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Research Article

Control of a wind conversion chain based on PMSG integrating a vienna rectifier and Shunt Active Power Filters

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Abstract – This article exposes an electricity production system, composed of a wind turbine with horizontal axis connected to a synchronous generator with permanent magnet (with pole), connected to the network via a power circuit combining a rectifier of Vienna controlled by the command vector with SVPWM modulation and shunt Active Power Filter (sAPF) using the P-Q algorithm. The simulation results show a good performance of the proposed control strategy.

Keywords – Wind Turbine,Vienna Rectifier, Pmsg, Foc, Sapf, Thd

I. INTRODUCTION

In recent times, with the appearance of ecological and economic constraints, which have pushed scientists to explore other ways for the production of electricity that respects nature and is sustainable, among them the wind power sector, which has experienced unrelenting growth, not negligible in recent years.

Wind energy is clean and sustainable. It is one of the fastest growing renewable energies the conversion of the kinetic energy of wind into electrical energy is multidisciplinary in nature, involving aerodynamics, mechanical systems, electrical machinery, power electronics, theory control and power systems. [1]

Wind power is increasingly chosen as a means of substitution for the conventional technique of electricity production in the world,

Installed wind capacity has steadily increased over the past two decades. From 2009 it has globally exponentially

from approximately 6 GW in 1996 to 158 GW in 2009. The wind power industry has achieved an average growth rate of more than 25% since 2000 and should continue this trend in the years to come.[1]

Many studies are undertaken to find the best approach for the exploitation of wind energy, two preferred topologies for wind energy, the first the One topology uses a permanent magnet synchronous generator (PMSG) and the second the double-feed machine (MADA), of these two types of machine the first seems very promising in the wind field, given that it has advantages such as power density. high, reducing the size and weight of the generator. In addition, there are no losses in the winding of the rotor, thus reducing thermal stress on the rotor.

Systems that use PMSG are composed of a wind turbine that directly drives the multipole generator. The system uses an AC-DC-AC power conversion system. [4]

Non-linear devices produce distorted current which produce harmonics which have several impacts on the utility network, to eliminate these constraints have used The Shunt Active Power Filters the use of these filters improves the reliability of the system is keeping total harmonic distortion (THD) as low as possible, thus improving the quality of the electrical network.

In this article, the analysis relates to a configuration of a system composed of a wind turbine coupled to a synchronous generator, linked to a vienna rectifier and a The Shunt Active Power Filters used to inject the energy of the 'wind turbine in the grid network under conditions of fixed wind speed and pitch angle, the proposed design is not only capable of supplying wind power to the network, but will also act as a power parallel active filter to attenuate current harmonics and

regulate the reactive power injected by the non-linear loads.

The control algorithm used in the active filtering of our system is called the instantaneous power method.

II. Materials and Method

A. *THE TURBINE MODELING*

Wind turbine is a machine that by definition, transforms wind energy into mechanical energy. The kinetic power of the wind is defined by the following equation. [2]

$$P_m = \frac{1}{2}\rho.A.V^3 \qquad (1)$$

Or ρ is the density of air, which are approximately 1.2 kg / m³.

As the turbine can only convert a percentage of the wind energy presented by the coefficient Cp, the expression for the aerodynamic power can be described as follows:

$$P_m = \frac{1}{2}Cp(\lambda).\rho.A.V^3 \qquad (2)$$

The specific speed λ is defined as the ratio between the linear speed of the turbine and the wind speed.

$$\lambda = \frac{R.\Omega}{V} \qquad (3)$$

Where *Ω*: is the angular speed of rotation of the blades.

The power coefficient Cp(λ, β) represents the aerodynamic efficiency of the Wind turbine, it depends on the specific speed λ and the angle of orientation of the blades β. It is determined by the following function:

$$C_p(\lambda,\beta) = C_1 \cdot (\frac{C_2}{A} - C_3 \cdot \beta - C_4) \cdot exp(-\frac{C_5}{A}) + C_6 \cdot \lambda \qquad (4)$$

Where $\frac{1}{A} = \frac{1}{(\lambda + 0.08 \cdot \beta)} - \frac{0.035}{\beta^3+1}$ (5)

The maximum power coefficient (Cp max = 0.4254) is attained for λ max = 9.07.

