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NEW CONTROL STRATEGY TO REDUCE THE FLUCTUATIONS OF THE DC BUS OF A WIND TURBINE USING THE DFIG.

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ABSTRACT

The wind turbine based on the doubly-fed induction generator (DFIG) plays an increasingly important role in power generation. This is thanks to the benefits of these generators compared to other machines. In this paper, we present a new control strategy that limits variations and the transient overshoots in the DC bus voltage, which cause problems and sometimes leads to destruction of converters (GSC) and (RSC). Good performance of DFIG depends strongly on the stability of the DC bus. Simulations on Matlab / simulink/ SimPowerSystems validate the effectiveness of our approach.

Keywords: *Grid Electrical, Power Quality, Doubly-Fed Induction Generator, Fluctuation Of DC Bus.*

1. INTRODUCTION

In recent years the world has known environmental phenomena, which have multi-forms impacts on socio-economic caused by CO2 emission [9]-[10], prompting countries to seek solutions.

In the energy sector, renewable energy is the effective solution to sustainable development.

The double-fed induction generator (DFIG) interested many researchers, its advantages over other wind turbines make it currently the most widely used. The converters are dimensioned 30% to 35% of the nominal power for a range of variation of ± 25% speed [1],[8]. DFIG has become reliable and robust with the new controls: control vector, direct torque control and
direct control of power, these controls are detailed in [2].

Generally the stator of the DFIG is directly connected to the grid and the rotor is connected through two power converters; DFIG side converter (RSC) and grid side converter (GSC). These converters are based (IGBT) that allow power flow in both directions, in sub-synchronous mode, the RSC is working rectifier and GSC inverter, so the power passes from the grid toward rotor of DFIG. In super-synchronous mode, the RSC is working rectifier and the GSC inverter, so the sense of power transits from the rotor DFIG toward grid. The operating conditions of these converters are different, but their topologies and their basic functions have many similarities [3].

The Both GSC, RSC converters are connected together with a DC bus that is
seat to various fluctuations and overruns caused by the voltage Sag/ Voltage Dips voltage swell. The operating performance of DFIG and the security of their converters highly dependent on the stability of the DC bus voltage especially during faults [4]. A few research of control the dc bus voltage of the back-to-back PWM converter have been studied [11]-[12], However, it is important to keep the dc-link voltage stable and limit the fluctuation of the grid-side converter current during a grid fault. Our study will focus on fluctuation, which affect the voltage of the bus continuous and causes the unbalance of the power exchanged with the rotor and grid.

This paper proposes a new control strategy to minimize the fluctuations of the DC bus, in the first section we will address the causes and effects of the fluctuation of the DC bus, in the second we will discuss the various solutions proposed to reduce fluctuation, then we will present our solution in the third section, and the fourth section is devoted to simulations and discussion of our work and finally a conclusion.

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2. THE CAUSES AND EFFECTS OF FLUCTUATIONS OF THE DC BUS.

Figure 1 shows the main rotor circuit connected to the grid via two converters RSC and GSC,in sub-synchronous mode energy passes from the grid to the rotor via the GSC and RSC in this case the GSC operates rectifier and RSC inverter for to have slip frequency to the rotor, in super-synchronous mode power passes in the opposite direction thus requiring the RSC operates rectifier and GSC operates a inverter, for synchronizing the frequency of the energy injected with the frequency of grid.

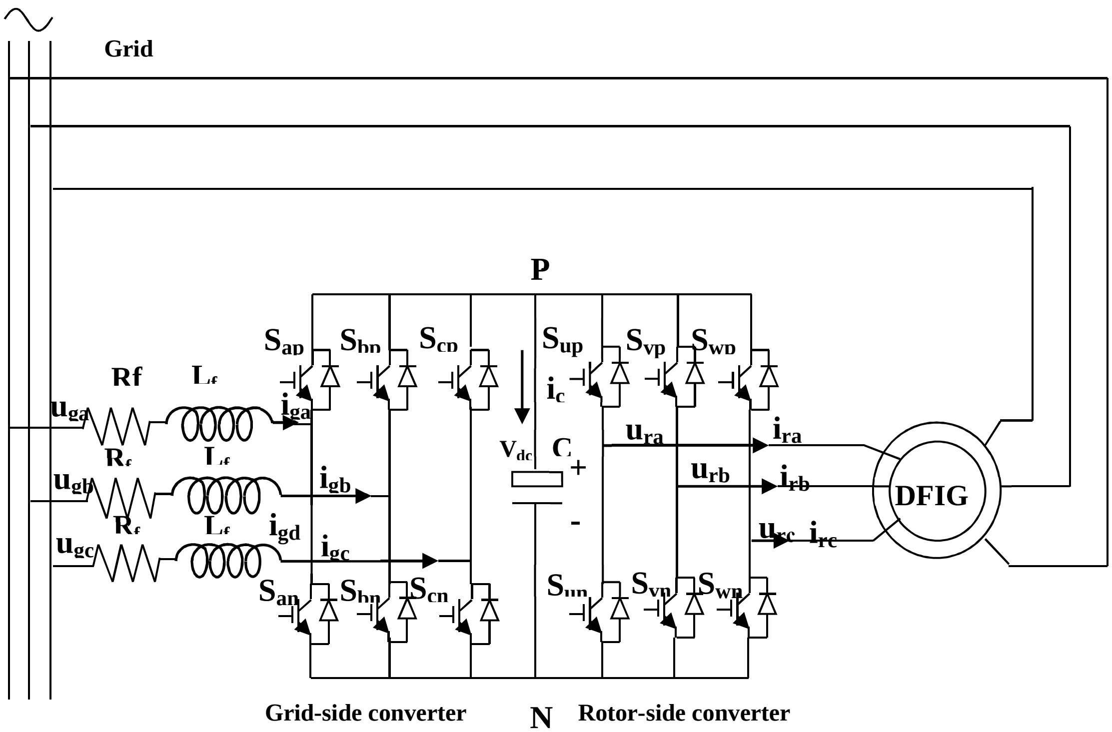

Fig1. Circuit diagram of the overall DFIG

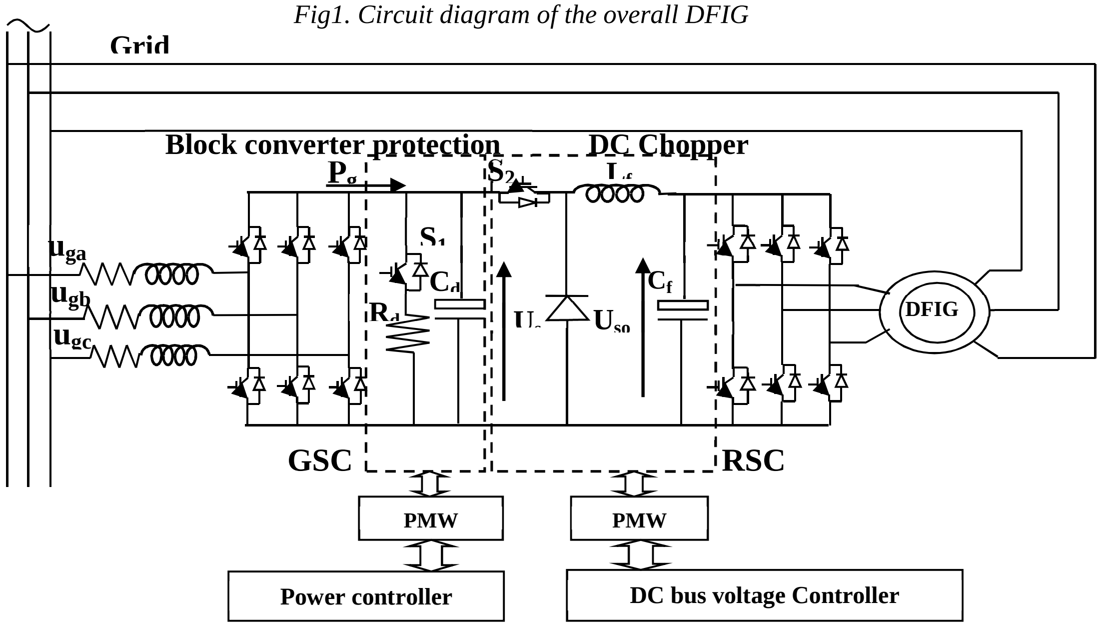

Fig.2. Diagram of vector control conventional GSC.

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The GSC command allows the control of DC bus voltage and active and reactive power exchanged between converters and the grid [5].

The RSC command allows control of the electromagnetic torque and stator reactive power of DFIG

The stabilization of the DC bus that connects the two converters is the key to good performance of DFIG. The DC bus voltage is often exposed to various changes and overruns. In [6], the GSC is often controlled by the vector control, the component of the d-axis voltage delivered by the GSC is fixed with the orientation of the grid voltage in the vector space and q component is the zero show fig2. In normal operation of the grid, the direct component of the output voltage of GSC is constant. The DC bus voltage is determined by the direct current component of the GSC and the power delivered by the generator rotor (P_g) The DC bus current will change when the power P_g change, which cause fluctuations in the voltage DC.
In addition to the GSC the dynamic response of the outer loop control of the DC bus voltage is slower than the inner loop of the current control for more details see [6].
So the grid side converter cannot transfer all the instantaneous power at the rotor side converter when the rotor current of DFIG suddenly increases. In this case, the stored energy will feed the RSC, which will cause a decrease in the DC bus voltage.
Conversely, when the power sent by the RSC toward GSC is higher of the power rated of the GSC, GSC cannot transferred more instantaneous power to grid, in this case the DC bus voltage will increase which causes a fluctuation in the DC bus due to the imbalance of power flow in both meaning.
