Abstract—This paper deals with the study of the behavior of stand alone wind energy converters (WEC) based on permanent magnet synchronous generator (PMSG). First, the WEC chain is described and the model of each component of the conversion set is studied. At this stage, a special attention is given to incorporate the saturation effect in the PMSG model. Then, the obtained model is used to analyze the dynamic behavior of this WEC faced to typical wind site profile and a variable electrical load. The obtained results help the authors to analyze the WEC performances as well as the impact of the generator saturation on the power conversion.

I. INTRODUCTION

Isolated sites electrical power supply remains a major problem of electrical engineering. They are small scale autonomous installations lower than 10kW. Several solutions such as solar panels, petrol or diesel generator, wind generator are already used. The wind energy is used for a very long time but for environmental concern, in recent years, renewable energy production took its rise.

Recently, in wind energy industry, there has been a gradual interest to build direct coupled permanent magnet synchronous generators (PMSG) with higher power ratings. Without gearbox, a wind driven permanent magnet synchronous generator can offer some obvious advantages, such as higher overall efficiency and reliability, reduced weight [1].

The use of permanent magnets (PM) avoids external DC excitation which is necessary for magnetizing the wound rotor synchronous generator in isolated wind power plant. When the machine is assumed directly coupled, a large number of poles pairs are required to obtain reasonable values of output voltage and frequency. Consequently, a larger diameter of both rotor and stator is needed.

So, the aim of this paper is to simulate the dynamic behavior of saturated permanent magnet stand alone wind energy converter (WEC) [2], [3]. The wind turbine is directly coupled with the PMSG. Also, the WEC is not connected on the grid. Figure 1 shows the synoptic diagram of the studied wind energy converter where one can distinguish the different components starting from the wind speed and finishing at the electrical load.

The WEC is located between two fluctuating (random varying) parameters which are the wind speed and the electrical load. The fluctuations of these quantities can produce several undesirable effects on the components behavior of the WEC. Indeed, in order to be able to study the dynamic behavior of these elements face to variations of fluctuating parameters, an accurate model of each element is necessary. So, the wind speed is modeled by an original approach based on Van Der Hoven spectral density [4] and the wind turbine torque is modeled thanks a polynomial approximation. Moreover, the proposed synchronous machine model in this paper includes magnetic saturation in order to predict accurately the machine performances [5]-[7].

The electrical load is then connected to the PMSG stator phases via a rectifier followed by a filter stage and an inverter [3], [8], [9]. Finally, the global model resulting from the connection of the different components models gives a powerful simulation tool helping to characterize the power conversion of this type of WEC.

II. MODELLING OF THE WEC COMPONENTS

A. Wind speed modelling based on the wind spectral characteristic of Van Der Hoven

The wind speed model is based on an original sampling of the Van Der Hoven spectral density (Fig. 2) and the expression of the wind speed is then given as follows [4]:

\[
V(t) = \frac{2}{\pi} \sum_{i=0}^{N_s} A_i \cos(w_i t + \varphi_i) + \frac{2}{\pi} \sum_{i=N_s}^{N} A_i \cos(w_i t + \varphi_i)
\]  

(1)

where \(N_s\) and \((N-N_s)\) are the number of samples of the slow component (first term of (1)) and the turbulence component (second term of (1)) respectively. \(A_i\) and \(\varphi_i\) are respectively the amplitude and the phase of each
sample.

Figure 3 represents an example of the simulated fluctuating wind speed around the 9.5m/s slow component.

\[ IS(f) = \frac{1}{2} \rho \pi R^3 \lambda^2 C_f (\lambda) \]  

(2)

with \( \rho \) the air density, \( \Omega \) the shaft rotational speed and \( \lambda \) the tip speed ratio.

Figure 4 and figure 5 represent respectively the torque coefficient obtained with 6 order polynomial regression and the simulated constant wind turbine torque.

C. Modelling of the PMSG

The PMSG generator is modelised by considering the PM electromotive force (EMF) of the stator phase to be sinusoidal. Therefore, the stator phases voltages can be expressed as follows in a vector-matrix form [4]:

\[ [v_g] = [L_s]^{-1} [l_b] + [L_s] \frac{\partial}{\partial \theta} [e_p] - [e_g] \]  

(3)

\([v_g] \) is the stator voltages vector, \([l_b] \) the stator currents vector, \([e_p] \) the vector of PM EMF, \([e_g] \) the stator resistances matrix and \([l_b] \) the stator inductances matrix.

The electromagnetic torque is obtained by:

\[ \Gamma_{em} = \frac{p}{2} [e_p]^T \frac{\partial}{\partial \theta} [\Phi_p] \]  

(4)

where \([\Phi_p] \) is the vector of PM fluxes embraced by the stator phases, \( p \) is the number of pole pairs and \( \theta \) the angular position of the rotor (north pole axis) with respect to the stator phase (a) axis.

To the previous equations, one must add the mechanical
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات