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Direct Power Control Strategy for Grid Connected Voltage Source Inverter

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Dedication

To my dear parents, for all their sacrifices, their love, their tenderness, their Support and

Their prayers throughout my studies to

My dear sisters for their constant encouragement and moral support to my dear brothers for

Their support and encouragement, to all my family for their support throughout,

Throughout my academic career, May this work be the fulfilment of your

Wishes so much claimed, and the fruit of your infallible support,

No words, no dedication could express my respect, my consideration, and

My love for the sacrifices they made for my instruction.

KHELFAOUI M^{ed} DJAMAL EDDINNE

Dedication

To My Very Dear Parents

I dedicate this thesis to my parents, for the love they always gave me their encouragement and all the help they gave me during my studies No words, no dedication could express my respect, my

Consideration, and my love for the sacrifices they made for my education and.

My well-being Find here, dear mother and dear father, in this modest work, the fruit of so much dedication and sacrifice as well as expression of my gratitude and deep love. May God their

Grant health, happiness, prosperity and long life so that I may one day fill their old age with joy to my dear friend **NASREDIN BOUTERA** for his permanent encouragement and his moral support.

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Acronyms

Bat	Battery
M-grid	Microgrid
DC	Direct Current
Rem	Remaining power sale
Sin	Sinusoidal
PWM	Pulse Width Modulation
Vdc	Output capacitor voltage
THD	Total Harmonic Distortion
A, b, c	Phases of three-phase system
D, q	Direct and quadrature component
α, .β,..0	Alpha, beta components & zero sequence component
Exch	Exchange
L-L	Line to line
Global	Global
Conv	Converter
Sgrid	Main grid
Ref	Reference
VSI	Voltage source inverter
DPC	Direct power control
VOC	Voltage oriented control
IGBT	Insulated gate bipolar transistor
CSI	Current source inverter
AF	Active PWM filter

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ABSTRACT.

General Introduction

General Introduction

Like many technologies in the energy industry, micro grids have been around in one form or another for many years but not in the name of "Microgrid", or with the same level of technical sophistication we see today. Campus-type power generation and distribution systems, often with many shared distributed power resources (usually fossil fuel generators and CHP systems) and multiple loads have been in place for years, many in facilities such as universities, military bases, and industrial parks **[1-2].**

A growing power system grid is always accompanied by a higher cost in further expansion and maintaining the required efficiency limits **[3-4].**

Micro grids are locally confined and independently controlled electrical power networks in which the distribution structure integrates the loads and distributed energy resources **[5-6].**

Locally distributed generators and energy storage devices that allow a small network to operate connected or isolated to a main grid **[7].**

Power electronics is a relatively new and growing field growth during the last decades, the evolution of power electronics implies their increased use in various applications, citing electrical control stash, control of emergency power supplies, heating by electrical induction, applications dedicated to electrical traction, compensation of harmonics, etc.As part of our work, we will focus on the direct control of power of a three-phase PWM rectifier **[8].**

Critical loads will be provided continuous power during reflux mode in networked mode, noncritical loads that may require additional power will be supplied by the Microgrid when the main switch is closed **[9]**.

There are several switch topologies suggested by several authors in the literature for a networked micro-network process. Most of the available literature uses VSI as a power electronic transducer with L, LC, LCL, and LCCL filter arrangements.

The only possible solution is to design the filter to avoid unnecessary resonance in the circuit. Instead, multilevel transformers, mesh transformers, matrix transformers, etc. are used in the network-connected mode of operation of the Microgrid system there are many issues or challenges that one can address in a Microgrid system the main issues are power quality and stability issues Energy quality issues include energy flow control and self-healing. The stability of the micro-grid is achieved by proper synchronization during the network connection mode and voltage/frequency control during the independent operating mode/or island mode.

Grid-connected mode control technology to achieve stable operation of a small grid depends on the power to be injected at a specified power factor. It involves the generation of a reference voltage and a current wave which must be synchronized with the network. Also, the voltage on the buses should be close to sinusoidal with respect to any variations in the connected loads in the system.

Our work is fragmented as follow**:**

The first chapter contains an introduction and general information on micro grids and direct power control as an effective Pulse width modulation method.

The second chapter explains direct power control and modelling of it and the study of grid connected inverter, where we present the main principles of direct power control (DPC) with a table of predefined commutation of the system.

Finally, the third chapter discusses the simulation of the previous models of direct power control (DPC) and study the results.

We end our work with a general conclusion which will summarize the main conclusions we will reach.

Chapter I

Micro-grid Overview

I.1 Introduction

It has recently been noted that the world's electricity systems are beginning to "decentralize, decarbonizes, and democratize", in many cases from the bottom up **[10]**.

These trends, also known as the "three elements," are driven by the need to rein in electricity costs, replace aging infrastructure, improve resilience and reliability, reduce carbon dioxide emissions to mitigate climate change, and provide reliable electricity to areas lacking infrastructure. While the balance of drivers and details of a particular solution may differ from place to place, Microgrid have emerged as a flexible structure for deploying dispersed energy resources **(DERs)** that can meet the large-scale needs of diverse communities from the New York capital to rural India.

In this chapter we make an overview for micro-grids and the concept and some examples with explication**.**

I.2 General about micro grids

Small networks **(Micro-grid)** are now emerging from laboratory benches and demo sites in commercial markets, driven by technological improvements, lower costs, a proven track record, and growing recognition of their benefits.

They are used to improve the reliability and resilience of electrical grids, to manage the addition of distributed clean energy resources such as photovoltaic and wind **(PV)** power generation to reduce fossil fuel emissions, and to provide electricity in areas not served by central infrastructure.

Microgrid form**:**

- Application range from a few kW to MW.
- Other applications: hospitals, military facilities, buildings, industrial complex.

I.2.1Definition of Microgrid

A number of definitions of Microgrid **[11]** and functional classification systems **[12]** can be found in the literature. The widely cited definition, developed for the US Department of Energy by Microgrid Exchange, a dedicated group of research and publishing experts, states that:

A small network is a collection of interconnected loads and distributed power Resources within clearly defined electrical limits that operate as a single unit an entity that can be controlled in relation to a network. Small network can be connected and Disconnect from the network to enable it to work in both the connected network and Island mode **[13]** this description includes three requirements:

1) - It is possible to identify the part of a distribution system that includes a small network as distinct from the rest of the system.

2) - That resources connected to a small network are controlled in coordination with each other rather than remote resources.

3) - That a small network can work regardless of whether it is connected to a larger network or not. The definition says nothing about the size of distributed energy resources or the types of technologies that can or should be used.

The question of the optimal aggregation scale is an open question in the Microgrid literature and an active area of investigation.

For example, is it better to integrate detached home customers into large community Microgrid or to deploy Microgrid technology at the individual home level , The advantages of a fully decentralized building integrated micro-grid approach **[14]** include the control of energy resources by customers and the fact that individual homes are already connected to the electrical distribution network, so that any changes are likely to be made behind the utility meter to add to the capabilities of the micro-grid There are no legal or Significant regulation is beyond what has already been encountered for the interconnection of rooftop solar installations today.

At the same time, this fully decentralized approach, especially if it includes island capacity, loses out on the cost savings at scale and the generation and load diversity that come with multiple generator and load networks.

I.2.2 Micro grids examples

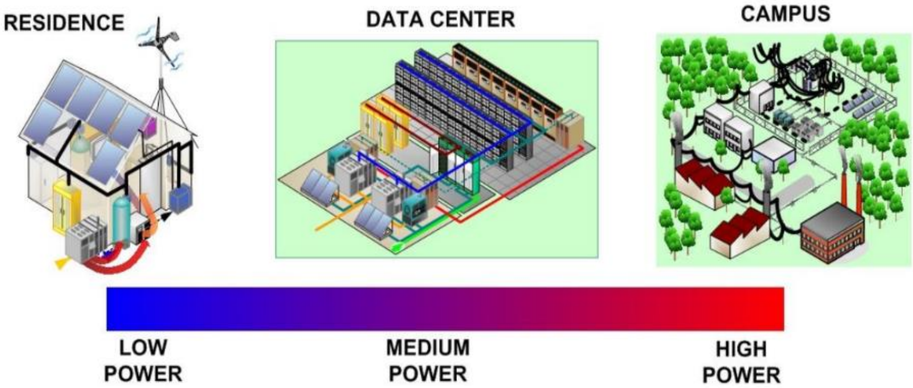
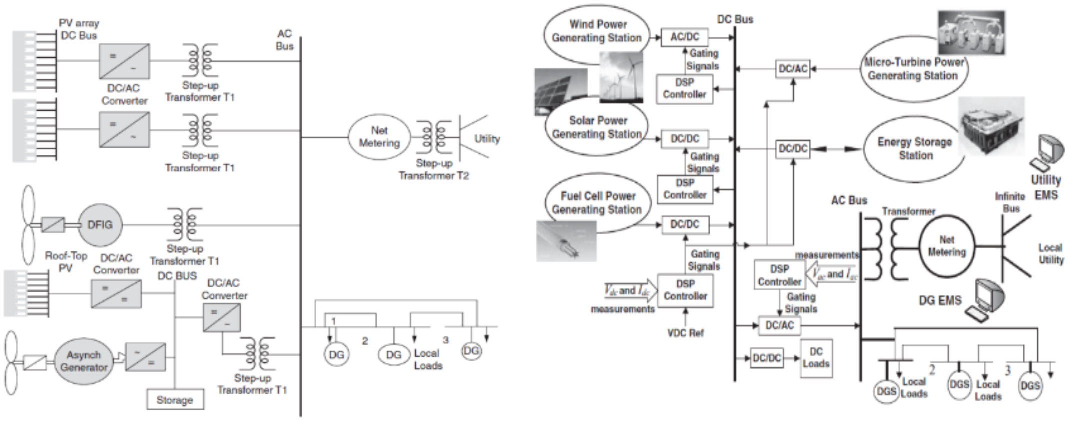


Figure I.1 Microgrid in system



(a) (b)

Figure I.2 Architecture of Microgrid **(a)** AC microgrid **(b)** DC microgrid

Figure I.3 microgrids system in alaska

I.3 Micro-grids history

I.3.1 history

The term "micro grid" appears to have come into use in the late 1990s when the US Department of Energy (USDOE), at the behest of the US Congress, began examining grid reliability and how to maximize the use of distributed generation resources in order to improve reliability and resilience. Multiple studies have been completed by industry participants especially the US Department of Defence (USDOD). Recently, a number of factors have boosted interest in small networks including Super storm Sandy in October 2012.

From the 1920s to the 1970s, the increased reliability offered by connecting multiple generating units with varied loads, lower construction costs per kilowatt, and the ability to extract power from large generation sources such as hydropower led to the development of the grid we see today **[5-6]**.However, these advantages seem to be bypassed and closed economically, environmentally and. Driven by facility restructuring, improved DER technologies, and economic risks associated with building massive generation facilities and transmission infrastructure, power generation companies have gradually shifted to smaller, decentralized units over time **[15]**.

This shift is driven by a set of DER benefits that have been studied in detail **[16-17]**, such as deferring investments in generation, transmission and distribution capacity, Volumetric current control or VAR (energy reactive), ancillary services, environmental emissions benefits, reduced system losses, energy savings, enhanced reliability, improved power quality, combined heat and power, demand reduction, and backup generation**.** These benefits do not accrue only to small distributed fossil fuel plants many of them also accompany the deployment of intermittent renewable generation sources, as shown in a foundation study of a 500 kW distributed PV power plant in California **[18-19]**.

The challenge of drastically reducing greenhouse gas emissions to avoid catastrophic climate disruption has led to government policies that incentivize the deployment of zero-carbon generation sources, many of which are suitable for distributed applications.

Beginning in the late 1990s, as we have described it, scientists and engineers in the United States and Europe began exploring decentralized solutions that could manage the integration of thousands or tens of thousands of distributed energy resources in a way that also increases reliability and resilience in the face of natural disasters, physical and cyber-attacks, and cascading energy output. The solution they settled on, it was a grid architecture that could manage the generation and demand for electricity locally in subsections of the grid and that could be automatically isolated from the larger grid to provide critical services even when the grid failed massively. This approach was named "Micro-grid".

While much of the north-eastern United States lost grid power as a result of the super storm, small network operators like Princeton University in New Jersey were able to keep the lights on and stay up and running without interruption. This opened the eyes of industry, regulator, and politicians to the resilience benefits of a micro grid that can continue to function when isolated from the utility grid, and which can increase the value and benefits of distributed energy resources. A number of states (such as New York, Connecticut, and California), in addition to the USDOE and USDOD, have funded studies on the development, design, and implementation of micro-grids. As a result, according to recent studies, there are currently more than 2,430 micro-grids operating in the United States and there were more than 19,575 megawatts of operating or planned capacity worldwide at the end of 2018.

A recent Binghamton Community Micro-grid feasibility study conducted by Bridgestone Associates provides a good example of a micro-grid, how to form it, and its community benefits. This study was funded in large part by a grant from the New York State Energy Research and Development Authority (NYSERDA) under the award program in New York.

The planned micro-grid will serve seven buildings in downtown Binghamton, New York, an area prone to severe flooding that cuts off city hall, emergency services (fire, police and ambulances) and a number of low-income and senior living facilities. The mini-grid will connect these buildings through underground electrical conduits and will include a 1000 kW plant, a 400 kW gas engine generator, a total of 600 kW solar PV, a 1200 kW hydroelectric plant, and a number of standby generators. The CHP will provide heating and cooling for a number of buildings that will be reinforced to withstand flooding. There will be one common point of coupling with the local electricity utility.

The CHP factory micro-grid controller will control the micro-grid during normal "blue sky" times and abnormal "dark sky" times isolated to the network. This small network will allow the city and emergency services to continue to function.

Figure I.4: Micro-grid station

I.3.2 Foundational micro-grid research

Systematic R&D programs **[20**] began with the efforts of the Reliability Electrical Technology Solutions (CERTS) consortium in the US **[21]** and the MICROGRIDS project in Europe **[22].** CERTS was formed in 1999 **[23],** and CERTS has been recognized as the origin of the concept of the modern networked micro-grid **[24]**.

A micro-grid network that can integrate multiple DERs and yet present itself to the existing network as a typical client or small generator has been envisioned, in order to remove the perceived challenges of merging DERs.

Emphasis has been placed on seamless and automatic island linkage and network reconnection and on passive control strategies such as reactive power versus voltage, active power versus frequency, and flow versus frequency **[25].**

The objectives of these strategies were to:

1) - Remove reliance on high-speed communications and master controllers, resulting in a "peer-to-peer" architecture.

2) - To create a flexible “plug and play” system.

It would not require extensive redesign with the addition or removal of DERs, in order to lower upfront costs for the system and to provide the freedom to locate cogeneration facilities near thermal loads CERTS SMALL NETWORK.

The concept has been deployed in a test environment **[26- 27]** and in small, real-world network projects **[28-29].** While CERTS' initial motivation was to improve reliability rather than reduce greenhouse gas emissions by themselves, CERTS micro-grids can integrate renewable micro-generation sources. The EU MICROGRIDS project explored similar technical challenges such as Safe Island and reconnection practices, energy management, control strategies under island and connected scenarios, protective equipment, and communication protocols **[30].** Active research continues on all of the leading topics in these early studies**.**

I.4 Advantages and Disadvantages of micro-grid

I.4.1 Advantages

• Ability to disconnect from utility grid during disturbance and operate independently.

• It reduces demand on utility grid thus prevents grid failure.

• We can use both electricity and heat energy so that overall efficiency increases.

I.4.2 Disadvantages

Voltage, frequency and power quality should be at acceptable limits

• Requires battery tanks to store which requires space and maintenance.

• Resynchronization to utility grid is difficult.

• Protection is difficult.

I.5 Fields of interest

Micro-grids have been around for decades, but until recently they were mostly used by college campuses and the military. So the total number of small networks is relatively small but growing.

Guide house (formerly Navigant) predicts the market will approach $39.4 billion by 2028. But the pace of installation is expected to increase as variable energy prices decline and concerns about electrical reliability increase, due to severe storms, cyber attacks, and other threats. Guide house expects global micro grid capacity to reach 1, 9888.8 MW by 2028, up from 3,480.5 MW in 2019.