The dynamic response of the DFIG during the voltage drop of the grid was discussed in [7], which shows the impact of voltage drop on the DC bus with the classical control that causes an increase in the DC bus voltage, the reaction speed of the DC bus becomes slow because of the ability, the DC bus voltage drops when the excitation power of the DFIG exceeds the maximum power delivered by the grid side converter. The effect of voltage dips on the DFIG was also treated in [1].
Symmetrical defects cause a large transition overcurrent in the rotor windings leading to a sudden increase of the injected power of RSC to the DC bus.

3. NEW STRATEGY TO ELIMINATE FLUCTUATIONS IN THE DC BUS VOLTAGE.

Figure below shows the blocks used to eliminate fluctuations in the DC bus voltage it is composed of two blocks, the first block the first block ensures the protection of the capacity of the converters and filtering, the second block is used to have the desired DC bus voltage,
While the GSC partially sized, cannot transfer such excess unnecessary power toward grid, resulting from fluctuations in the DC voltage;
According to [8], overshoots and fluctuations of the DC bus voltage cause the following disadvantages: reduction of the duration life of capacity, the high voltage reduces the efficiency of power converters and sometimes destruction of converters. To reduce fluctuations in the DC bus voltage, researchers have proposed solutions, in [6], a control strategy based on rotor power is proposed to limit the fluctuation of the dc bus voltage, Swell of the grid voltage has been treated in [4]; a flexible control of the DC bus has been proposed to maintain the dc bus voltage constant for this defect.
The presence of the coil L_f and the capacitance C_f to achieve filtering of the corrugations to give the DC voltage a rate quasi-continuous.