B. *MODELING OF the PMSG*

The dynamic equations of the permanent magnet synchronous generator (PMSG) can be written in a dq frame of reference as follows: [2] [3] [8]

$$\begin{cases} V_d = -R_s.I_d - L_d\frac{dI_d}{dt} + L_q\,\omega.I_q \\ V_q = -R_s.I_q - L_q\frac{dI_q}{dt} - L_d\,\omega.I_d + \phi_f\,\omega \\ J\frac{dw}{dt} = T_w - T_{em} - B.w \\ T_{em} = \frac{3}{2}P\,[(Lq - Ld)I_d.I_q + \phi_f.I_q] \end{cases} \qquad (6)$$

Note that: the p-number of pole pairs, the resistance Rs of a phase stator, Vd, Vq and Id, Iq are components on the axes d and q of the voltage, respectively of the stator current. J is the rotational moment of inertia of the rotor and generator [kg.m²], ω is the rotor angular velocity in [reds / s], Tw is the mechanical torque applied to the alternator shaft in Nm, Tem is the electromagnetic torque developed by the alternator in Nm and B is the coefficient of viscous friction in Nm.

C. *FIELD ORIENTED CONTROL (FOC)*

Many methods are used to control the synchronous generator with permanent magnet among them the flux orienting control or (Zero Direct-axis Control: ZDC) to have an optimal operation of the machine.

The principle of this control consists in imposing a zero current Id which will bring the stator current Is back to its quadratic component as shown in the equations: [2]

$$i_s = \sqrt{i^2{}_{sd} + i^2{}_{sq}} \qquad (7)$$

$$Te = \frac{3P}{2}\emptyset_f \cdot i_{sq} = K_t \cdot i_s \qquad (8)$$

As the magnetic flux of the rotor is constant, the torque has a linear relationship with the stator current, which implies that the behavior will be similar to a DC motor, where the electromagnetic torque is proportional to the armature current.

For current control in dq fram we use the PI controller, the decoupled output of the controller can be expressed as follows:

$$v_{sd} = -(k_{pd} + \frac{k_{id}}{s})(i_{sd-r} - i_{sd}) + w_e \cdot L_q \cdot i_{sq} \qquad (9)$$

$$v_{sd} = -\left(k_{pq} + \frac{k_{iq}}{s}\right)\left(i_{sq-r} - i_{sq}\right) - w_e \cdot L_d \cdot i_{sq} + w_e \cdot \phi_f \qquad (10)$$

The decoupling output voltage (equation 8 and 9) obtained in the dq frame will be transformed to the stationary Vabc frame, which in turn will be considered as the vector modulation input reference voltage (SVPWM) which will generate pulse signals from the rectifier switches of Vienna rectifier

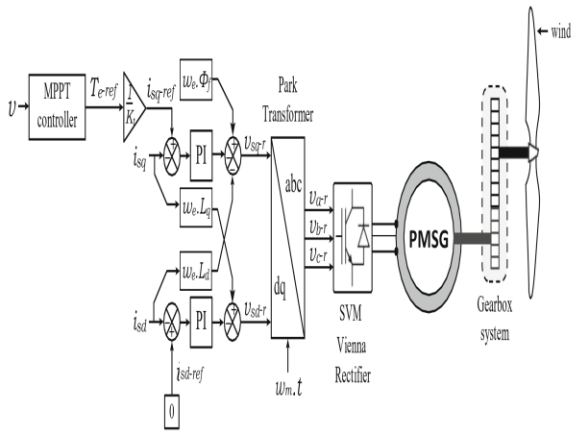


Fig . 1. Schematic diagram of the PMSG FOC control

D. *VIENNA RECTI ER*

Vienna rectifier is a unidirectional rectifier comprising three switches and eighteen diodes as shown in figure 2.

Some of the advantages of this type of converter include: it gives a balanced DC link voltage from a sinusoidal input current, low voltage across the switches, high switching operation and high efficiency.