The research firm sees North America and Asia Pacific as centres of growth.

At the international level of the European Union, two major research efforts have been devoted exclusively to small networks. Within the Fifth Framework Program (1998-2002), Micro grids: Large-Scale Integration of the Small Generation with Low Voltage Networks activity was funded in the amount of €4.5 million. The consortium, led by the National Technical University of Athens (NTUA), brought together 14 partners from seven EU countries, including utilities such as EdF (France), PPC (Greece) and EdP (Portugal); Manufacturers, such as Enforce, SMA, Germanous, URENCO; As well as research institutions and universities such as Labe in, INESC Porto, University of Manchester, ISET Kassel and Cole de Mines. The research and development objectives were:

• Study the operation of micro-grids to increase the penetration of renewable and renewable elements while reducing carbon emissions.

Study the operation of small networks in parallel with the network and islands, as faults may follow.

• Define and develop control strategies to ensure efficient, reliable and economic operation and management of small networks.

• Determining appropriate protection and grounding policies to ensure safety, fault detection, disconnection and operation on the island.

• Identification and development of required communications infrastructures and protocols.

• Determining the economic benefits of operating the micro-grid and suggesting systematic ways to quantify them.

• Simulate and display the micro-grid process on laboratory scales.

I.5.1 mode of operation (utility regulation)

The distribution generators vary, thus, their Microgrid structures. The structure of Microgrid consists of the five major:

(a) Micro sources or distributed generators.

(b) Flexible loads.

(c) Distributed energy storage devices.

(d) Control systems.

(e) The point of common coupling components.

Which are connected to a low-voltage distribution network, capable of operating in a controlled, coordinated manner, in both the connected to the utility grid or landed states? As to the operation of micro grids, there exist different approaches. Different types of renewable energy resources are involved as the power generators in a Microgrid.

The components within micro grids form a wide variety. The components of Microgrid are shown in **Figure I.5** a simplified Microgrid system is equipped with (a) controllable generation like diesel generators and load bank, (b) not controllable generators (limited) like the photovoltaic cell and wind turbine, and (c) distributed energy storage like batteries and super-capacitors is schemed in **Figure I.5.**

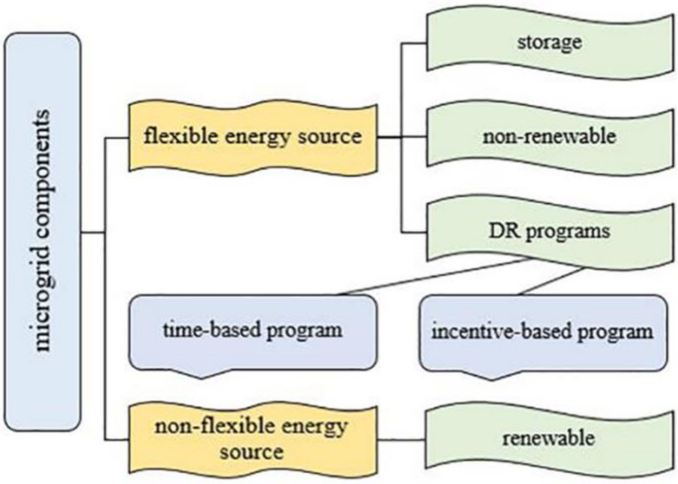


Figure I.5 Schematic of a Microgrid with different connected energy sources

A mini-grid is likely to be considered an electrical business if it intends to serve multiple, otherwise unrelated, retail customers, cross a public road with power lines, and/or obtain a concession from a local authority.

The reasons for this conclusion are discussed below in more detail. If a government utility regulating agency decides that services provided by micro-grids qualify as utilities, that agency can regulate the prices charged for electricity and decide whether to approve the construction of the facility, among other authorities, all of which have significant implications for micro-grid developers and owners. In the event that the micro-grid is considered as a distribution tool, it may incur a service obligation, which means that the service will be required to provide the service upon a written or verbal request from a potential retail customer.

All small networks that intend to use public roads to distribute electricity to customers (e.g. send thermal energy or electricity through a public street) require permission from the local municipal authority **[29].** This permission can be in the form of a "privilege" or other "less consent". The ability of a micro-grid to obtain this permission depends in large part on whether a pre-existing electric utility is granted an exclusive concession, effectively blocking competitors. In New York, for example, if an existing franchise is not exclusive, state law still requires the use of a competitive process to determine the franchisor, allowing incumbents and other service providers to compete against the small network developer for the franchise.

Due to their small scale and limited range of services, it is unlikely in most cases that a mini-network will require a franchise, and therefore, most mini-networks will not be subject to the jurisdiction of the utility regulation agency; however, these cases are adjudicated on a project-by-project basis in the courts.

In addition, small networks that sell to retail customers may have to comply with various consumer protection laws. Finally, regardless of its status as a distribution facility, small grids that produce power through combustion (such as small turbines or diesel generators) are subject to federal and state laws governing emissions and will require a permit under certain conditions.

The choice of business or ownership model will also affect the degree to which the benefit privilege or lesser approval influences; these considerations have been discussed previously. Current regulations governing electrical utilities in the United States reflect a process referred to as "restructuring," and colloquially as "deregulation," which occurred in the mid- and late 1990s in many states in the United States, similar to deregulation in other key areas Industries such as airlines, railways, telecommunications, etc. **[31]**. In general, the restructuring provided the separation of the generation, transmission and distribution functions of what were previously vertically integrated monopolies. In the case of New York, generators can sell electricity in competitive wholesale markets or directly to local distribution facilities or retailers for resale to customers. The system operator (in the case of New York, NYISO) is responsible for balancing supply and demand at all times. The ecosystem of players in the restructured electricity market in New York includes smaller generating companies called Independent Power Producers (IPPs). Small networks, as such, do not fit neatly into the categories of market participants identified through restructuring, possibly because they go beyond the categories of generation, transmission, and distribution. As a result, more work is needed to integrate it into the regulatory legal structure.

I.6 Conclusion

Microgrid remain a niche application or become ubiquitous depends on two key factors the degree to which regulatory and legal challenges can be successfully overcome, and whether the value they provide to landlords and communities in terms of energy quality and Reliability (PQR) and other economic benefits that weigh any cost premiums incurred to obtain those benefits. These questions are now answered in courtrooms and commercial markets around the world as power grids evolve to address social and economic concerns and incorporate 21st century technology to update Thomas Edison's original vision of the grid.

And the micro-grids are reviewed in chapter is reported to have excellent performance in the field.

In this chapter, we presented an overview of Micro-grid sand some of examples about it.

Chapter II

Direct power control strategy

II.1 Introduction

Direct power control is a voltage based control of PWM, Various control techniques have been proposed in the literature to control grid-connected inverters among them, Direct Power Control (DPC) technique, which can control active and reactive power. The DPC technique is based on a switching table to send the inverter control signals. Another alternative to DPC has been widely used.

This chapter shows details and DPC modelling as the basic and system block diagram of DPC and grid connected inverter.

II.2 Control strategies PWM

PWM method in two categories a voltage based and virtual flux based control

II.2.1 voltage based

• Voltage Oriented Control (VOC)

Ensures high dynamic and static performance across an indoor unit current control loop But the quality mainly depends on the current control strategy. It has a complex algorithm and no sensitivity to line inductance variation.

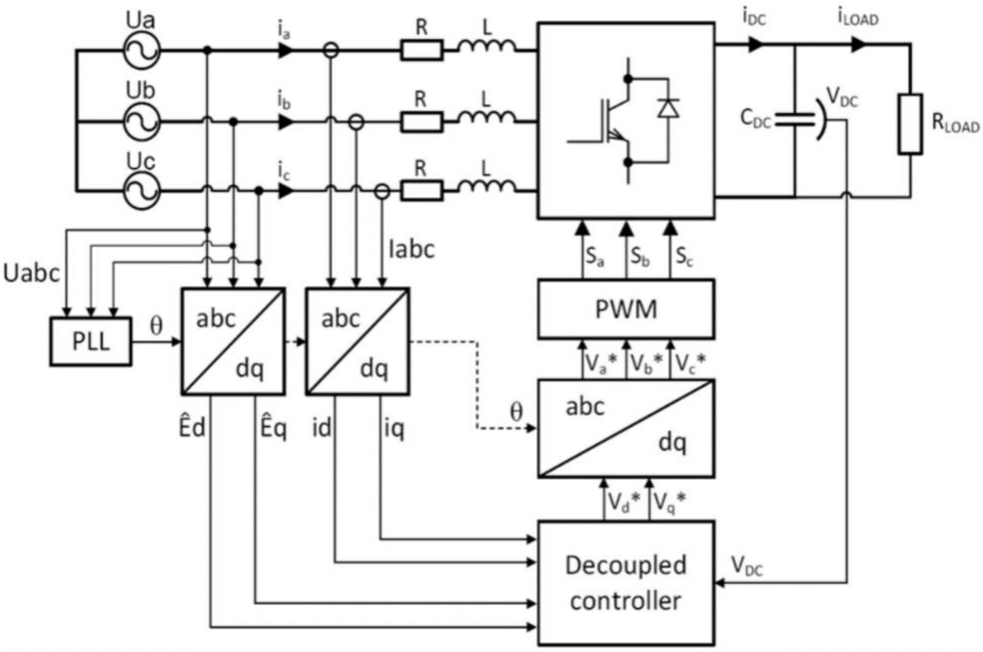


Figure II.1: Diagram of VOC

• Direct power control (DPC)

Is based on instantaneous control of active and reactive power control loop there is no internal current control loop and no PWM modulator block. Switch case determined using a switch table based on instantaneous errors between the command and the estimated values for the active and reactive power.

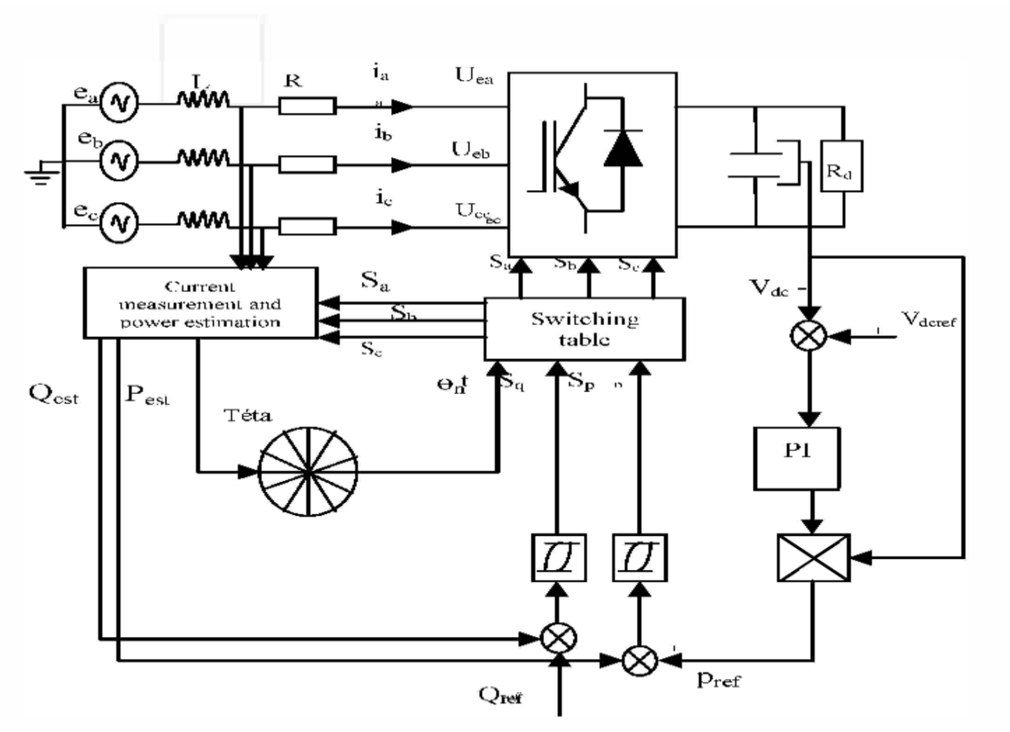


Figure II.2: Diagram of DPC

II.2.2 Virtual flux based control

Is compatible with direct scaling of instant message control

• VF OC

The virtual flux oriented control (VFOC) which are close to vector-controlled ac motors, So this strategy seems to bathe simplest technique used to forcing the supply current to follow its reference.

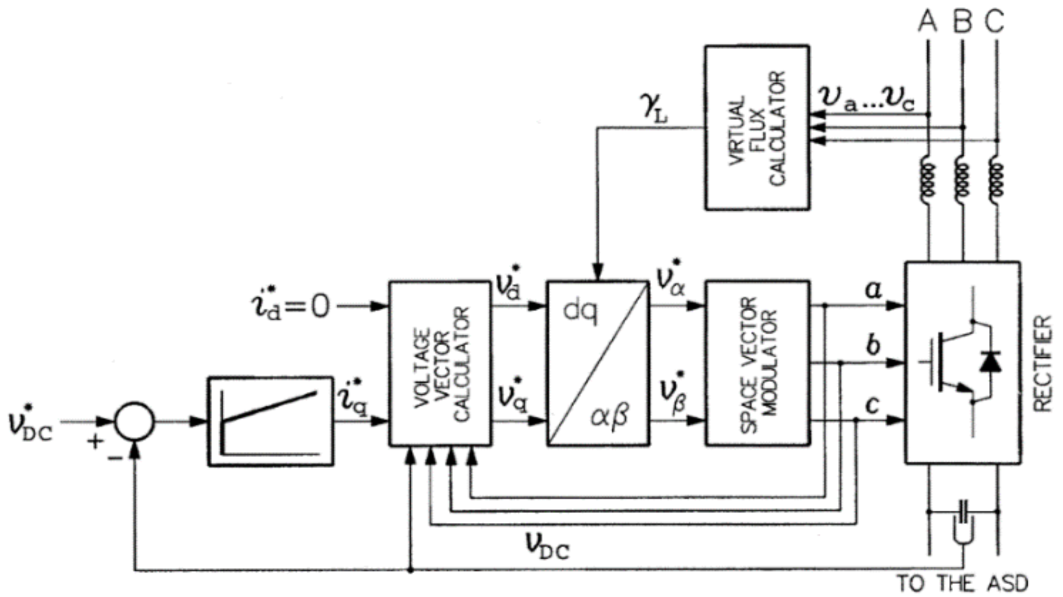


Figure II.3: Diagram of VF OC

• VF-DPC

The VF-DPC is maintained. The inverter switching states are appropriately selected by a switching table according to the instantaneous error between references and estimated values of active and reactive power. However, to permit more flexibility in the vector selection, a single band hysteresis is replaced by a double band strategy and to achieve a proper mid-point balancing, a method to decide on the correct redundant vector is employed.