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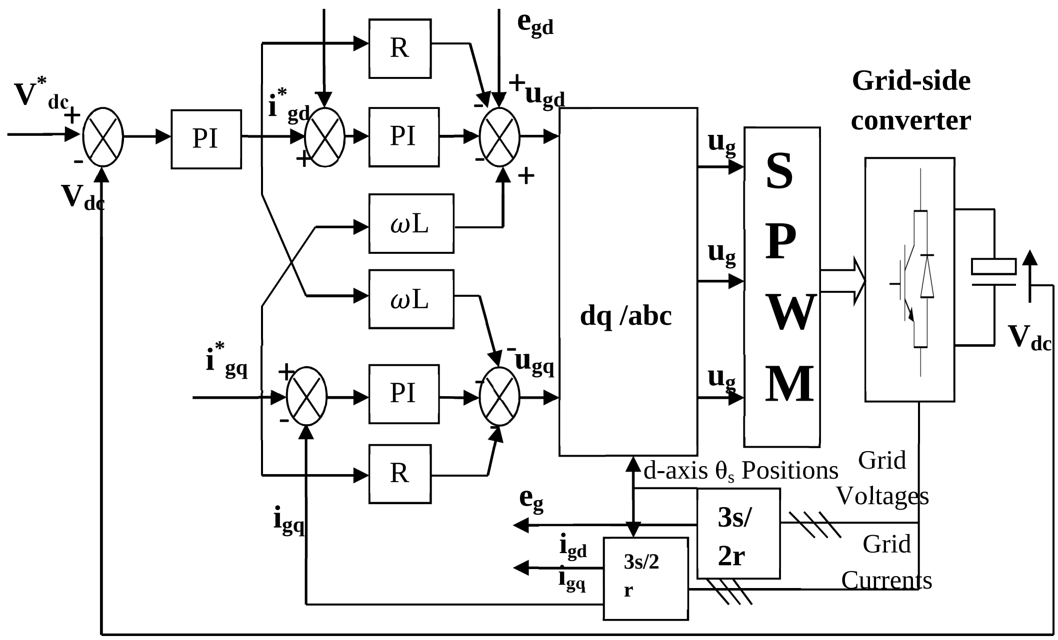

Fig.3 Diagram of control strategy to mitigate the fluctuation of DC bus voltage.

Figure below shows the blocks used to eliminate fluctuations in the DC bus voltage it is composed of two blocks, the first block the first block ensures the protection of the capacity of the converters and filtering, the second block is used to have the desired DC bus voltage, the presence of the coil L_f and the capacitance C_f to achieve filtering of the corrugations to give the DC voltage a rate quasi-continuous.

3.1 During normal operation.

During normal operation of the DFIG, the voltage Us is equal to the nominal value of the DC bus and the power which passes by the converters is less than rated power of converters, in this case the power controller sends a pulse for opening of the $IGBT_1$ (S_1) and the DC bus controller sends a pulse for closing of $IGBT_2$ (S_2).

The dc voltage stability is ensured by the coil L_f and capacity C_f.

3.2 During a fault.

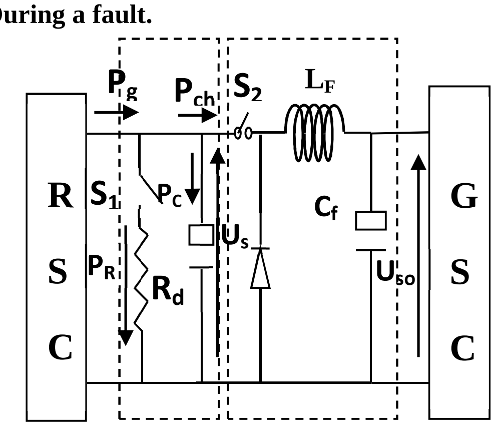

Fig.4 Control Block Diagram

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a) Power controller

When the fault occurs, the overcurrents appears in the rotor winding which causes the overshoot of the power injected by The RSC toward the DC bus, When the fault occurs, the overcurrents appears in the
rotor winding which causes the overshoot of the power injected by The RSC toward
the DC bus and a fluctuation on DC bus voltage in this time the excess of energy will be dissipated in the resistor R_D.
Using the balance of power in the DC bus, the dynamic response of the dc bus voltage is:

