DESIGN AND IMPLEMENTATION OF DOUBLY FED INDUCTION MACHINE IN AN FUEL CELL VEHICLE

P SHILPA GAYATRI

PG scholar,Balaji institute of Technology & Science, JNTUH, Warangal, Telangana, India

MD ERSHAD ALI

M.Tech,Asst. Professor, Balaji Institute of Technolgy & Science, JNTUH, Warangal, Telangana, India

ABSTRACT-- This work is aiming to study and control of drive train of an electric vehicle based on doubly fed induction machine (DFIM), the power structure of this machine and the control strategy applied allow operating over a wide range of speed variation, for both applications: engine and recovery. Therefore the power of the machine can reach twice its rated power. After modeling different parts of the drive train a numerical simulation in MATLAB / Simulink is carried out. The results show the good performance of the vector control, and the structure of power applied to the DFIM.

IndexTerms—.DFIM, PWM Converters, Battery, Gearbox, control of vehicles drive train

I. INTRODUCTION

Industrial applications of variable speed drives require increasingly important performance and a maximum reliability and minimum cost. Indeed, currently the use of AC machines is becoming more
common as these machines are characterized by their robustness and longevity compared to commutator machines [1-2].

  Literature shows the great interest shown in the double-fed induction machine (DFIM) for various applications: as a generator for wind energy and for certain industrial applications, such as rolling and traction or propulsion maritime. Indeed, most work on this machine have been the subject of the study of the structure where the stator is directly connected to the network and the rotor powered by a power electronics converter. The advantage of this solution is that the converter is sized at 30% of the rated power of the system and therefore the variation of speed limit near the speed of synchronization
However, the objective of this work is to operate the DFIM in a wide range of speed variation, for application in a drive train of an electric vehicle; for this the machine is connected through two power converters with pulse wide modulation control (PWM), these converters are both powered by a battery,which is a key element for development of electrical vehicles, namely the energy density is low and the charge time very long [4]. In the drive train we use only one machine (DFIM) for the motorization of the vehicle, and for recovering energy during braking. The advantage of the power structure chosen is not only to operate the machine in a wide range of speed variation, but also to give to the machine the capacity to operate up to twice its rated power. So the power density is improved. Figure (1) illustrates the schematic diagram of the drive train:
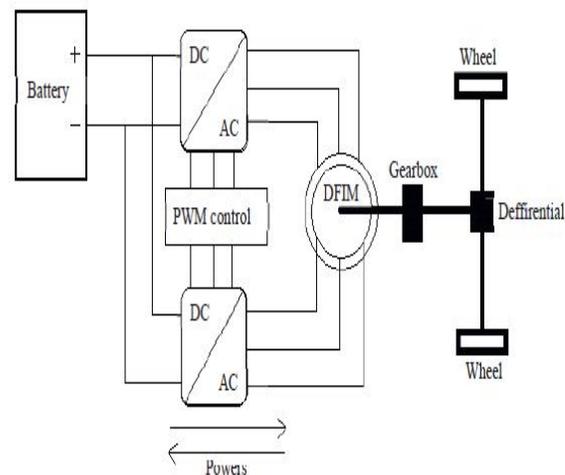

Fig (1): Representative diagram of the electric vehicle drive train

The ability of the DFIM to start with high torque makes possible the elimination of clutch and gearbox. The torque is the size dimensioning; therefore the machine must be heavier and bulky, so more expensive. The use of fixed ratio gearbox overcome these problems and allows to have a

simple machine that can provide the required torque.
The power electronic converters used for power transfer between the battery and the DFIM are sized at 100% of rated power of the machine, those are bidirectional converters with PWM control, they absorb power from the battery when the machine operates as a motor and they provide to it when the machine operates as a generator (braking).

Semiconductors used depends on power level passing converters; for low powers are used IGBT. For high power converters based on IGCT or GTO semiconductors can be used. Variable-speed drives with a rated power up to 40MW (IGCT) or 100MW (GTO) have been installed. A disadvantage of these
semiconductor types is their lower switching frequency, compared with IGBT's [5].

2. DFIM model
Two-phase equivalent model of the DFIM represented in the reference (dq) linked to the rotating field is given as follows

With S: Laplace Operator
In order to achieve good decoupling between the axes d and q, we define intermediate voltages as follows:

Couplingtermsappeartocompensate;   , these expressions allow to obtain relations between the intermediate voltages and the stator and rotor currents in d or q axes. So:

With:
$Ts= Ls / Rs$; stator electrical time constant;
$Tr = Lr / Rr$; rotor electrical time constant;
$\sigma = (1-M2/ (Lr. Lr))$; dispersion coefficient.
The coupling terms can be expressed as follows:

From system of equations (5), the transfer's functions following are obtained:

3. Converters model
The matrix giving the model of powers electronics converters used is expressed as

4. Battery model
The model of battery used for application in electric vehicle should have the specifications as follows [8]:
- It should simulate the variation of the battery's terminal voltage on certain load demand or current demand;
- It should be simple and require limited times for mathematical calculation and iteration;
- The model should be involved with as few as possible or none of the parameters that are related to the battery's chemical process.