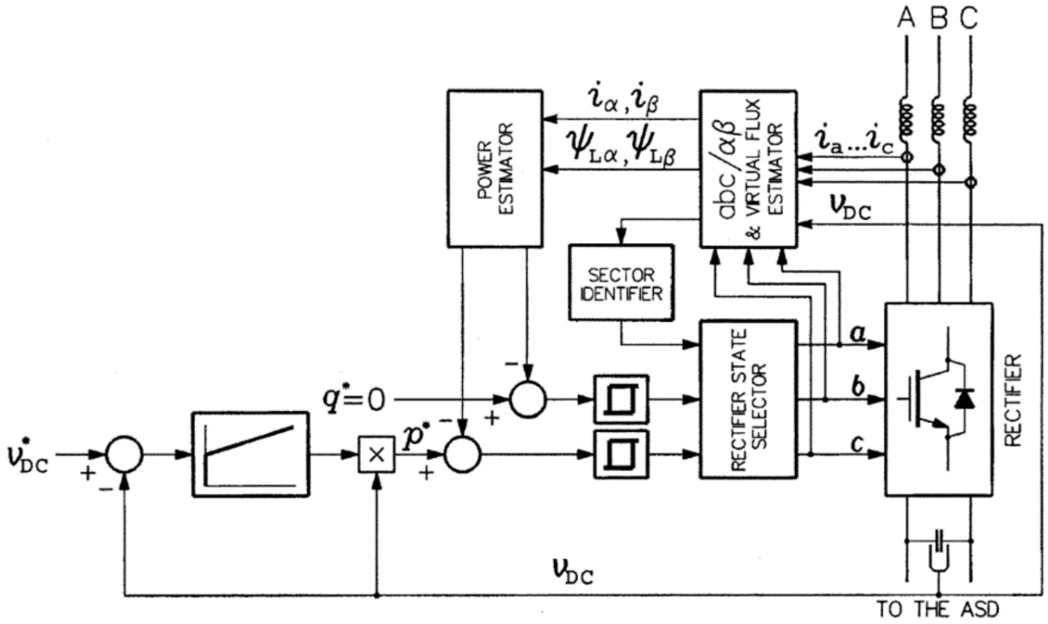


Figure II.4: Diagram of VF-DPC

All of these control strategies can achieve the same main goals, such as high and close power factor Sinusoidal inputs for current waveforms **[31-32].**

The DPC strategy is chosen primary due to its simpler algorithm and good dynamic performance and instantaneous variables with all harmonic components are estimated (improvement of the power factor and efficiency) and this strategy has decoupled active and reactive power control.

II.3 Control strategy DPC

In work, we present simplified of:

• Direct power control

II.3.1 Basic block diagram of DPC

Direct power control, such as high power factor and near sinusoidal input current waveforms. Direct Power Control **(DPC)** emerged as competitive with the vector control technique. This method of ordering was proposed by T. Neghouchi in 1998. DPC control is based on the selection of a voltage vector of such that errors between measured and reference quantities are reduced and maintained between the limits of the hysteresis bands.

Two control techniques were used to implement DPC commands:

• DPC using voltage vector: based on the position of the voltage vector in the frame stationary α-β.

• DPC using virtual flow: based on the calculation of a virtual flow.

On the other hand, DPC control is a power-based control technique Active and reactive with the advantages of robustness and rapid control.

This chapter is organized as follows: first of all the discrete model for a three-phase two-level rectifier is bestowed. Secondly, supported the system model the direct power management law comes, associate degreed an accommodative management law and therefore the stability study of the system area unit bestowed. Within the last section of the chapter experimental results area unit enclosed and analysed so as to verify the theoretical study that has been bestowed within the previous sections.

II.3.2 Inverter modelling and control (grid-connected inverter)

The fundamental types of control can be classified into two categories: current control and voltage control. When the inverter is connected to the network, the network controls the amplitude and frequency of the inverter output and the inverter operates in current control mode. The classical current control can lead to other control methods can be obtained such as active and reactive power control/voltage control.

The equations that describe the input currents dynamics and therefore the output DC voltage dynamic are often derived from the system model. Following the technique conferred in **[34],** the system models are often obtained within $\alpha\beta$ frame.

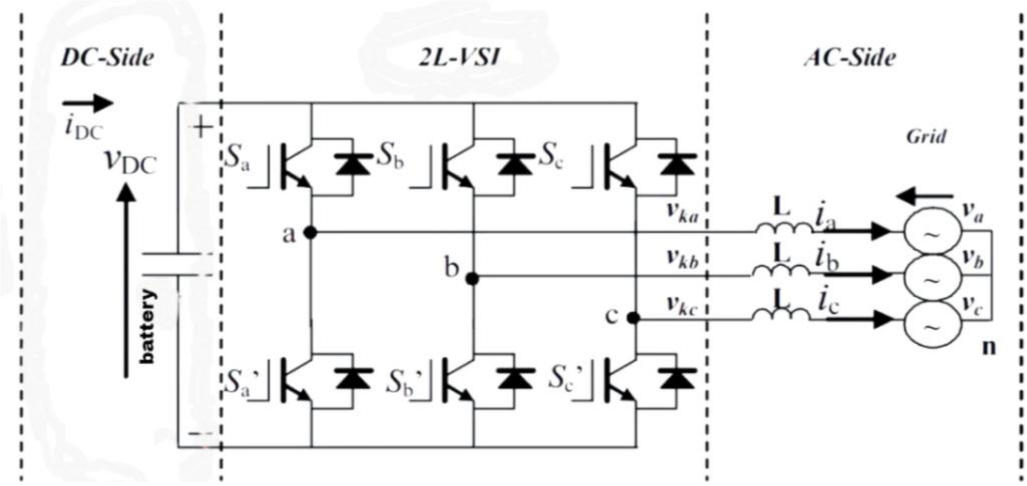


Figure II.5: Grid connected converter

II.3.2.1 Two-level three-phase inverter modelling

The general structure of a two-level voltage inverter is shown in Figure (II.5), the inverter consists of three arms, each arm has two two-way switches Can be open and closed. It can be MOSFET for Ultra High Low Frequency IGBT high power high frequency power, or ultra-high power low frequency (GTO). To simplify the study, the midpoint O is created by each of the two capacitors fictitious Take half the DC voltage.

II.3.2.2 Vector representation

The table **II.2** represents the different states and the coordinates of the output voltage vector V_i on the plan $\boldsymbol{\alpha\beta}$ corresponding to each state.

Table II.1: State of the inverter and coordinates in the vector Vi plane $\alpha\beta$

Sc	Sb	Sa	U	U	U	Ucα	Ucβ	V1
0	**0**	**0**	0	0	0	0	0	V6
0	**0**	**1**	$\frac{-Vdc}{3}$	$\frac{-Vdc}{3}$	$\frac{2Vdc}{3}$	$\frac{-Vdc}{\sqrt{6}}$	$\frac{-Vdc}{\sqrt{2}}$	V5
0	**1**	**0**	$\frac{-Vdc}{3}$	$\frac{2Vdc}{3}$	$\frac{-Vdc}{3}$	$\frac{-Vdc}{\sqrt{6}}$	$\frac{Vdc}{\sqrt{2}}$	V3
0	**1**	**1**	$\frac{-2Vdc}{3}$	$\frac{Vdc}{3}$	$\frac{Vdc}{3}$	$-\sqrt{\frac{2}{3}}Vdc$	0	V4
1	**0**	**0**	$\frac{2Vdc}{3}$	$\frac{Vdc}{3}$	$\frac{Vdc}{3}$	$\sqrt{\frac{2}{3}}Vdc$	0	V1
1	**0**	**1**	$\frac{Vdc}{3}$	$\frac{-2Vdc}{3}$	$\frac{Vdc}{3}$	$\frac{Vdc}{\sqrt{6}}$	$\frac{-Vdc}{\sqrt{2}}$	V6
1	**1**	**0**	$\frac{Vdc}{3}$	$\frac{Vdc}{3}$	$\frac{-2Vdc}{3}$	$\frac{Vdc}{\sqrt{6}}$	$\frac{Vdc}{\sqrt{2}}$	V2
1	**1**	**1**	0	0	0	0	0	V7

We noticed that there is a null vector V0 the figure II.4 shows the representation of 8 vectors nonzero in the plane$\alpha\beta$, which can be generated by inverter and formed in a vector diagram Inverter or switching hexagon.

The purpose of the inverter control is to make the output voltage (V_a, V_b, V_c) also as close as possible to the three reference sinusoidal voltages(V_a, V_b, V_c) as represented in Figure II.3, these vectors being able to be represented by a single vector of reference in the$\boldsymbol{\alpha\beta}$plane as a constant amplitude$\boldsymbol{\vec{v}^*}$ **of**$\boldsymbol{v^*}$ and equal to Amplitude desired with a simple tension and rotates around the centre of the hexagon with a speed constant angular **e**$\boldsymbol{\omega = d\theta/dt}$ corresponding to the desired electrical impulse

$$\vec{v}^* = v^* \, e^{j\theta} \qquad \text{II. (1)}$$

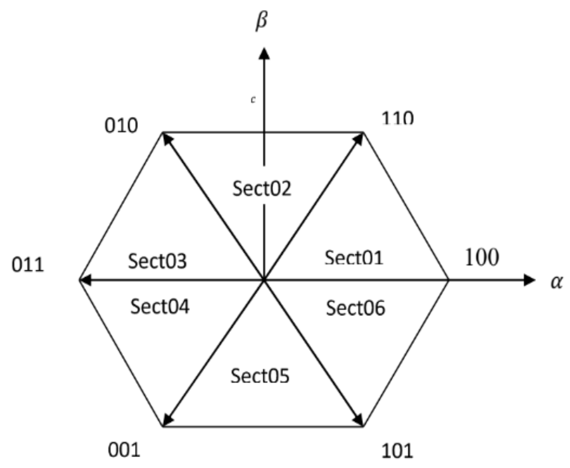


Figure II.6: Representation of the eight states of the inverter in vector form

II.3.3 System block diagram

The main plan of DPC planned in and next developed by **[35]** is comparable to the well-known direct power control as chapter I shown.

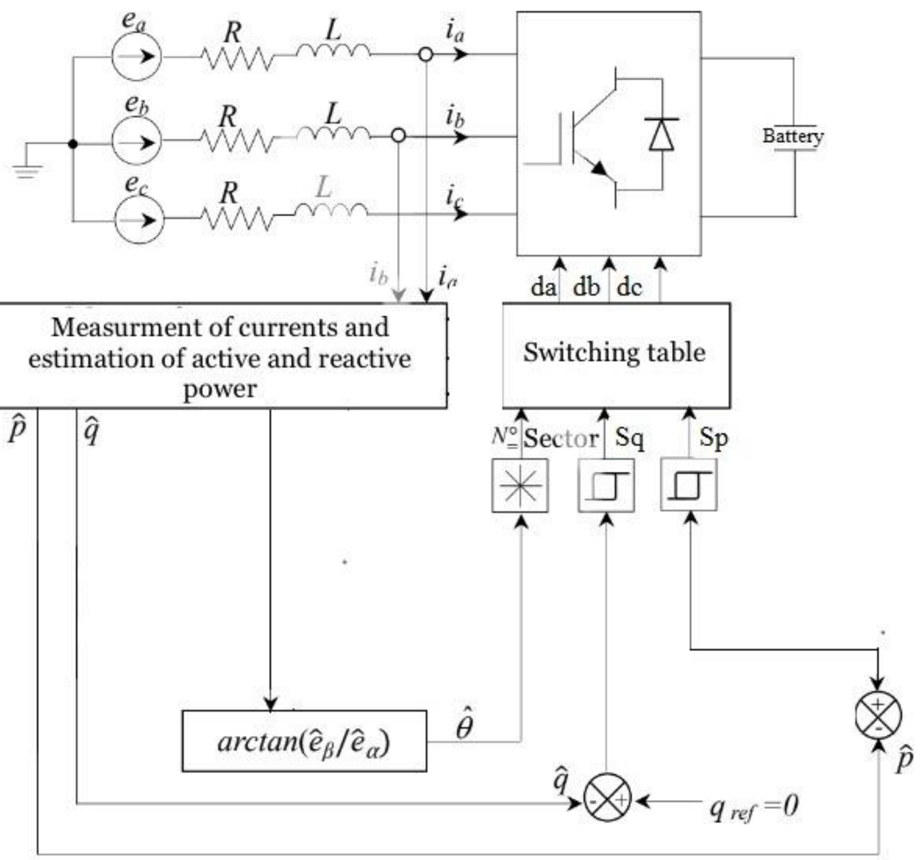


Figure II.7: Diagram of the general direct power control **(DPC)** command

II.3.4 Principle of direct power control

The DPC consists of selecting a control vector from a switching table. The latter is based on the digitized errors, d_q of the instantaneous active and reactive power supplied by the two-stage hysteresis regulator and the angular position of the calculated voltage vector.

Based on the value of this position, Figure **(II.5)** shows the overall configuration of direct power control with grid connected converter for a three-phase.

The first we made a converter grid that make the current from AC to DC and the end we make a battery instead of Vdc.

And the main thing is the blocks that made the command, the source gives the V_{abc} and $I_{\mathbf{abc}}$ as it shown in our models, and we bring it to convert V_{abc}, I_{abc} to $V\alpha$, $V\beta$ and $I\alpha$, $I\beta$this is the first block. And when we have $I\alpha$, $I\beta$ can change it to make phase theta and P and Q with these equations:

$$\mathbf{P= V\alpha I\alpha + V\beta I\beta} \qquad \text{II. (2)}$$

$$\mathbf{Q= - V\beta I\alpha + V\alpha I\beta} \qquad \text{II. (3)}$$

And for theta:

$$\emptyset = \mathbf{arctan}\left(\frac{e\beta}{e\alpha}\right) \qquad \text{II. (4)}$$

After that goes to grid voltage sector select on it the program of theta and P and Q goes to sum for comparison of p_{ref} and q_{ref} and after that to hysteresis dp and dq and in the end goes to the last block for bring da and db and dc to the command part .

DPC consists of selecting a control vector from a switching table **[37].** The latter is based on the digitized errors dp, dq of the active and reactive powers instantaneous **(errors between the estimated active and reactive powers and those of reference)**, provided by two-level hysteresis controllers, as well as on the position angular of the estimated voltage vector. Depending on the value of this position, the plane **(α-β)** is divided into twelve sectors where each sector must be associated with a logic state of the rectifier **[38].**

The commands of reactive power q_{ref} and active power p_{ref} unit compared with the estimated alphabetic character and p values, in reactive and active power physical phenomenon controllers, severally.

The digitized sign of the reactive power controller is outlined as:

$$\mathbf{dq = 1 \text{ for } q < q_{ref} - Hq} \qquad \text{II.(5)}$$

$$\mathbf{dq = 0 \text{ for } q > q_{ref} + Hq'} \qquad \text{II. (6)}$$

And similarly of the active power controller as:

$$dp = 1 \text{ for } p < p_{ref} - Hp \qquad \text{II.(7)}$$

$$dp = 0 \text{ for } p > p_{ref} + Hp' \qquad \text{II.(8)}$$

II.3.5 Instantaneous power estimation

Takahashi defines the instantaneous active power by the scalar product between the currents and line voltages and reactive power by the vector product between them **[000].**

$$p = V(abc) . i(abc) = V_a i_a + V_b i_b + V_c i_c \qquad \text{II. (9)}$$

$$q = V(abc) . i(abc) = V'_a i'_a + V'_b i'_b + V'_c i'_c \qquad \text{II.(10)}$$

Hence V'_a, V'_b, V'_c are backward by 90° on V_a, V_b, V_c respectively.

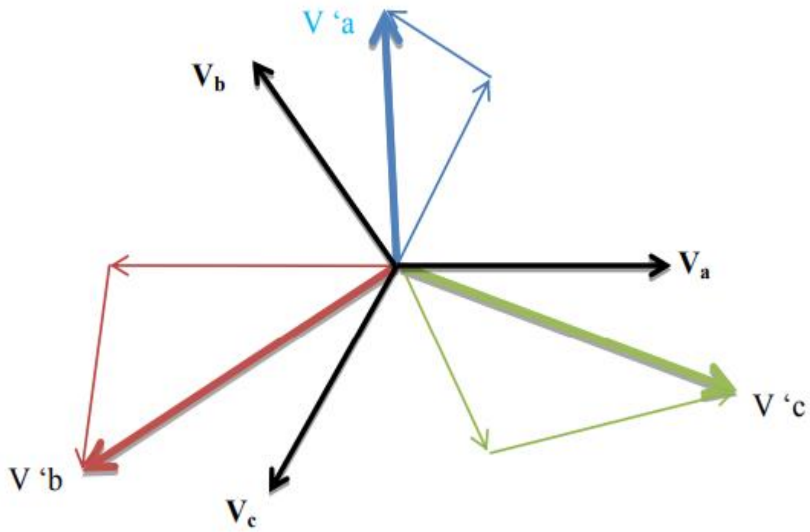


Figure II.8: Vector representation of vectors

The same equation can be described in the following matrix form:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} Va & Vb\,Vc \\ V'a & V'bV'c \end{bmatrix} = \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \qquad \text{II. (11)}$$

V: Instantaneous source voltage.

II.3.6 Grid Voltage estimating

Voltage sectors are required to use the switch table, so the knowledge of line voltage is essential.