Vienna rectifier and increasingly used in the field of wind power, micro-turbines and distribution of low voltage direct current (LVDC) (output voltage levels of 400V-750V-1500V). [6]

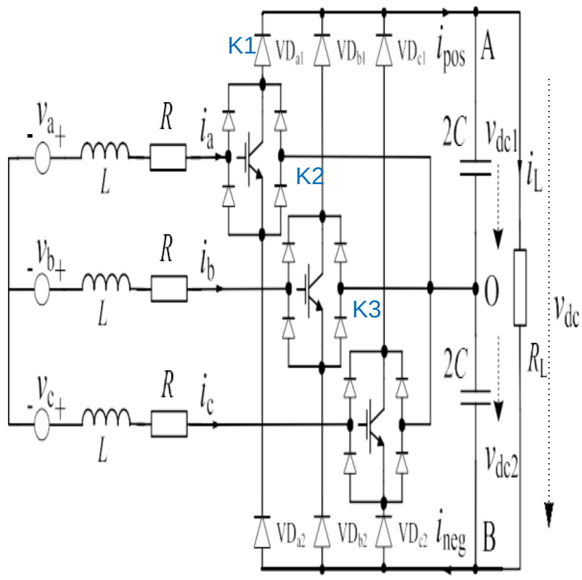


Fig . 2. The Vienna rectifier topology

E. *SHUNT ACTIVE POWER FILTERS*

The proliferation of non-linear loads, and with the generalization of static converters in industrial activities and by consumers, leads to a degradation of the quality of voltage and current forms and affects the reliability of power electronic equipment.

The Shunt Active Power Filters can be used to compensate for harmonic and unbalanced currents as well as reactive power.

The Shunt Active Power Filters is connected in a common point between the system source supply and the charging system which presents the source of the polluting currents circulating in the lines of the GRID. [5] [7]

The performance of The Shunt Active Power Filters depends on the design of the structure, the control of strategies and the robustness of the controllers, for our study we choose the P-Q algorithm as a control strategy

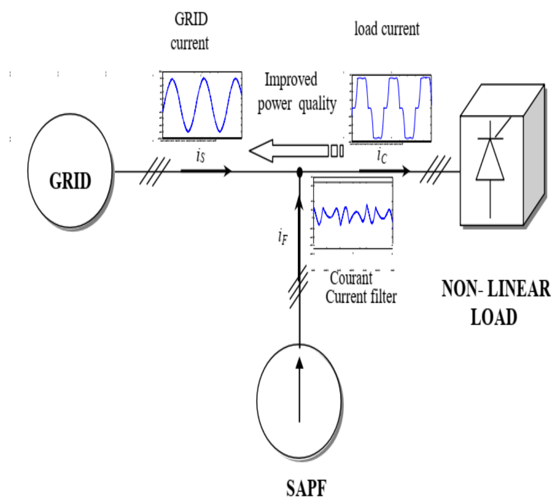


Fig . 3. General structure of The Shunt Active Power Filters

The p-q algorithm for extracting harmonic currents presented in the figure (4) illustrates the different steps for obtaining the harmonic components of the current of a nonlinear load. [5]

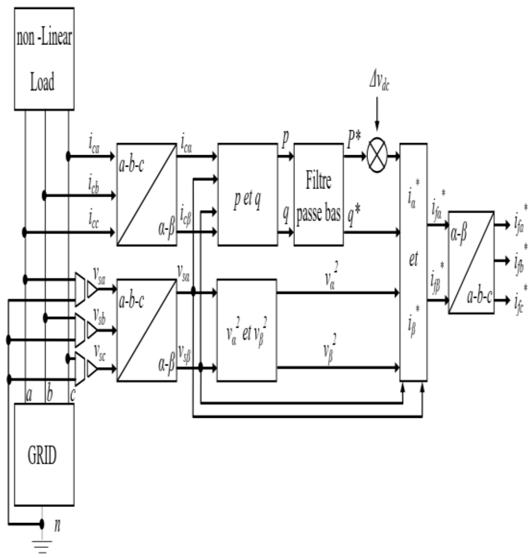


Fig . 4. P-Q Algorithm for extracting harmonic currents.

F. *SIMULATION RESULTS AND DISCUSSION*

Our system (PMSG-VIENNA RECTIFIER-SAPF) (Fig 5 and 6) studied is not only able to supply the wind energy extracted and injected to the network, but it can also considerably attenuate the harmonics due to the presence nonlinear loads.