$$P_{IN} = P_g - P_C \qquad (1)$$

$$\frac{d\frac{1}{2}CU_S^2}{dt} = P_g - P_{ch}$$

$$d\left(\frac{1}{2}CU_S^2\right) = (Pg - P_{ch})\,dt$$

$$= (Pg - P_{ch})\,dt$$

$$\frac{1}{2}CU_S^2 = \int (P_g - P_{ch})\,dt$$

$$U_S = 2/C \int (P_g - P_{ch})\,dt$$

$$U_S = \sqrt{2/C \int (P_g - P_{ch})\,dt} \qquad (2)$$

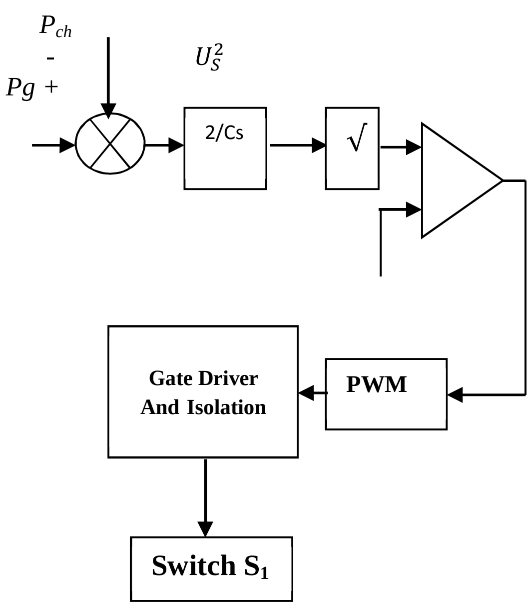

Fig.5 Power controller Block diagram

The relation (3) shows that the voltage U_S depends on the difference between the power delivered by the RSC and the power
input of DC chopper. Excess power sent by RSC is dissipated through R_d.

b) DC bus voltage controller

The average value of Uso

$$<U_{so}(t)> = 1/T \int_0^T U_s(t)\,dt \qquad (3)$$

$$<U_{so}(t)> = 1/T \int_0^{\alpha T} U_s(t)\,dt$$

$$<U_{so}(t)> = 1/T \; (U_s)_0^{\alpha T}$$

$$<U_{so}(t)> = \alpha U_s \qquad (4)$$

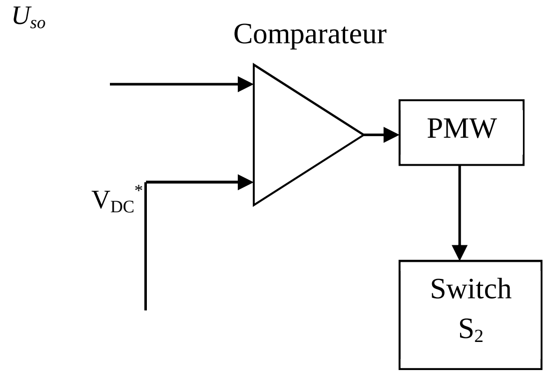

Fig.6 DC bus voltage controller Block diagram

From the expression (4), the output voltage of the chopper depends on the voltage across the capacitor C_d and the duty ratio α, when the block of the power controller operate for protected the converters and the associated elements, the fluctuation of the DC bus voltage will be eliminate by the DC chopper

4. RESULTS AND DISCUSSIONS.

The simulations were performed on a wind farm consisting of six DFIG; with a rated output of 1.5 MW each see Table 1. The fault occurs on the grid at time t = 0.03s and lasts for 0.1s, the line voltage returns to its nominal value at time 0.13s.
The parameters of the machine:

rated power	1.5 MW
frequency	50 Hz
Rated voltage of the stator	690 V
stator resistance	0.0048 mΩ
Stator leakage inductance	0.1386 mH
rotor resistance	0.00549 mΩ
Rotor leakage inductance	0.1493 mH
DC bus voltage	1150V
Discharge resistor	1 Ω