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad \text{II. (12)}$$

And for current:

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \quad \text{II. (13)}$$

The overall configuration of direct power control without voltage sensor for a three-phase inverter DPC consists of selecting a control vector from a switching table. The latter is based on the digitized errors dp, dq of the active and reactive powers instantaneous **(errors between the estimated active and reactive powers and those of reference),** provided by two-level hysteresis controllers, as well as on the position angular of the estimated voltage vector.

Depending on the value of this position, the plane **(α-β)** is divided into twelve sectors where each sector must be associated with a logic state of the rectifier.

II.3.7 Sector determination

Where headquarters & HP area unit the physical phenomenon bands The digitized variables stateless person, dq and also the voltage vector position **γUL = arc tg (uLα/uLβ)** or flux vector position **γΨL = arc tg (ψLα/ψLβ)** type a digital word, that by accessing the address of the look-up table selects the suitable voltage vector in keeping with the switching table. The region of the voltage or flux vector position is split into twelve sectors, as shown in Fig up and also the sectors are often numerically expressed as:

$$(n-2)\frac{\pi}{6} \le \gamma < (n-1)\frac{\pi}{6} \quad n=1\ldots12 \quad \text{II.(14)}$$

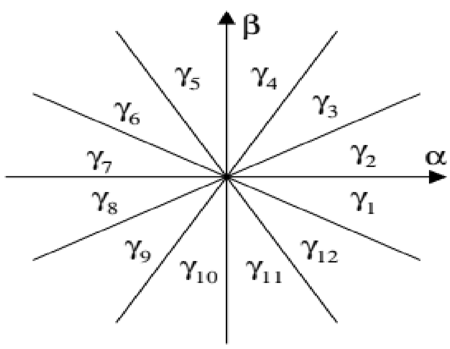


Figure II.9: Sector selection for DPC

When we control the phase angle **ε** and the amplitude of converter voltage us, we control indirectly the phase and amplitude of the line current.

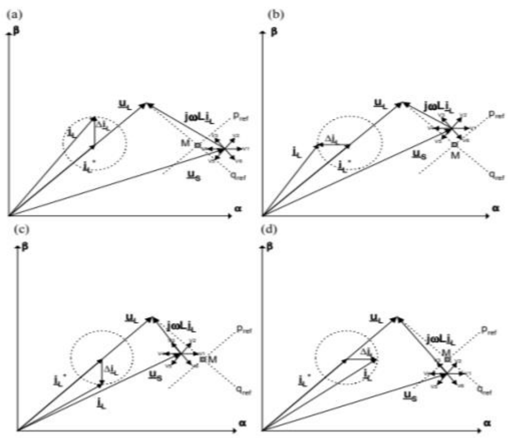


Figure II.10: Instantaneous power variation

a) - $P_{ref}<q$, $q_{ref}>q$ **(0, 1)** II.(15)

b) - $P_{ref}>p$, $q_{ref}>q$ **(1, 1)** II. (16)

c) - $P_{ref}>p$, $q_{ref}<q$ **(1, 0)** II. (17)

d) - $p_{ref}<p$, $q_{ref}<q$ **(0, 0)** II. (18)

The selection of vector is made so that the error between q and q_{ref} should be within the limits. It depends not only on the error of the amplitude but also the direction of q.

Some DPC behaviour is unsatisfactory for example when the file the reactive power vector is close to one of the sector bounds, two of the four active vectors wrong vectors. These faulty vectors can only alter instantaneous activity capacity without error correction reactive power. This is clearly visible on the stream. A few ways to improve DPC behaviour in sector bonds are well known.

One of them is adding more sectors or hysteresis. So, look up table generally with a difference in:

• Number of sectors.

• Dynamic performance.

• Hysteresis control

II.3.7.1 Number of sectors

The vector plane is usually divided into **6** or **12** sectors. She has Effect to look up table construction.

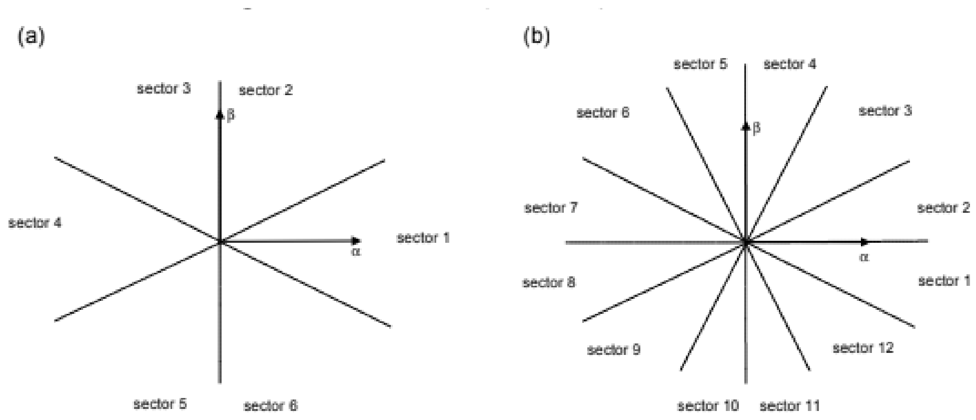


Figure II.11: Voltage plane with **(a)** and sectors **(b)** 6 – 12

Knowledge of the estimated voltage mains is necessary to determine the states of optimal switching. For this, the work plane **(α, β)** is divided into twelve sectors , **(The six nonzero vectors divide the α-β plane into six sectors each of which is divided into two equal sectors, in order to obtain precise control)** .

These can be determined by the following relationship:

$$(2k - 3)\frac{\pi}{6} < \theta_k < (2k - 3)\frac{\pi}{6}k = 1, 2, 3; 12 \qquad \text{II. (19)}$$

'k' is the sector number

Sets of each space vector of transformer voltage are used for the instantaneous change of active and reactive power.

Status is displayed for vector It is located in the k-th sector **(k = 1, 2, 3, 4, 5, 6)** of the plane. In the table, the single arrow means a little difference and the two arrows a Great contrast. As can be seen from the table, the increase in reactive power **(↑)** is obtained by applying the space vector UK, UK+ 1, and UK+ 2.

On the contrary, decreasing Reactive power **(↓)** is obtained by applying the vector UK-2, UK-1 or UK + 3. Active power Increase when UK+2, UK+3, UK+1, UK-2 or U0, U7 and lower active power are applied When UK, UK-1 is applied.

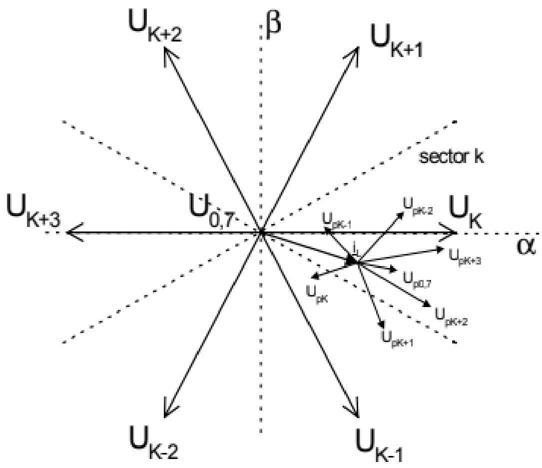


Figure II.12: Variation of converter voltage space vector

II.3.8 Hysteresis Controllers

The amplitudes of the instantaneous active and reactive hysteresis band have a relevant effect on the converter performance. In particular, the harmonic current distortion, the average converter switching frequency, the power pulsation, and the losses are strongly affected by the amplitudes of the bands.

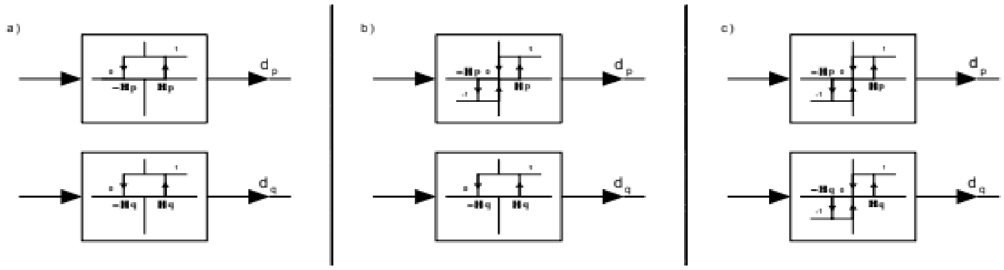


Figure II.13: Hysteresis controllers

The great simplicity of the implementation of the two-level comparator is the last choice of this type of regulator. In addition, energy considerations on the inverter impose a limited number of switching or for the same width of control hysteresis; the two-level comparator will require fewer switching.

The bandwidth of the hysteretic controller has a significant impact on the performance of the converter especially the current distortion, the average switching frequency of the converter, power ripple. In addition, losses are strongly affected by the hysteresis band the controller proposed in DPC is an active and reactive power regulator.

This regulator has a three-level hysteresis and other improvements can be considered the output of the hysteretic controller is given by the Boolean variables, dq representing the overflow or underflow of the power amplitude by respecting the following expressions **[39].**

II.3.9 The switching table

The dp and dq error digital signals and the working sector are the inputs of the switching Table **(II.2)**, where the switching states da, db and dc of the inverter are stored.

By using the table, the optimum switching state of the converter can be chosen from each switching table according to the combination of the digital signals dp, dq and sect.

That is to say, the choice of the optimum switching table is made so that the error active power can be restricted in a hysteresis band of 2hp width, and even for the reactive power error, with a band of width **2**hq.

Table II.2: Look up table **(switching table)**

dp	dq	$\gamma 1$	$\gamma 2$	$\gamma 3$	$\gamma 4$	$\gamma 5$	$\gamma 6$	$\gamma 7$	$\gamma 8$	$\gamma 9$	$\gamma 10$	$\gamma 11$	$\gamma 12$
1	**0**	V5	V5	V6	V6	V1	V1	V2	V2	V3	V3	V4	V4
1	**1**	V3	V3	V4	V4	V5	V5	V6	V6	V1	V1	V2	V2
0	**0**	V6	V1	V1	V2	V2	V3	V3	V4	V4	V5	V5	V6
0	**1**	V1	V2	V2	V3	V3	V4	V4	V5	V5	V6	V6	V1

II.4 Simulation of inverter controlled by DPC

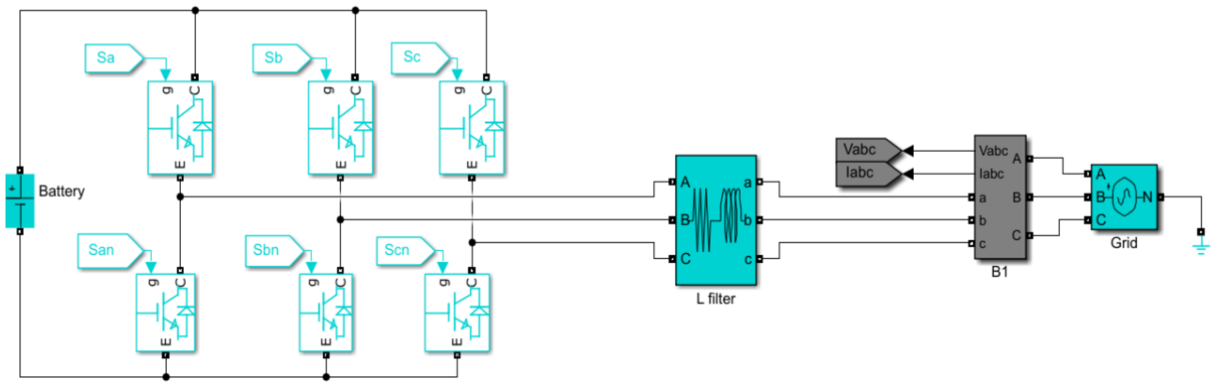


Figure II.14 Grid connected converter

01st step: conversion **abc** $\rightarrow \boldsymbol{\alpha\beta}$

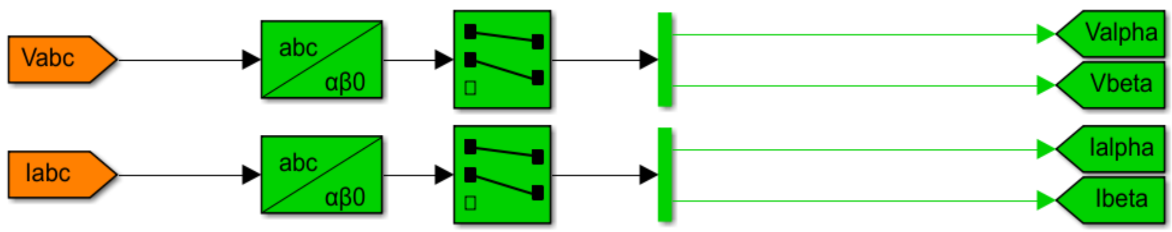
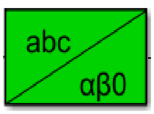


Figure II.15 Converting Vabc to $V\alpha\beta$

The conversion blocks 

are used:

$$\begin{bmatrix} u_\alpha \\ u_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix}$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

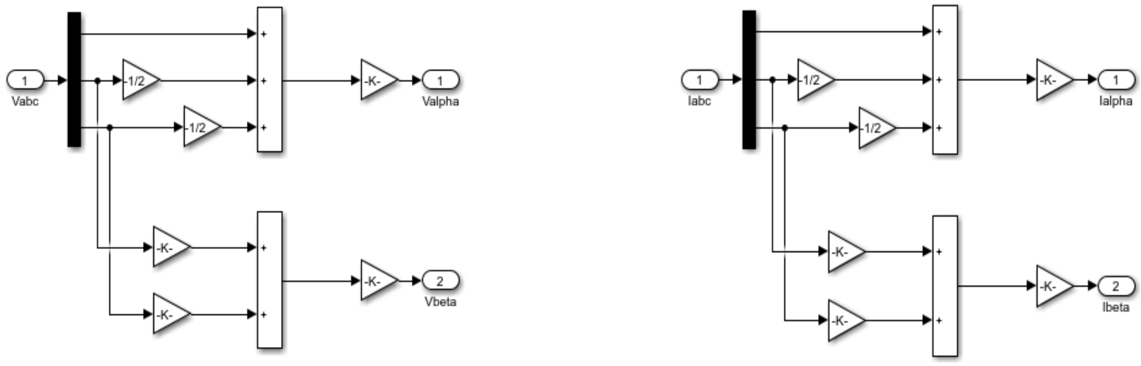


Figure II.16 Details of conversion **abc** to $\alpha\beta$

02nd step: Calculation of powers and Theta:

A- The powers P and Q:

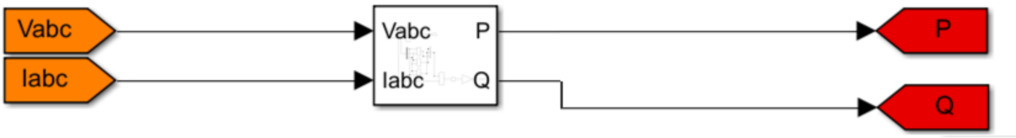
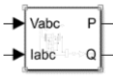


Figure II.17 Converting Vabc iabc to q, p

The power calculation simulink block  is used. This block calculates the instantaneous active and reactive powers.