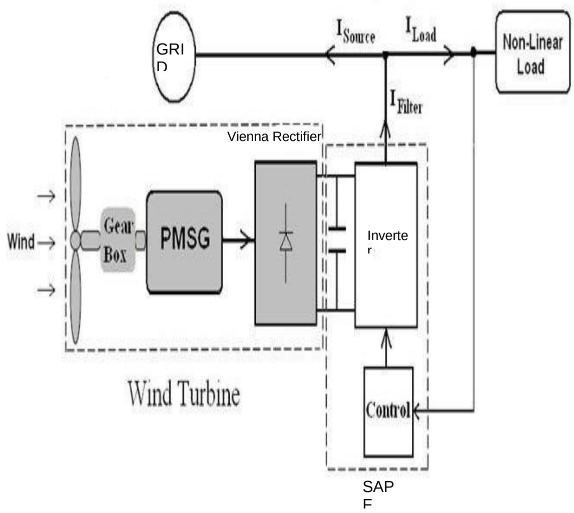


Fig . 5. Wind Energy Conversion System (WECS)

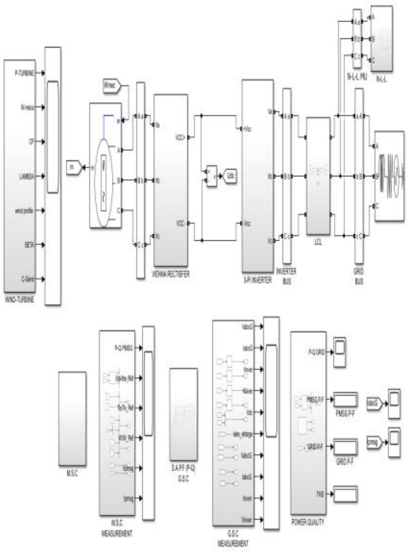
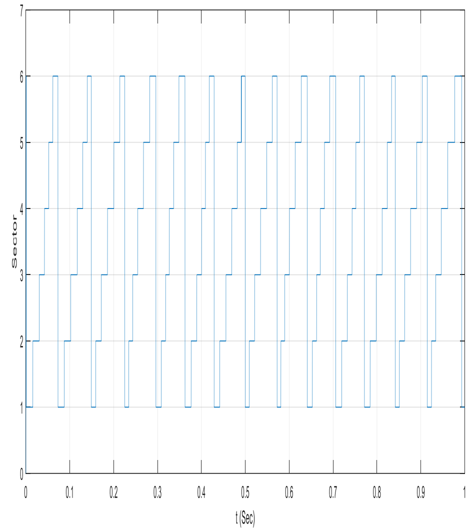


Fig . 6. MATLAB/SIMULINK model for the studied system configuration (WECS and power system)

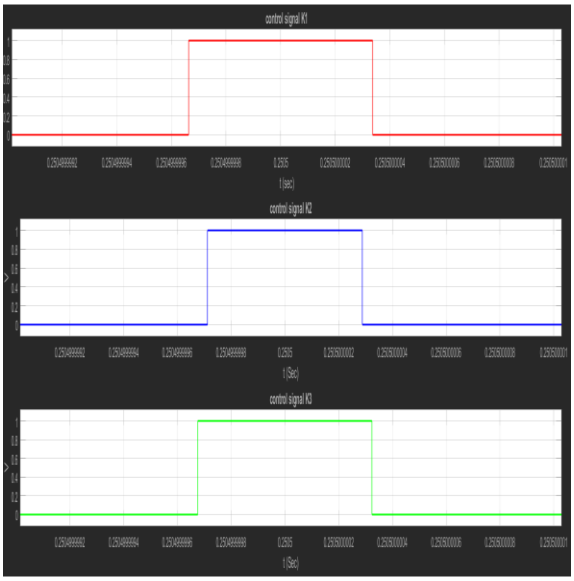
TABLE I. Parameters of the proposed pmsg-vienna rectifier-sapf system

GRID Voltage	380 V
frequency	50 Hz
Wind Turbine Settings	
J	0.21
f	0.0001
R	25
G	3
ro	1.225
CPMax	0.4254
LAMDOPT	9.07
Wind Speed	15 m/s
Béta angle	0
PMSG Settings	
P	5
Lqs	0.00835
Lds	0.00835
Rs	0.7
FIF	0.433
LCL filter	
Cf	12e-3
DC Link Capacitor	0.005025
L1	120e-4
L2	1e-4
Rf	10.081
SAPF	
Control Algorithm	P-Q

