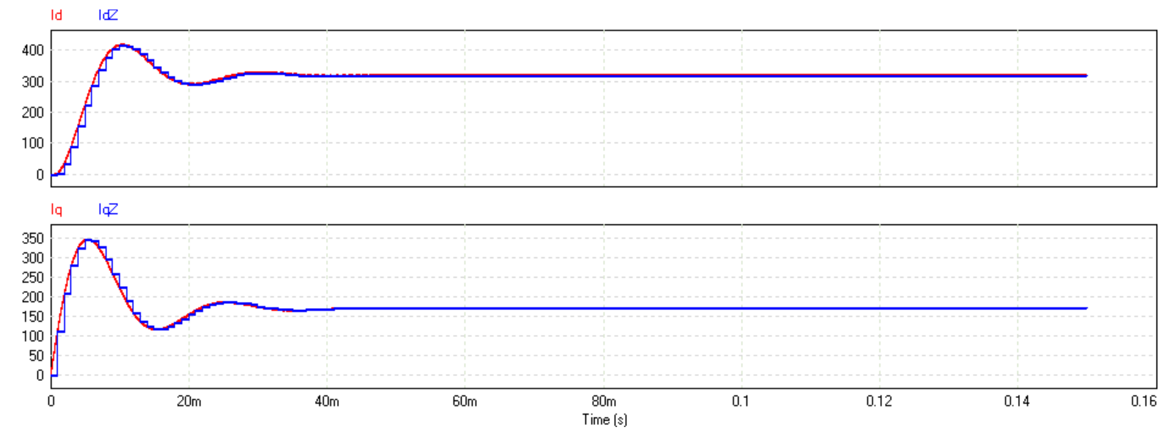

Fig (3): Actual and discrete current in dq reference frame.

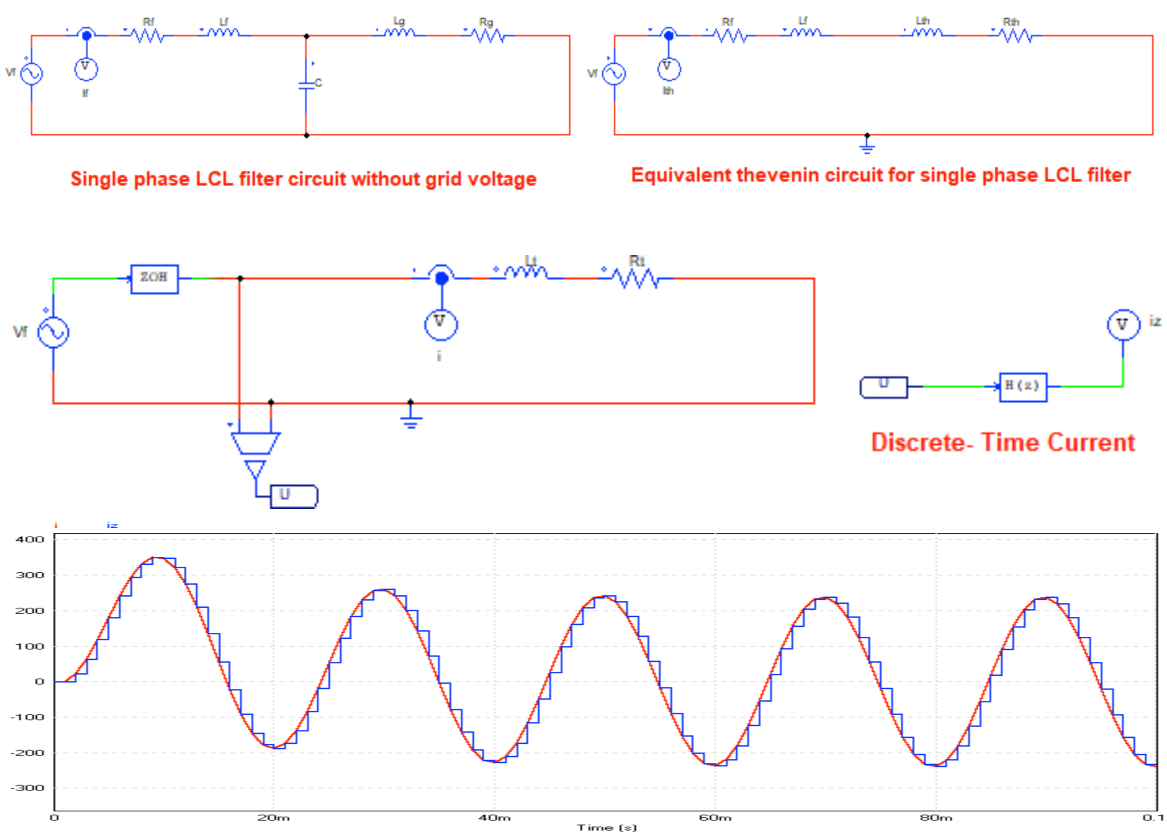

Fig (4): PSIM model of the single phase LCL-filter by using Thevenin theorem