Next, we use the blocks for calculating the average applied to the instantaneous values over a period. And to get p and q in the next block

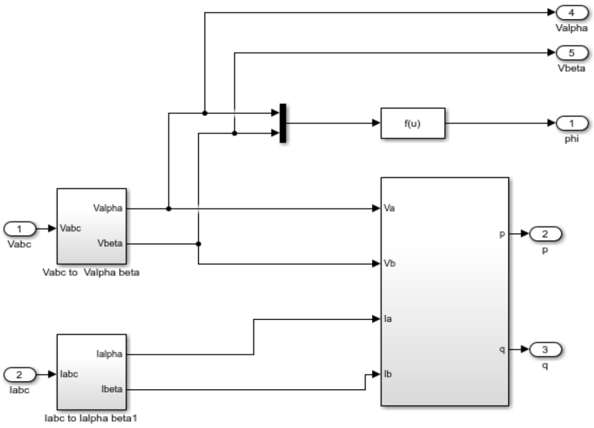


Figure II.18 Block converting Vabc and Ia, bc to p & q

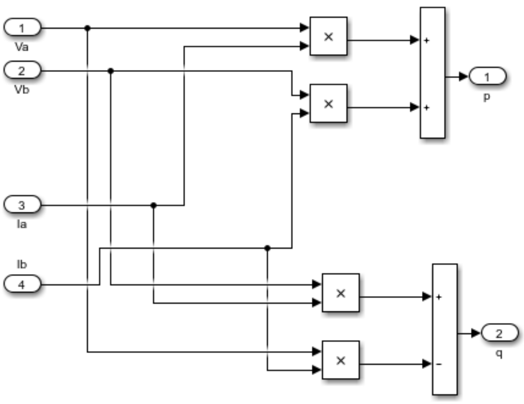


Figure II.19 Converting Va, Vb, Ia, Ib, to p q

We made the block **(figure 22)** as this equation:

P=VaIa + VbIb II. (20)

Q= - VbIa +VaIb II. (21)

2nd step power calculation and teta:

B –tetacalcul:

Figure II.20 V beta V alpha to teta

The arctangent calculation simulink block is used.

This block provides the phase between Vbeta and Valpha between **[-pi**, **pi].**

03rd step: Calculation of the sector of Theta:

Figure II.21 Grid voltage sector selected

To determine the sector of the phase we use an s-function

The programme of grid voltage sector selected:

```
GridVoltageSectorSelect*
function S = fcn(phi)
if (phi>=0)&(phi<pi/6)
    S=2;
elseif (phi>=pi/6)&(phi<pi/3)
    S=3;
elseif (phi>=pi/3)&(phi<pi/2)
    S=4;
elseif (phi>=pi/2)&(phi<2*pi/3)
    S=5;
elseif (phi>=2*pi/3)&(phi<5*pi/6)
    S=6;
elseif (phi>=5*pi/6)&(phi<pi)
    S=7;
elseif (phi>=-pi)&(phi<-5*pi/6)
    S=8;
elseif (phi>=-5*pi/6)&(phi<-2*pi/3)
    S=9;
elseif (phi>=-2*pi/3)&(phi<-pi/2)
    S=10;
elseif (phi>=-pi/2)&(phi<-pi/3)
    S=11;
elseif (phi>=-pi/3)&(phi<-pi/6)
    S=12;
else
    S=1;
end
```

Figure II.22 Function of grid voltage sector selected

04th step: Calculation of Sp and Sq:

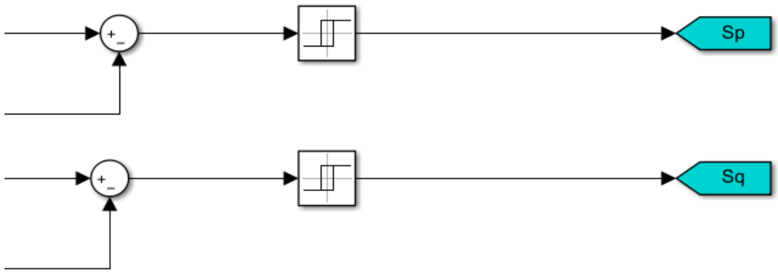


Figure II.23 Fromhys to sp and sq

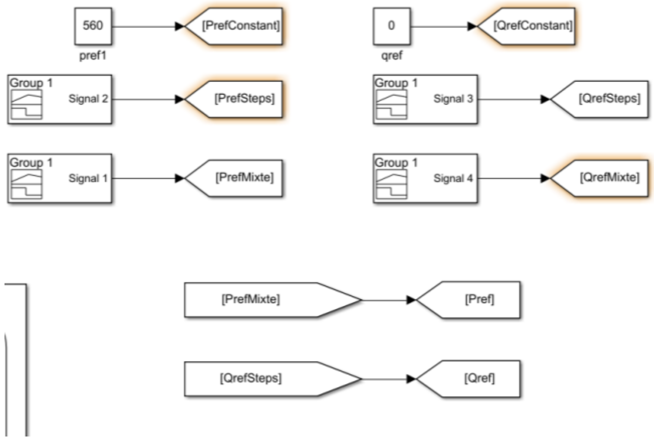


Figure II.24 Variable and constantpref and q_{ref} regulation

05th step: command generation look up table:

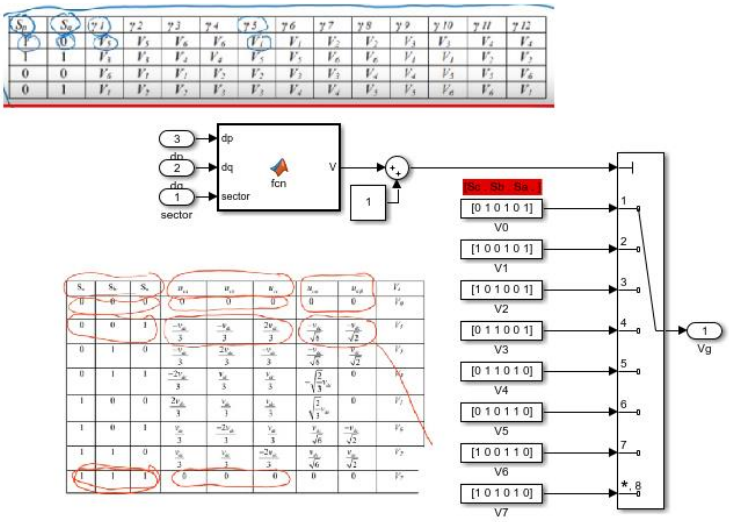


Figure II.25 Looks up table

Function:

```
function V = fcn(dp,dq,sector)
%sector 2
if     (sector==2)&(dp==1)&(dq==0), V=5;
elseif(sector==2)&(dp==1)&(dq==1), V=3;
elseif(sector==2)&(dp==0)&(dq==0), V=1;
elseif(sector==2)&(dp==0)&(dq==1), V=2;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==3)&(dp==1)&(dq==0), V=6;
elseif (sector==3)&(dp==1)&(dq==1), V=4;
elseif (sector==3)&(dp==0)&(dq==0), V=1;
elseif (sector==3)&(dp==0)&(dq==1), V=2;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%sector 3
elseif (sector==4)&(dp==1)&(dq==0), V=6;
elseif (sector==4)&(dp==1)&(dq==1), V=5;
elseif (sector==4)&(dp==0)&(dq==0), V=2;
elseif (sector==4)&(dp==0)&(dq==1), V=3;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==5)&(dp==1)&(dq==0), V=1;
elseif (sector==5)&(dp==1)&(dq==1), V=5;
elseif (sector==5)&(dp==0)&(dq==0), V=2;
elseif (sector==5)&(dp==0)&(dq==1), V=3;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==6)&(dp==1)&(dq==0), V=1;
elseif (sector==6)&(dp==1)&(dq==1), V=5;
elseif (sector==6)&(dp==0)&(dq==0), V=3;
elseif (sector==6)&(dp==0)&(dq==1), V=4;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==7)&(dp==1)&(dq==0), V=2;
elseif (sector==7)&(dp==1)&(dq==1), V=6;
elseif (sector==7)&(dp==0)&(dq==0), V=3;
elseif (sector==7)&(dp==0)&(dq==1), V=4;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==8)&(dp==1)&(dq==0), V=2;
elseif (sector==8)&(dp==1)&(dq==1), V=6;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==8)&(dp==1)&(dq==0), V=2;
elseif (sector==8)&(dp==1)&(dq==1), V=6;
elseif (sector==8)&(dp==0)&(dq==0), V=4;
elseif (sector==8)&(dp==0)&(dq==1), V=5;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==9)&(dp==1)&(dq==0), V=3;
elseif (sector==9)&(dp==1)&(dq==1), V=1;
elseif (sector==9)&(dp==0)&(dq==0), V=4;
elseif (sector==9)&(dp==0)&(dq==1), V=5;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==10)&(dp==1)&(dq==0), V=3;
elseif (sector==10)&(dp==1)&(dq==1), V=1;
elseif (sector==10)&(dp==0)&(dq==0), V=5;
elseif (sector==10)&(dp==0)&(dq==1), V=6;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==11)&(dp==1)&(dq==0), V=4;
elseif (sector==11)&(dp==1)&(dq==1), V=2;
elseif (sector==11)&(dp==0)&(dq==0), V=5;
elseif (sector==11)&(dp==0)&(dq==1), V=6;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==12)&(dp==1)&(dq==0), V=4;
elseif (sector==12)&(dp==1)&(dq==1), V=2;
elseif (sector==12)&(dp==0)&(dq==0), V=6;
elseif (sector==12)&(dp==0)&(dq==1), V=1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
elseif (sector==1)&(dp==1)&(dq==0), V=5;
elseif (sector==1)&(dp==1)&(dq==1), V=3;
elseif (sector==1)&(dp==0)&(dq==0), V=6;
else   (sector==1)&(dp==0)&(dq==1), V=1;
end
```

Figure II.26 Programme fun look up table

II.5 Conclusion

The principle of direct power control, presented in this chapter, has provided very interesting solution for the treatment and modelling of the method of DPC.

This direct control is based on the instantaneous evaluation of the active powers and responsive to each switching table of the converter, and requires no sensor of AC voltage to know the position of the linevoltage

Chapter III

DPC of micro-grid

III.1 Introduction

In the previous chapter we've talked about the DPC and the steps that we should follow, in this chapter we realize a simulation and discus results of DPC in three ways:

The first way is the model with L filter and the second one is the filter LCL in the same model, but we've change L with LCL**.**

And in the last one we take two copies of the models LCL and we change the settings and we make a new grid converter for this model "Para" which has two of the converter grid LCL which are connected to each other. Then we merge them to make this model LCL "Para" that it shown in (**fig.III.17).**

In the end we present the advantages and disadvantages and we made a short conclusion that talk all about this chapter.

Modeling a two-level grid-connected inverter

The figure below (Figure III.I) shows a voltage source inverter topology bidirectional the three phases are connected to the supply by inductive impedance (R-L). Voltage the DC Vdc supplied by the micro-grids system is assumed to be constant.

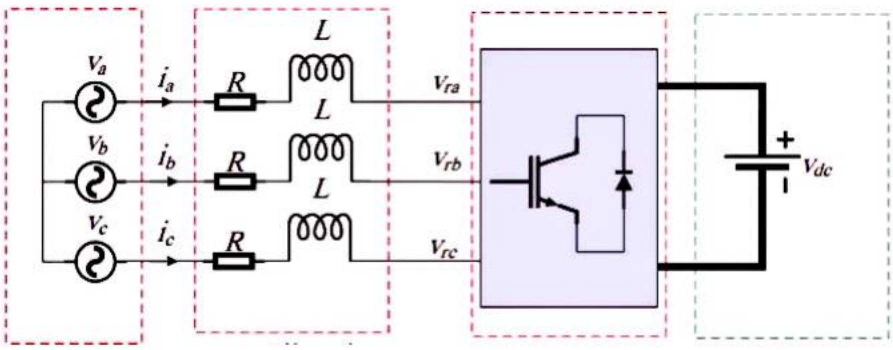


Figure III.1 Electrical diagram of a three-phase inverter connected to the network

III.1.1 Two-level three-phase inverter

With the laws of mails we find

$$Va = L\frac{dia}{dt} + Ria + Vra \qquad \text{III. (1)}$$

$$Vb = L\frac{dib}{dt} + Rib + Vrb \qquad \text{III. (2)}$$

$$Vc = L\frac{dic}{dt} + Ric + Vrc \qquad \text{III. (3)}$$

The voltages Va , Vb , Vc are inverter output voltages.

III.1.2 Connection filter

The filter is a connection consists of the perfect inductor L and a resistor R For the first model.

III.1.3 Electrical network

A three-phase network is modeled by a balanced sinusoidal three-phase system as follows:

$$Va = Vm \sin(w_0 t) \qquad \text{III. (4)}$$

$$Vb = Vm \sin(w_0 t - \frac{2\pi}{3}) \qquad \text{III. (5)}$$

$$Vc = Vm \sin(w_0 t - \frac{4\pi}{3}) \qquad \text{III. (6)}$$

Or $w_0 = 2 \int_0$ is the pulsation and Vm is the maximum voltage value.

III.1.4 System Description of filter LCL

Figure III. II shows the general structure of the grid-connected three-phase VSI with

LCL-filter, where Li and Lg are the inverter-side and grid-side inductor, C is the capacitor with series damping resistor, Rd. Resistors Ri and Rg, are the inverter and grid-side resistances, respectively.

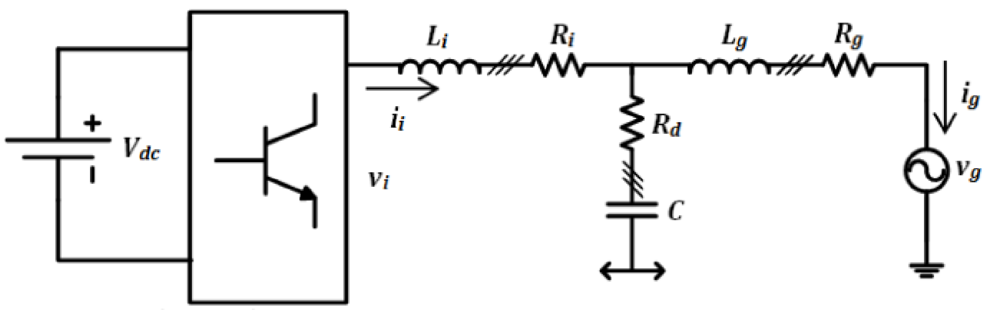


Figure III.2 Electrical diagram of a three-phase inverter connected to the grid

III.1.5 modeling of filter LCL

Grid voltage is assumed to behave as an ideal voltage source which is capable of sinking all harmonics when deriving the LCL transfer function that is responsible for closed loop system bandwidth in grid-connected operation of the inverter. All the parasitic resistors (Rd, Ri and Rg) are neglected to represent the worst damping performance of the system For grid-side control.

$$\frac{ig(s)}{vi(s)} = \frac{1}{s\ 3LiLgC+s(Li+Lg)} \qquad \text{III. (7)}$$

Transfer function for the inverter-side current to inverter-side voltage is:

$$\frac{ii(s)}{vi(s)} = \frac{s2LgC+1}{s3LiLgC+s(Li+Lg)} \qquad \text{III. (8)}$$

Transfer function for the grid-side current to inverter-side current is:

$$\frac{ig(s)}{ii(s)} = \frac{1}{s2LgC+1} \qquad \text{III. (8)}$$

Where ig and ii are grid-side current and inverter-side current and vi and vg are the inverter-side and grid-side voltages respectively. Figure 2.2, shows the Y-connected and delta Δ-connected capacitor branch for LCL-filter. The resonance frequency of the LCL-filter with Y-connected capacitor is given by:

$$\omega_{2res} = (Li+Lg/LiLgC) \qquad \text{III. (9)}$$

Resonance frequency of the LCL-filter with Δ-connected capacitor is given by [13];

$$\omega_{2res} = 1/3 * (Li+Lg/LiLgC) \qquad \text{III. (10)}$$

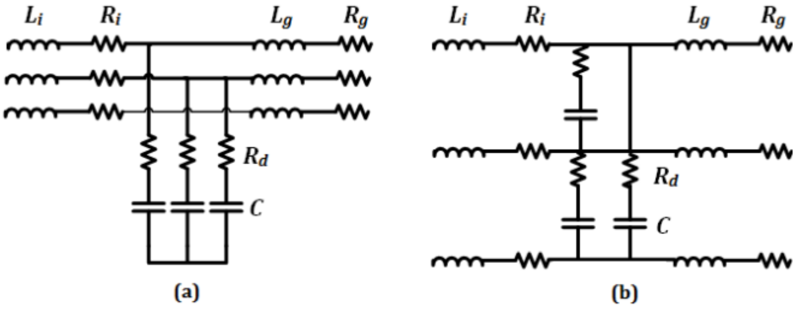


Figure III.3 Y-connected and delta-connected capacitor branches.