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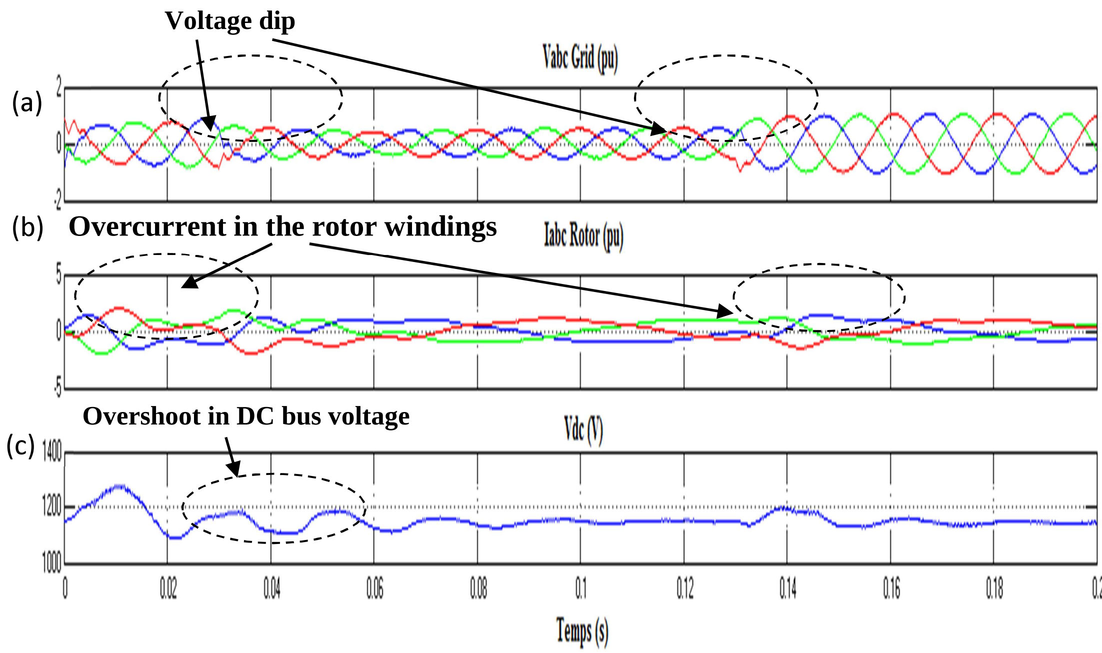

Fig.7 Grid voltage, rotor current and the DC bus voltage with the traditional control