III. RESULTS

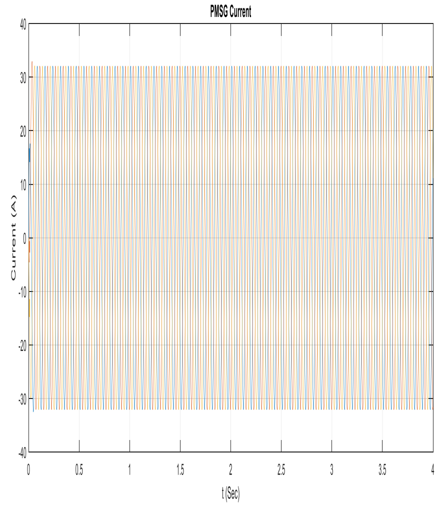


(a)

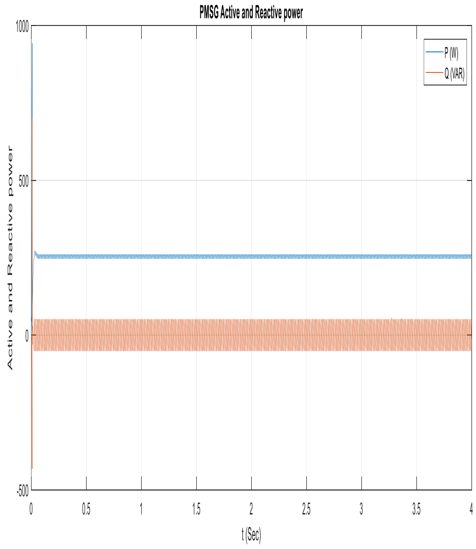


(b)

Fig . 7. (a): Instant location of Vref sectors, (b): K1, K2 and K3 switch pulse signal



(a)



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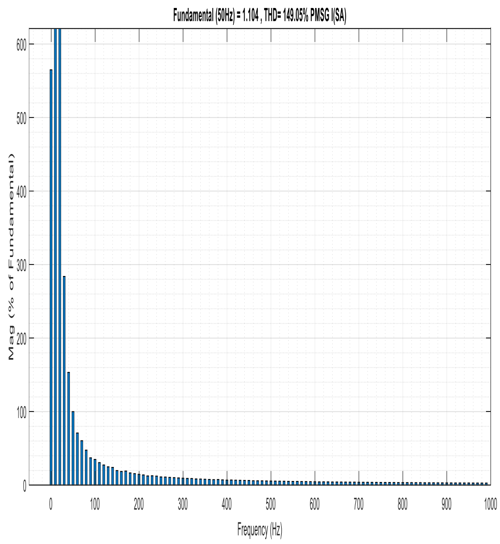
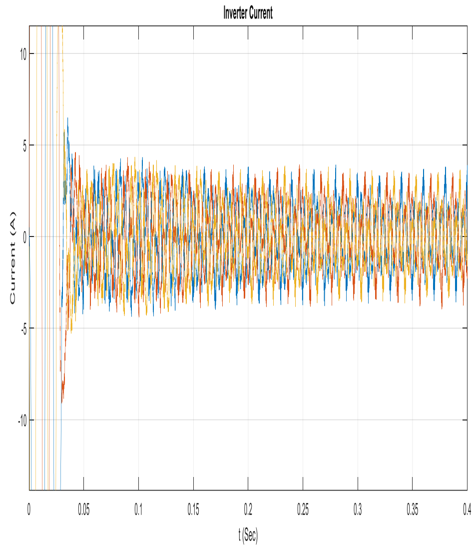
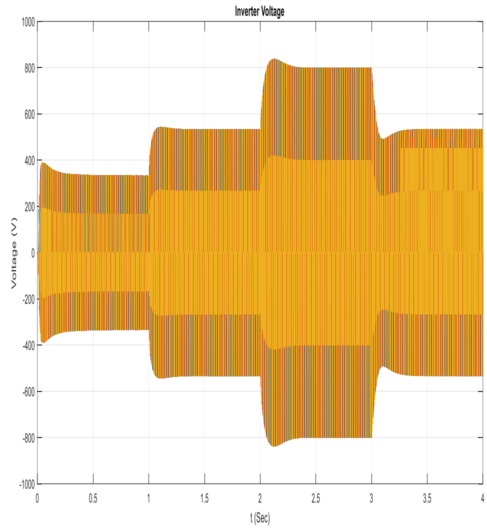