Δ-connected capacitor offers higher attenuation when compared with the connected capacitor. Furthermore, there are reduced harmonics in the current flowing into the Δ-connected capacitor compared to Y-connected **[10].** In the case of lowers witching frequencies, harmonics become significant and inverter control signal is distorted by these capacitor harmonics. However, the Δ-connected configuration can distort the grid-injected current, if the phase lock loop (PLL) is sensitive to grid line to-line voltage harmonics the analysis in this chapter will be based on connected capacitor branch. Therefore, can be further expanded as;

$$L_T C = k2 * (1+\mu)2 / 4\pi 2 f sw 2 \mu \qquad \text{III. (11)}$$

III.2 DPC of a single three phase grid-connected Inverter

The simulations and the result of each model presented:

III.2.1 L filter and SV-PWM

We present here the simulation results obtained for different tests. The study by simulation was performed for parameters used in simulation are:

Table III.1: The parameters of simulation L filter

line resistance	0.25 **Ω**
Line inductance	0.01 **H**
Maximum grid voltage amplitude	Em=$220\sqrt{2}$**V**
Frequency	50 **Hz**
Battery	600 **V**
Phase	Ø=120°

Simulation Model: Model1Lfilter.slx

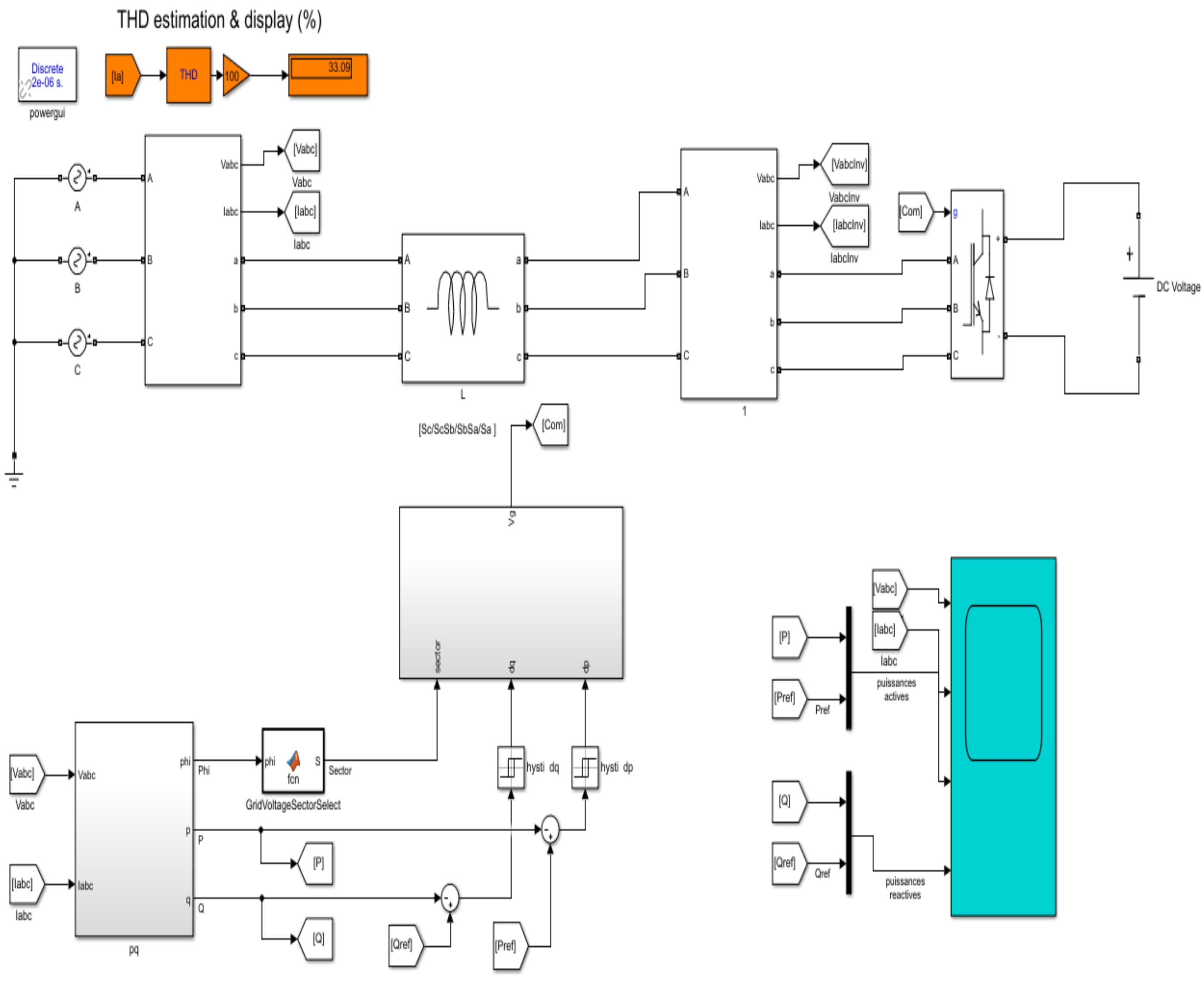


Figure III.4: DPC with model L filter

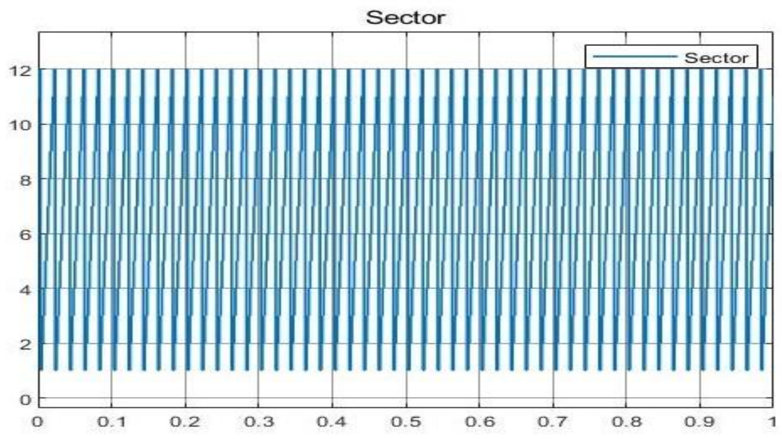


Figure III.5: Sector

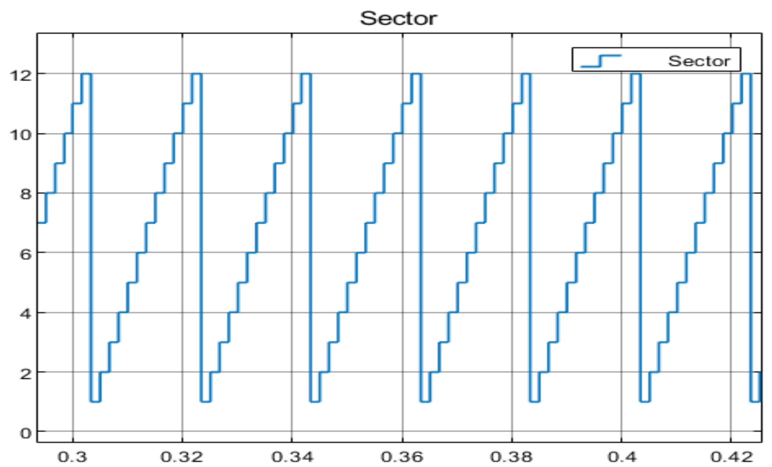


Figure III.6: Sector zoomed

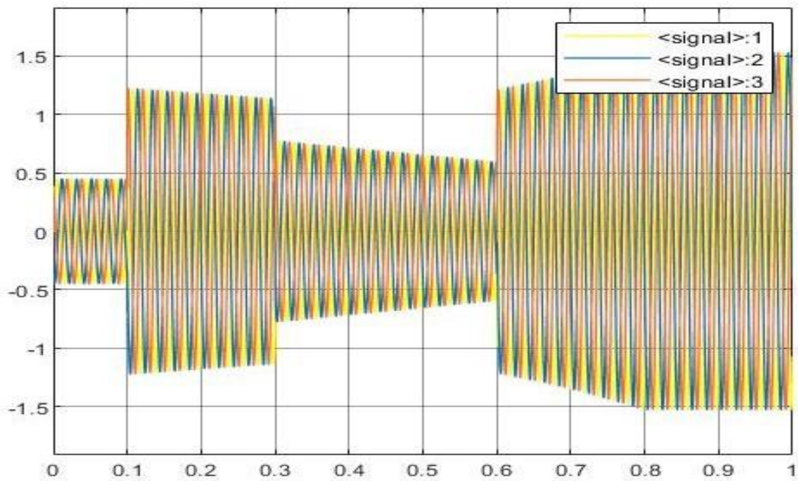


Figure III.7: Source current

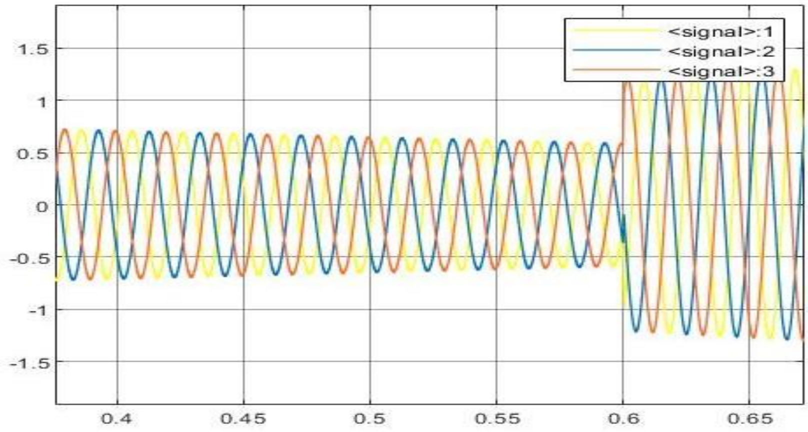


Figure III.8: Source current zoomed

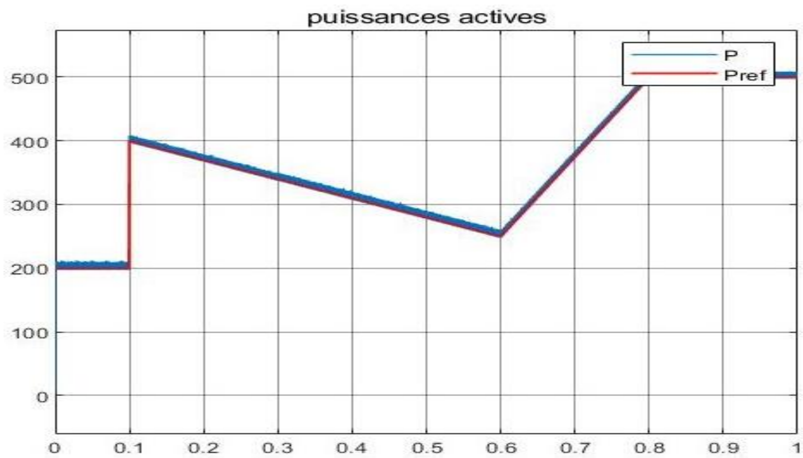


Figure III.9: Active power and its reference

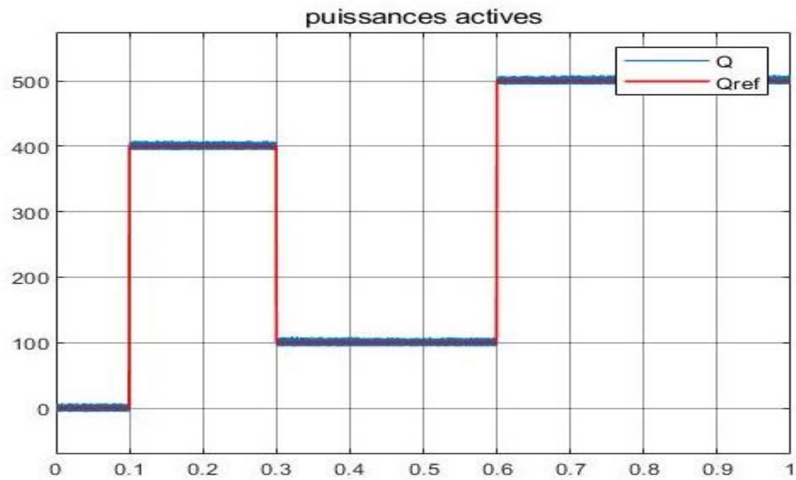


Figure III.10: Reactive power and its reference

Results and Description 1

These simulations are all about model L filter that showed (the sector, the current, power active and reactive) with pref and qref a variable in terms of time. For 02 different references profiles of P and Q and current **(L = 0.01 H).**

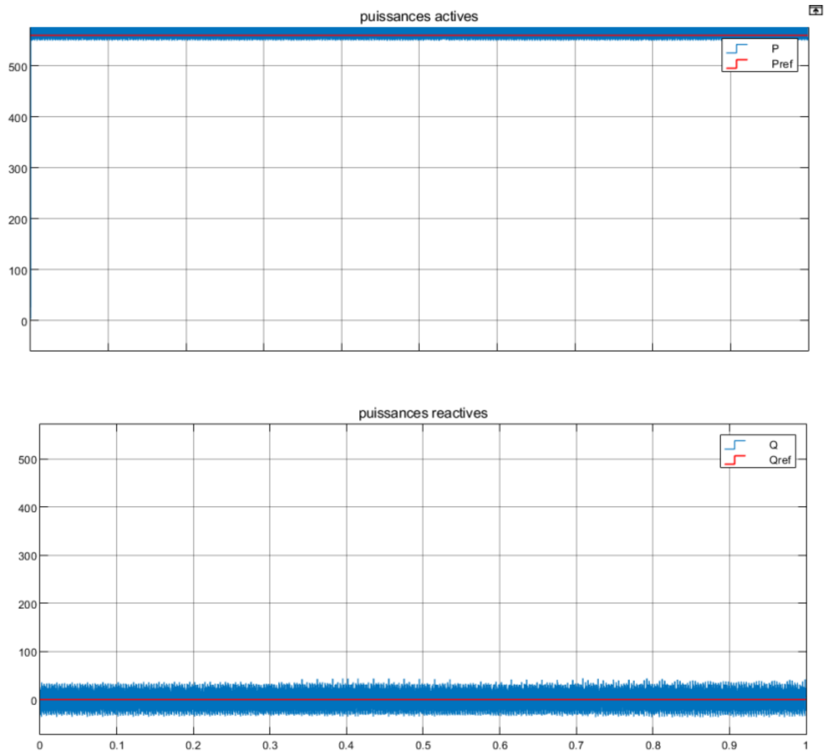


Figure III.11: Active and reactive power and its reference

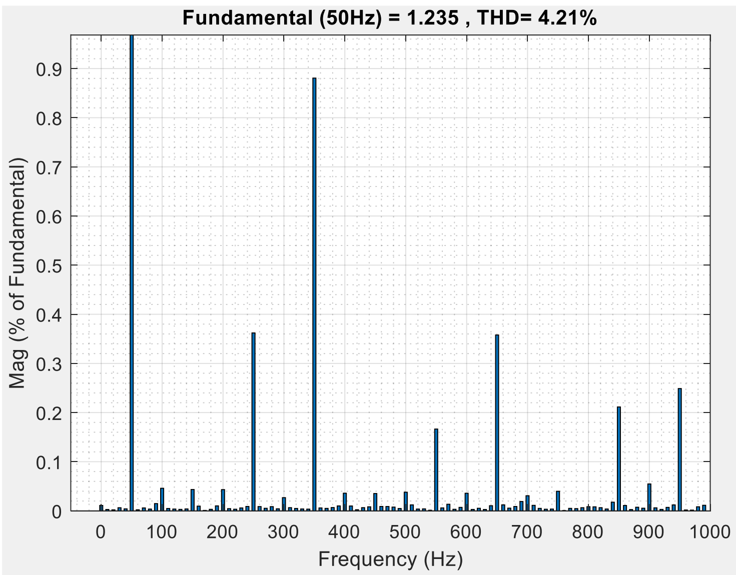


Figure III.12: Different values of filter inductance L THD

Results and Description 2

These simulation are about L filter but we fixed pref and qref, we study the THD of this L filter that give us 4.21% is great. For P_{ref} = 560 ETQ_{ref} = 0 for different values of filter inductance L to study THD L = 0.01 H, **THD = 4.21%**

III.2.2 LCL filter and SV-PWM

The simulation model LCL presented the same model like the first one of L filter but the deferent between the two in LC.