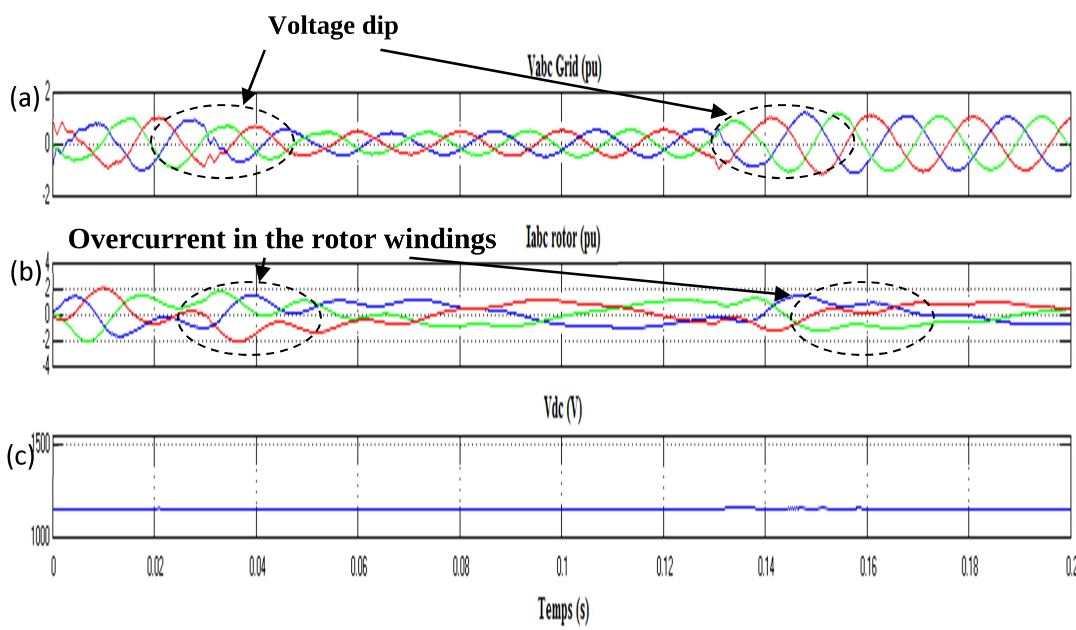

Fig.8 Grid voltage, rotor current and the DC bus voltage with the proposed control.

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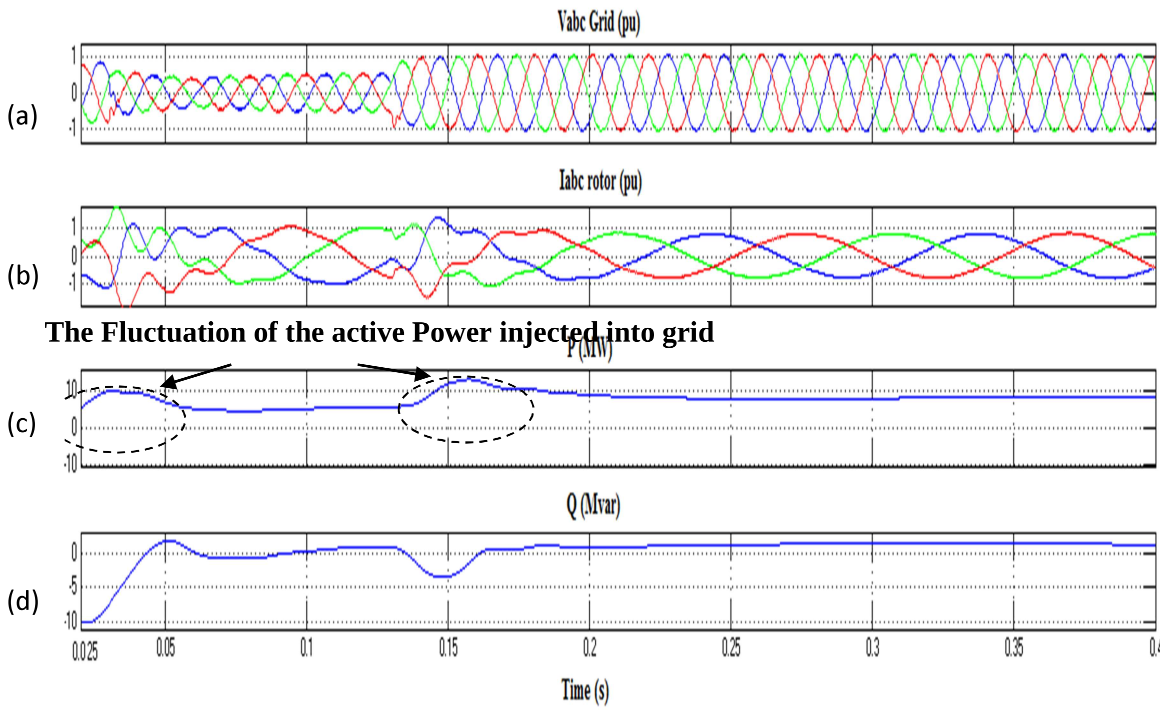

Fig.9 Grid voltage, rotor current and the active and reactive power with the traditional control.