(c)

Fig . 8. (a): PMSG Current, (b): PMSG Active and Reactive Power,
(c): PMSG I(Sa) phase THD analysis



(a)



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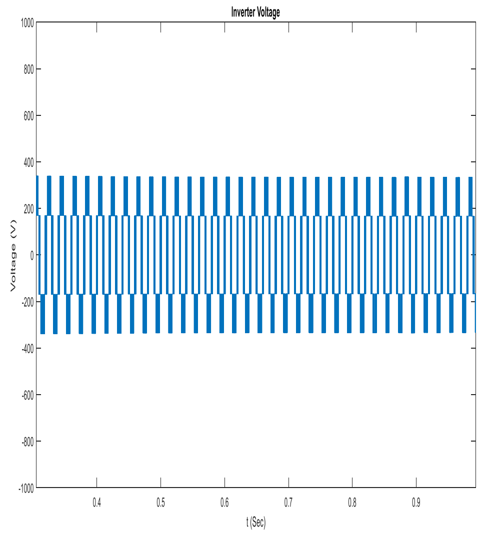


(c)

Fig . 9. (a): Inverter Current, (b): Inverter Voltage, (c): Zoom of Inverter Voltage

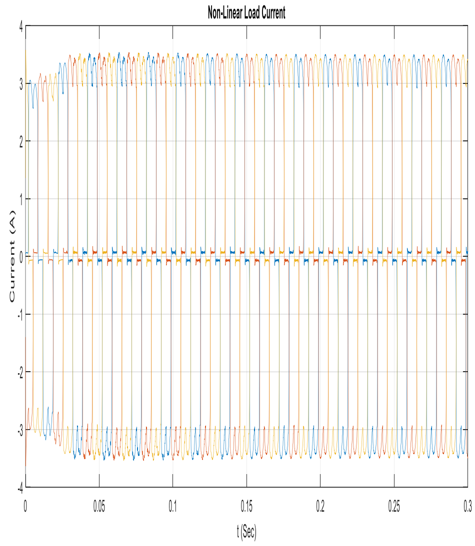


Fig . 10. Non-Linear Load current

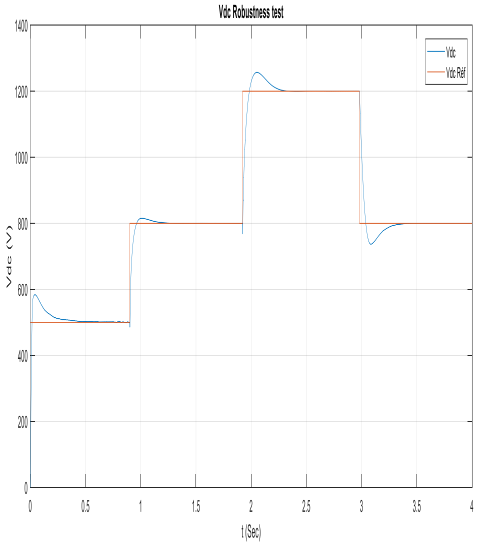
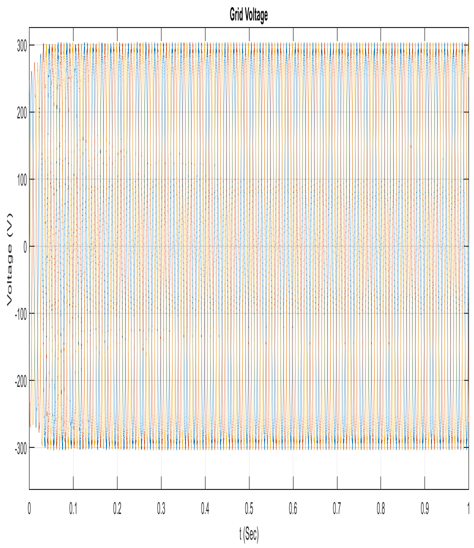
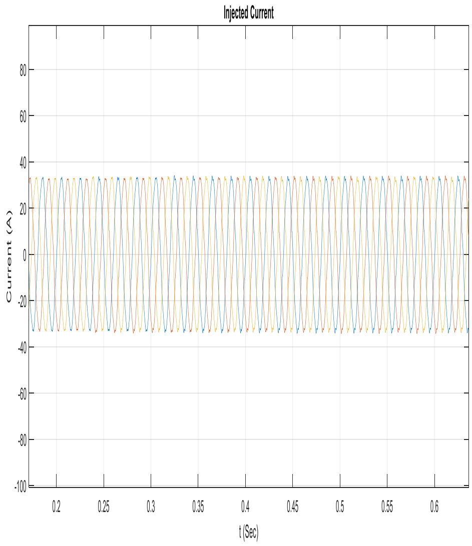


Fig . 11. Voltage Vdc and its Reference



(a)



(b)

Fig . 12. (a): GRID Voltage, (b): Injected Current,

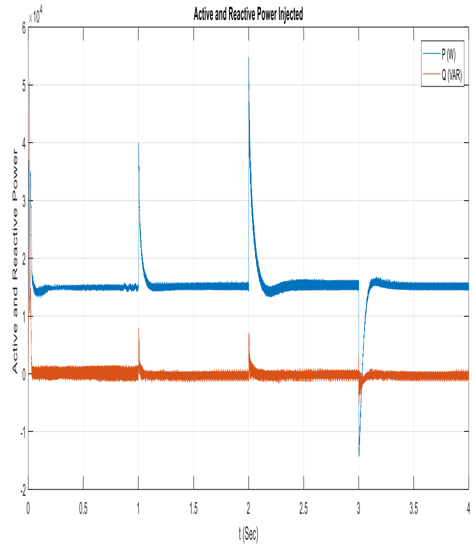
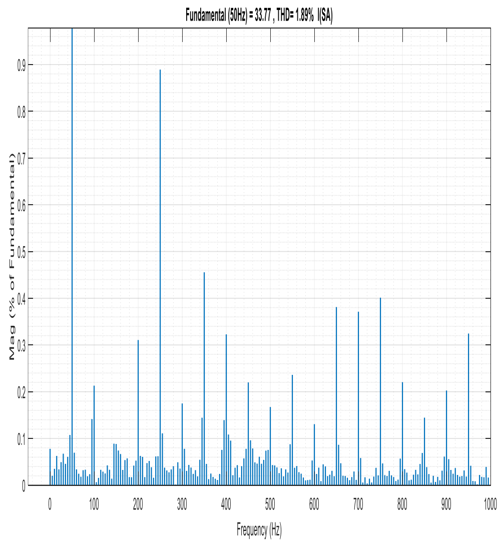
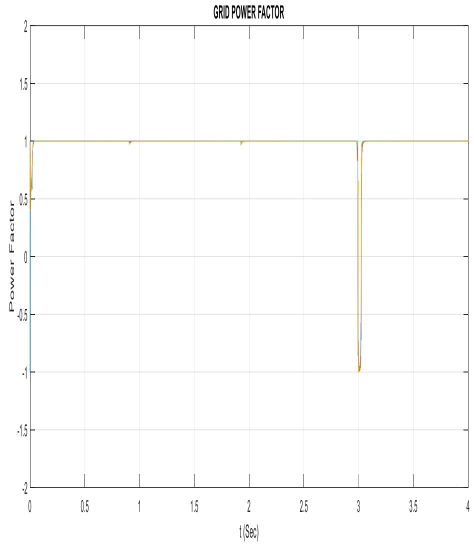


Fig . 13 Active and Reactive Power Injected to GRID



(a)



(b)

Fig . 14 (a): GRID I(Sa) phase THD analysis, (b): GRID Power Factor

IV. DISCUSSION

From the fig 11 we can see very well the DC bus voltage Vdc perfectly follows the setpoint given, namely 500 V, 800 V, 1200 V and finally 800 V

From fig 13, we see that the PMSG provides active Power to the network while the reactive Power remains zero.

V. CONCLUSION

According to the analysis of the THD of phase I(Sa) (fig14 (a)) which gives a rate of 1.89% and a unity power factor (fig 14 (b)) we can say that the Shunt Active Power Filters of our system plays its role perfectly of harmonic attenuator despite the presence of the non-linear load and the harmonics present in the current produced by the PMSG which is around 149%.

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