We present here the simulation results obtained for different tests the study by simulation was performed for parameters used in simulation are:

Table III.2: The parameters in LCL filter

line resistance	0.25**Ω**
Line inductance	0.05 **H**
g line	0.001 **H**
Maximum grid voltage amplitude	Em=220$\sqrt{2}$**V**
Capacitor	0.000005 **F**
Frequency	50 **Hz**
Battery	600 **V**
Phase	Ø=120°

Simulation model: Model1LCLfilter.slx

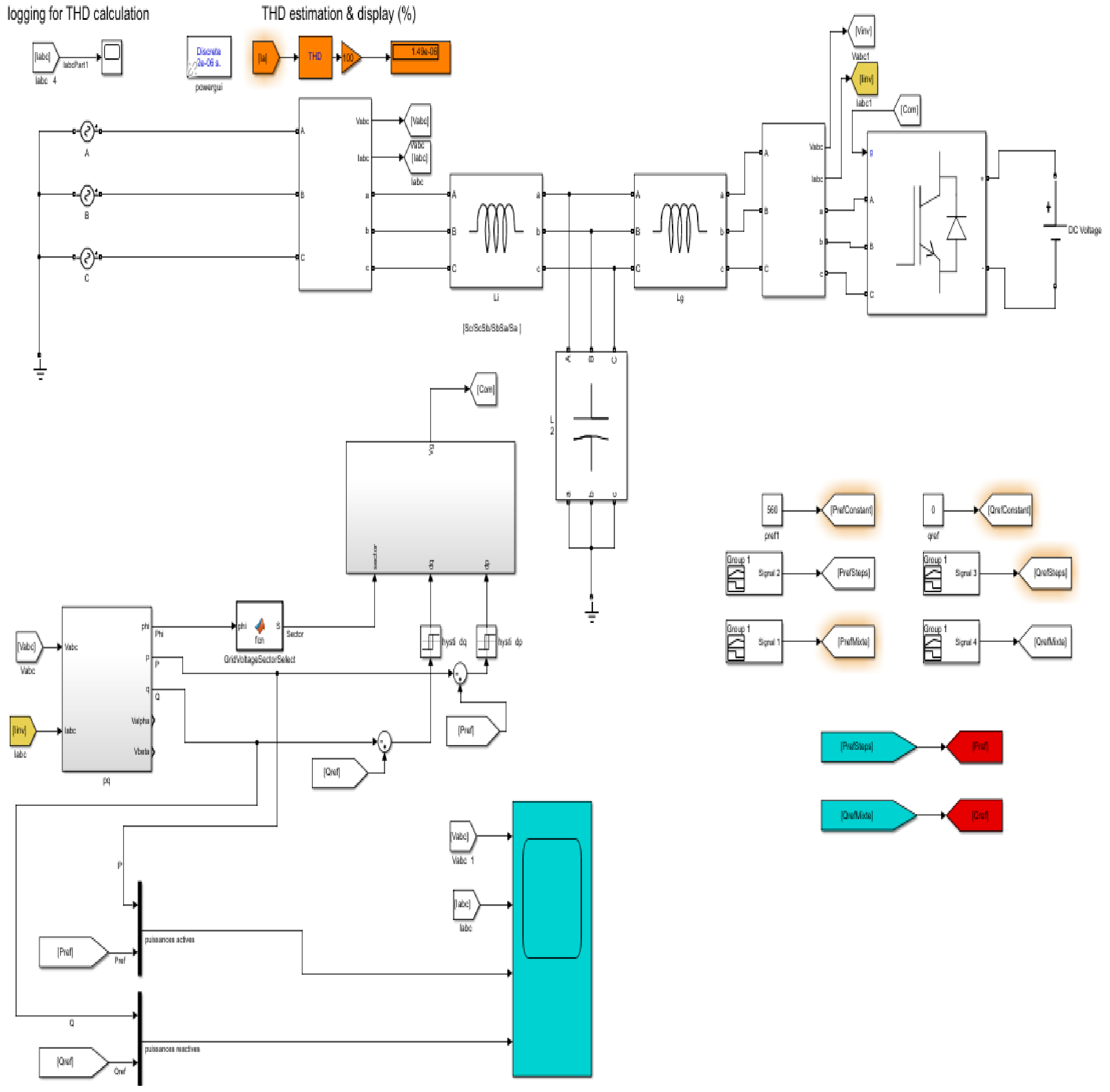


Figure III.13: DPC with LCL filter

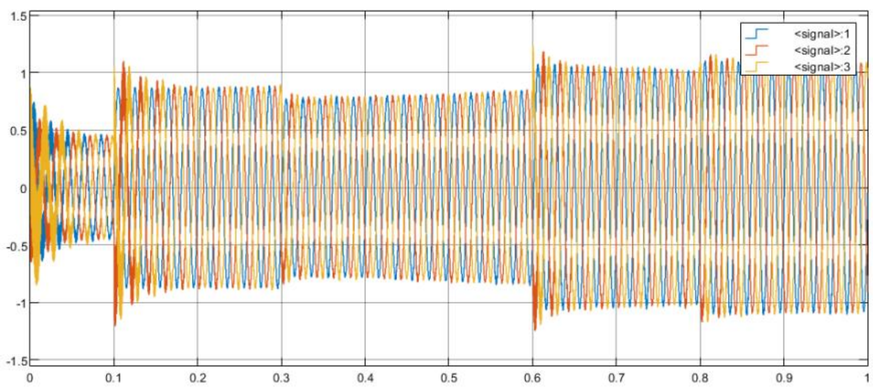


Figure III.14: Source curèrent LCL filtre

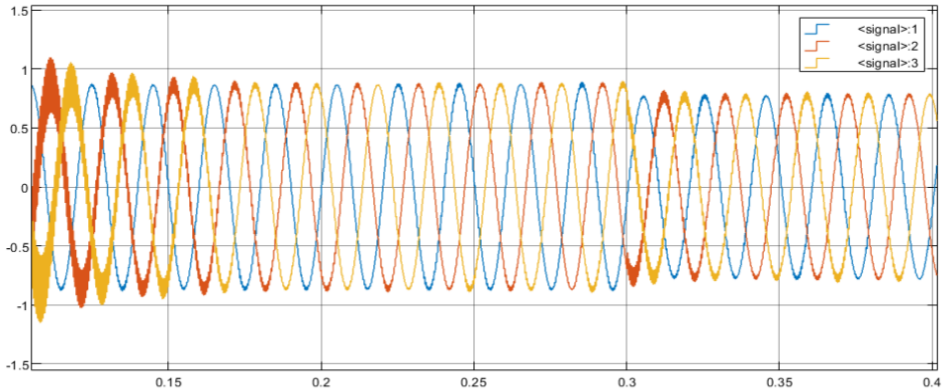


Figure III.15: Source current zoomed

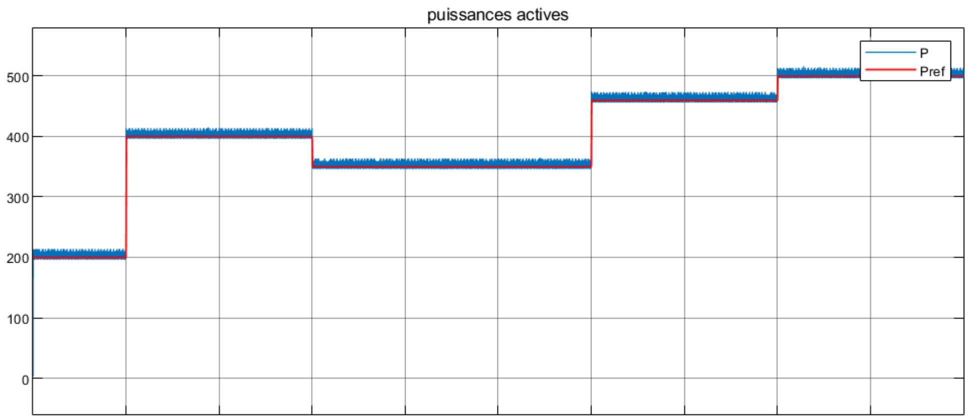


Figure III.16: Active power and its reference

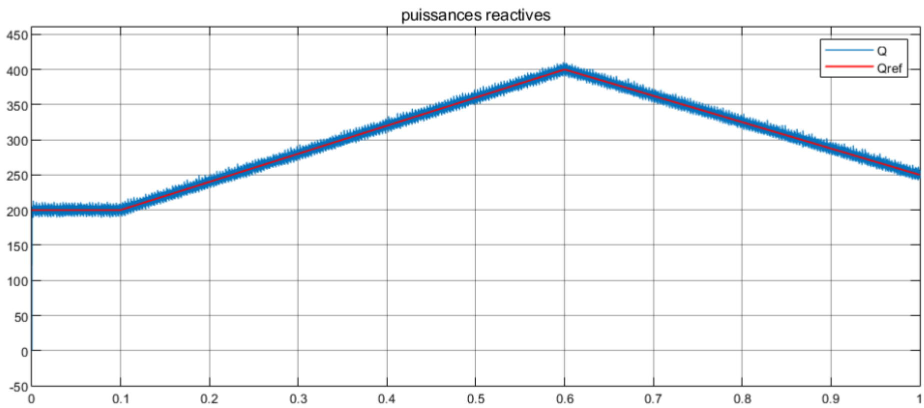


Figure III.17: Reactive power and its reference

Results and Description 3

These simulations are all about LCL filter that showed (the current, power active and reactive) with pref and qref a variable in terms of time For 02 different references profiles of P and Q **(Li = 50mH (inverter side)),** C =5μF, Lg = 1mH **(grid side).**

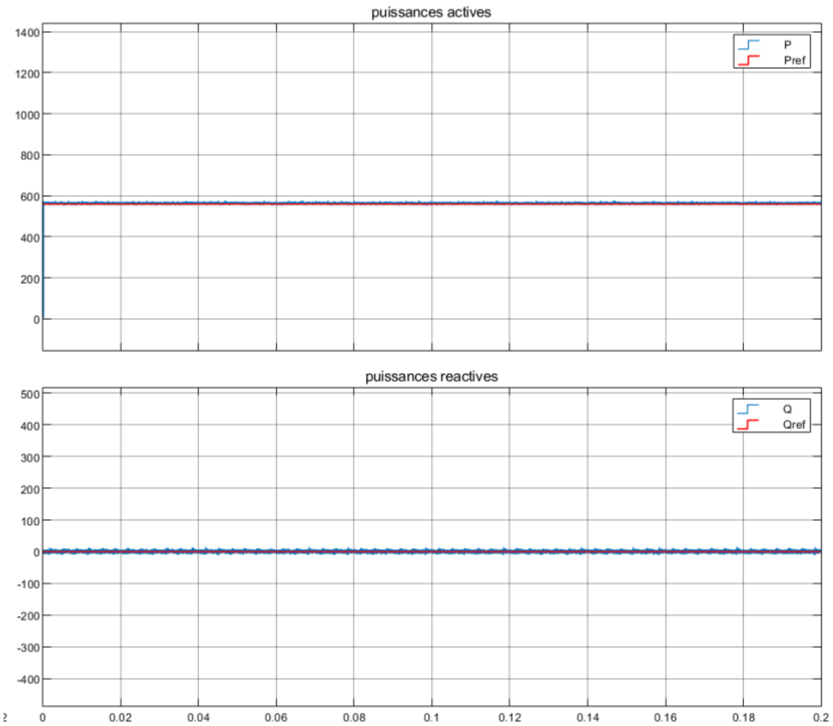


Figure III.18: Active and reactive power and its reference of LCL

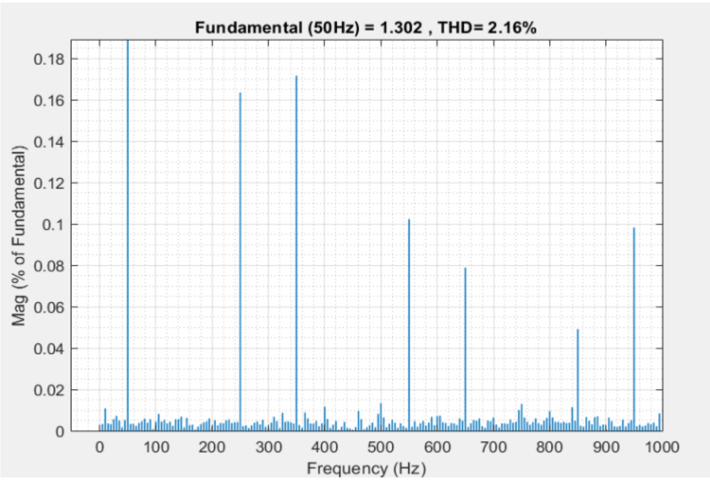


Figure III.19: Different values of filter inductance LCL

Results and Description4

These simulation are about LCL filter but we fixed pref and qref, we study the THD of this LCL filter that give us 2.16% is great. For constant references of P and Q **(Li = 50mH).**

III.2.3 LCL filter Para and SV-PWM

The simulation of LCL Para presented two of LCL model mixed, we present here the simulation results obtained for different tests the study by simulation was performed for parameters used in simulation are: Parameters used in this simulation are the same table of model LCL filter **(Table III.2).**