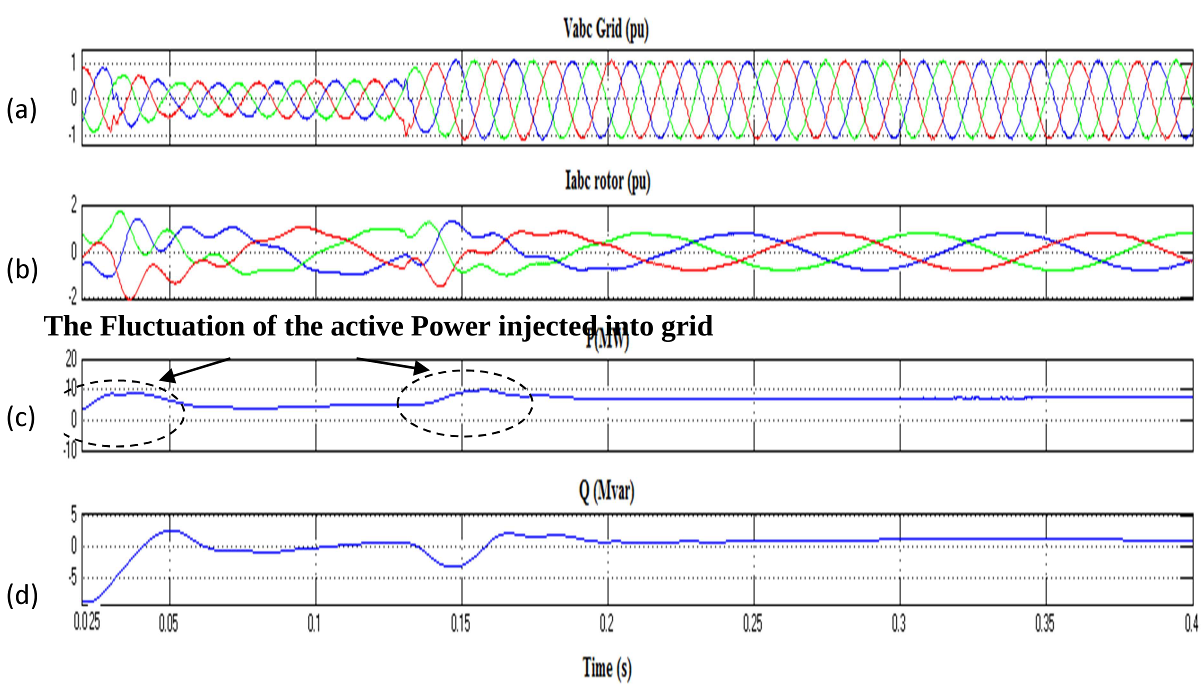

Fig.10 Grid voltage, rotor current and the active and reactive power with the proposed control.

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Figures 7 - (a) and 8 - (a) show a voltage dip occurs on the grid at time t_1 = 0.03s, the default cause an overcurrent in the rotor winding 7- (b) and 8 - (b).This overshoot is produced from the response of the stator flux, which disrupts the DC bus voltage as shown in fig 7 - (c) and lead to the abruptly excess of the power transferred by the RSC toward the dc bus link with the traditional control.

The fluctuation in DC bus voltage has been eliminated by the proposed control as shown in Figure 8 - (c) which dissipates the excess power in the resistor.

Figure 9 - (c) represents the power injected to the grid with the conventional control, Figure 10- (c) shows that the power injected to the grid is less fluctuated.

5. CONCLUSION:

In this paper, a new control strategy to eliminate fluctuations in the DC bus voltage and protect the power converters was proposed. this strategy based on the principle to dissipate power during fluctuations in a protective resistor for protects the two converters, Thereafter the DC bus voltage is maintained at the desired value by a chopper block, thus the active power injected to the grid is less fluctuated with the monitoring, control of these two blocks is made by a comparison between the reference voltage and the one desired. Simulations of Matlab/ Simulink / SimPowerSystems show the effectiveness of this new strategy compared to conventional control however, the power eliminated is a loss in the resistor. The works can aim to solve this problem in order to improve the efficiency.

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