Simulation model: Model1LCLpara

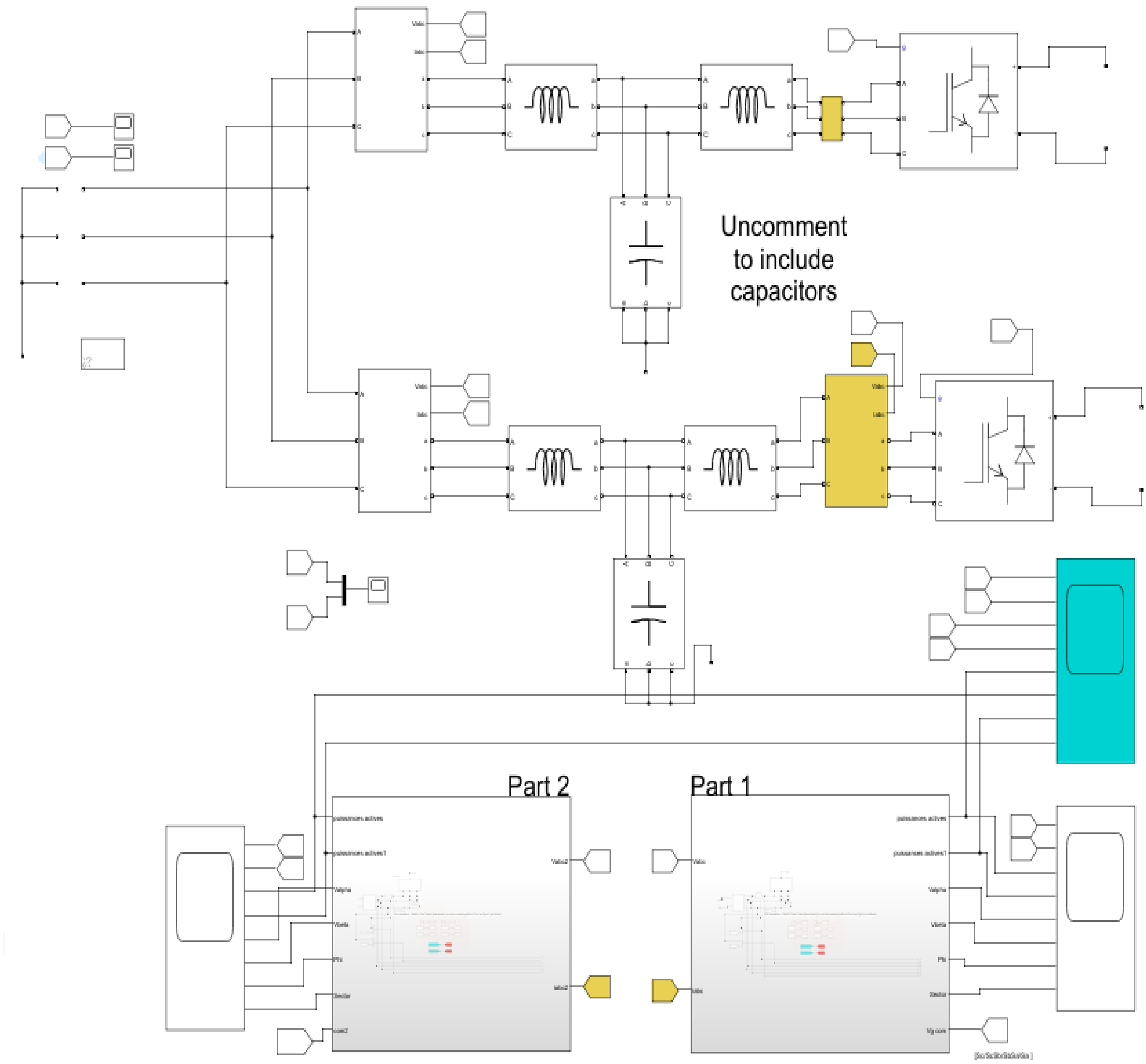


Figure III.20: DPC with model LCL Para

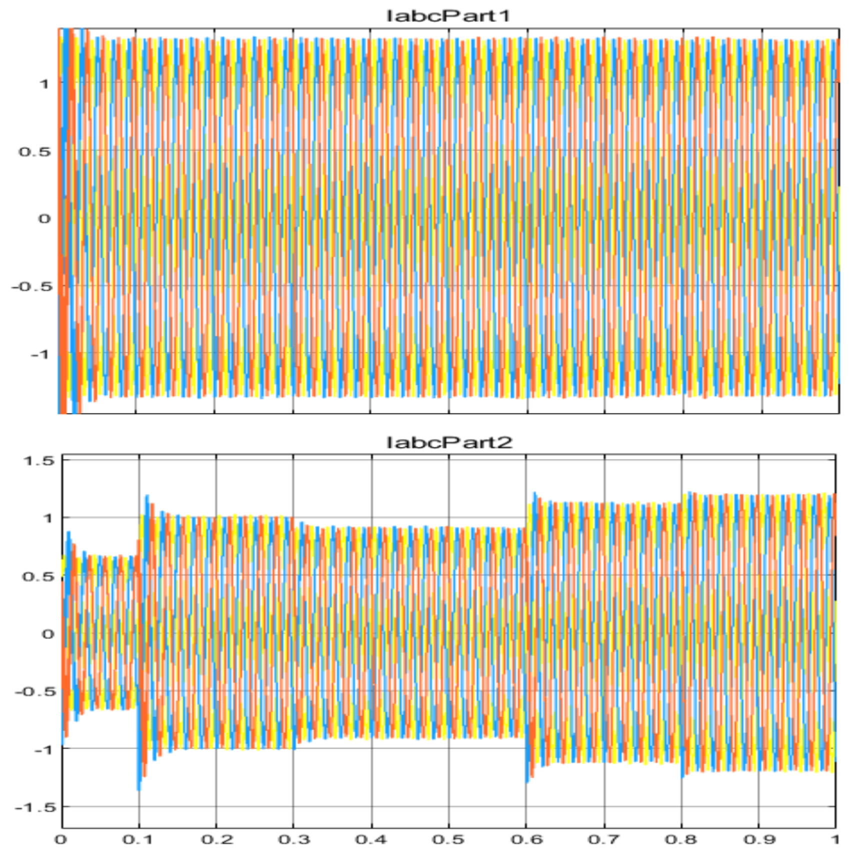


Figure III.21: Current part 01 and part 02 of model LCLpara

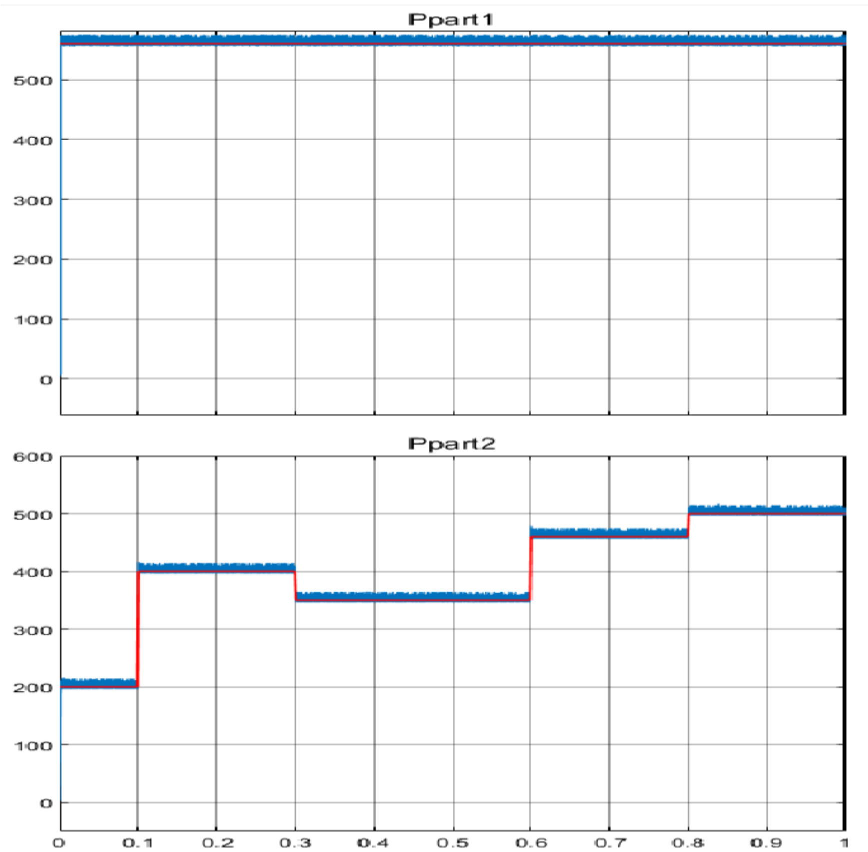


Figure III.22: Power active part 01 and part 02 for LCL Para

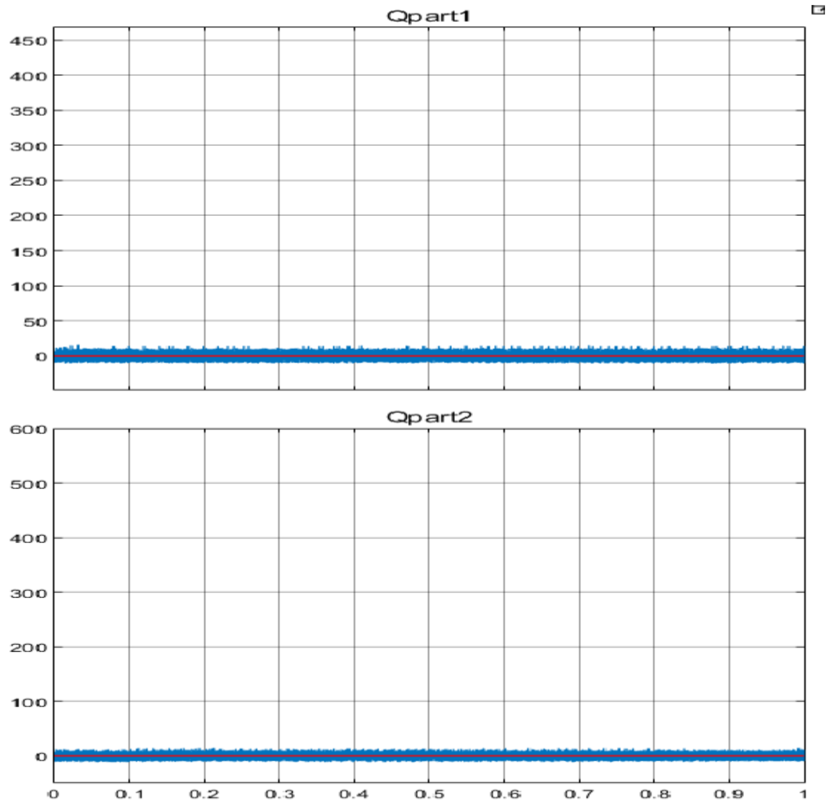


Figure III.23: Power reactive part 01 and part 02 for LCL Para

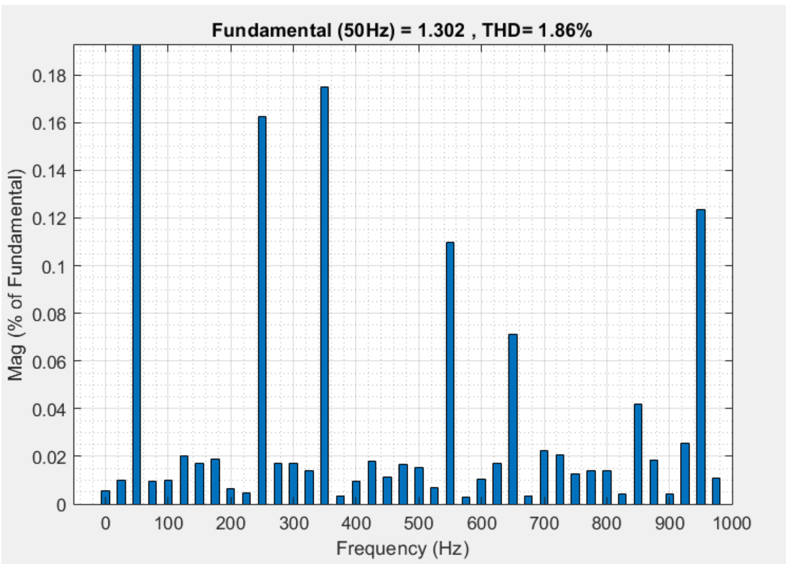


Figure III.24: Different values of filter inductance LCL Para THD

Results and disruption 5

For part 01 the Pref and qref are constant (Pref = 560), (qref =0), and part 02 for 02 different references profiles of P and Q (Li = 50mH) (inverter side), C =5□F, Lg = 1mH (grid side).

III.2.4 Interpretation of simulation results

It can be observed that the active and reactive powers perfectly follow their reference values **(with no certain fluctuation or overflow)** in all models. It was also noted that the line current harmonic spectrum THD and deferent between the models L and LCL and LCL "Para" filter while the THD of L filter is 4.21 % and LCL filter is 2.16 % and LCL "Para" 1.86 %.It can be concluded that the DPC gives betters results for harmonic minimization and responds very quickly to changes in the power set point. DPC models represented in the table III.3, table III.4 summarizes the main characteristics.

Table III.3: representation of simulation result between the three models

DPC Models	Frequency of commutation	p	q	THD
L filter	constant	560	0	4.21 %
LCL filter	constant	560	0	2.16 %
LCL Para	constant	560	0	1.86 %

The following table summarizes the main characteristics.

Table III.4: Table of the main characteristics

TECHNIQUE	ADVANTAGES	DISADVANTAGES
DPC	- No separate PWM block - No current regulation loop - No coordinate transformation - Good dynamics - Simple algorithm - Decoupled active and reactive power control - Instantaneous variables with all harmonics components estimated (improve power factor and efficiency)	- High inductance and sample frequency needed - Power and voltage estimation should be avoid at the moment of switching - Variable switching frequency - Fast microprocessor and A/D converters required

III.3 Conclusion

In this chapter, the DPC command with a commutation table of three-phase inverter is studied. First of all, the configuration and the principle of the DPC have a major drawback linked to the periodicity of the control signals of the switches, which cannot be controlled.

In addition, it requires a high sampling frequency to obtain precise and efficient control of the active and reactive powers.

The principle of direct power control, presented in this chapter, has brought a very interesting solution to the treatment of the issues at the source. This direct control is based on the instantaneous evaluation of the active and reactive powers at each switching table of the converter.

In conclusion, it can be deduced from the simulation results that the DPC is very effective in dealing with the drawbacks presented.

General Conclusion

General Conclusion

The work presented in this thesis exposes the direct power control DPC General Information on harmonics and pollution of electrical networks has been present. Then, and first of all, a modeling of grid control was made just to compare the performance with the three-phase PWM rectifier (based on transistors) which was made second. Finally, the direct power control (DPC) based on the estimation of voltages of the network was presented and applied to the three-phase. The simulation results obtained clearly show the validity of the techniques of command presented in this thesis. They allowed us to have continuous tension controllable, adjustable active and reactive power, distortion rate harmonic (THD) reduced with unity power factor.

We studied, a modeling study of the inverter used as an inverter connected to the network, then exposed the DPC commands and carried out the simulation of the three-phase inverter controlled by the various direct controls of the power connected to the network, such as the command direct power predictive direct power control with variable switching frequency and constant. These algorithms are simple; do not require any modulation blocks or loops. Current regulation and they directly control the active and reactive powers.

At the end and for the continuity of the research related to this work, we propose perspectives:

• The implementation of the commands presented in this thesis in order to verify experimentally the theoretical results.

• Resume the study presented by changing the three-phase rectifier by a multi-level rectifier to further improve the desired performance.

• Improve the control technique presented (DPC), by fixing the frequency of switching by the application of the DPC_SVM, the fuzzy DPC or the DPC neuronal.

• Apply other three-phase PWM rectifier control techniques such as: Predictive CPD, VOC, etc.

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ABSTRACT: In this memoire, several direct feed forward power control methods are proposed for DC /AC converters **(three-phase grid-connected Inverter).**

Different versions of prediction methods have been proposed, also with variable and constant switching frequencies. Methods guarantee high transient dynamics and low THD of line currents the proposed method is compared to well-known method: direct power control based on the ST-DPC switching table and direct power control.

Several simulations and experimental results show that the feed forward method can improve transient response and reduce higher harmonic distortion even at low switching frequencies. In addition, it is possible to work without a line voltage sensor.

Keywords: three-phase grid-connected Inverter, DPC, and THD.

RESUME: Dans ce mémoire plusieurs méthodes de contrôle de puissance à réaction directe sont proposées pour les convertisseurs DC/AC **(onduleur triphasé connecté au réseau).**

Différente versions de méthodes de prédiction ont été proposées, également avec des fréquences de commutation variables et constantes

Les méthodes garantissent une dynamique transitoire élevée et un faible THD des courants de ligne

La méthode proposée est comparée à des méthodes bien connues: commande directe de puissance basée sur la table de commutation ST-DPC et commande directe de puissance.

Plusieurs simulations et résultats expérimentaux montre que la méthode d'anticipation peut améliorer la réponse transitoire et réduire la distorsion harmonique supérieure même à des fréquences de commutation basses de plus il est possible de travailler sans capteur de tension de ligne.

Mots clés: Onduleur triphasé connecté au réseau DPC et THD

ملخص :في هذه المذكرة، تم اقتراح العديد من طرق التحكم في الطاقة المباشرة للتغذية الأمامية لمحولات التيار المستمر / التيار المتردد **(العاكس المتصل بالشبكة ثلاثي الأطوار).**

تم اقتراح إصدارات مختلفة من طرق التنبؤ، وأيضًا بترددات تبديل متغيرة وثابتة. تضمن الطرق ديناميكيات عابرة عالية و**THD**منخفض لتيارات الخط، وتتم مقارنة الطريقة المقترحة بالطريقة المعروفة: التحكم المباشر في الطاقة على أساس جدول تبديل **ST-DPC**والتحكم المباشر في الطاقة.

تظهر العديد من عمليات المحاكاة والنتائج التجريبية أن طريقة التغذية الأمامية يمكنها تحسين الاستجابة العابرة وتقليل التشوه التوافقي العالي حتى عند ترددات التحويل المنخفضة. بالإضافة إلى ذلك، من الممكن العمل بدون مستشعر جهد الخط.

الكلمات الرئيسية: العاكس المتصل بالشبكة من ثلاثي أطوار، DPC، و**.**THD