There have been many proposals battery model; one of this is the Thevenin equivalent circuit, shown in figure (2). It is a linear electrical battery model [9].
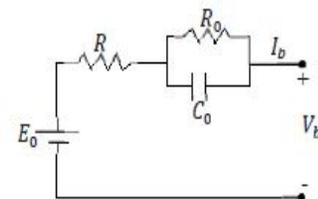
Fig(2): Thevenin equivalent circuit of battery

5. Vehicle Dynamics

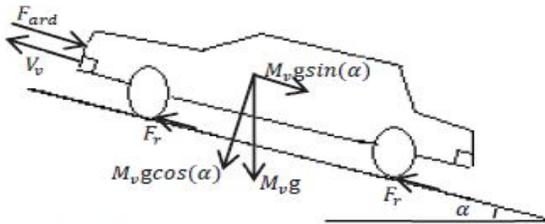Equation governing vehicle dynamics is given as following [10]:


Fig (3): Various forces applied to the vehicle

Which   is called the rolling resistance coefficient and P is the normal load on the Wheel. Where ρ is the air density, Af is the frontal area of the vehicle, Cd is aerodynamic coefficient, Vv is the vehicle speed and Vw is the wind speed. Where g is the earth gravity and Mv is the total weight of the vehicle.

fuel cell

A fuel cell is like a battery in that it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical energy into electrical energy and also, as a by-product of this process, into heat. However, a battery holds a closed store of energy within it and once this is depleted the battery must be discarded, or recharged by using an external supply of electricity to drive the electrochemical reaction in the reverse direction.

A fuel cell, on the other hand, uses an external supply of chemical energy and can run indefinitely, as long as it is supplied with a source of hydrogen and a source of oxygen (usually air). The source of hydrogen is generally referred to as the fuel and this gives the fuel cell its name, although there is no combustion involved. Oxidation of the hydrogen instead takes place electrochemically in a very efficient way. During oxidation, hydrogen atoms react with oxygen atoms to form water; in the process electrons are released and flow through an external circuit as an electric current.

Fuel cells can vary from tiny devices producing only a few watts of electricity, right up to large power plants producing megawatts. All fuel cells are based around a central design using two electrodes separated by a solid or   liquid electrolyte that carries electrically charged particles between them. A catalyst is often used to speed up the reactions at the electrodes. Fuel cell types are generally classified according to the nature of the electrolyte they use. Each type requires particular materials and fuels and is suitable for different applications

Fuel Cell Stack
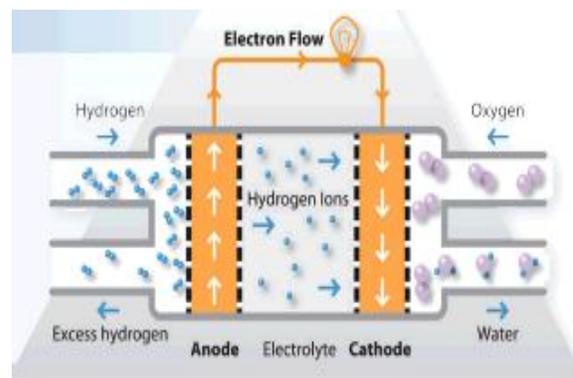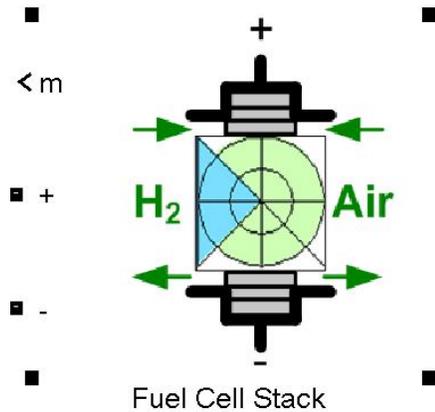
Fuel cell

6. Vector control of the DFIM

A vector controlled doubly fed induction machine is an attractive solution for high restricted speed rang electric drive and generation application, it consists in guiding an electromagnetic flux of the DFIM along the axis d or q.[5] In our case we choose the direction of reference (d,q) according to the direct
stator flux vector, so the model of steady DFIM will be simplified as follows:

Such as:

The magnetization of machine is assured by the rotor direct current, so the stator current in the d axis is taken to zero (The current and voltage in this line are then in phase:
and
In this case we obtain a unity power factor at the stator, so the stator reactive power is zero Qs =0.These simplifications

lead to the electromagnetic torque expression:
From the expressions of equations which have been established, we can draw a connection summary table setting the objectives of the control strategy with the references of action variables involved

7. Powers distribution

The distribution of stator and rotor active powers is a requirement in the control strategy to be applied. Indeed, this allows increasing the range of speed variation and the power density of the machine. Such as if the stator and rotor resistance windings terms are neglected, the following relationship is imposed:

Therefore, the stator and rotor active powers distribution, involve the stator and rotor pulses distribution\ and vice versa. Working with a slip $g = -1$ we obtain the following relationship:

So: Table (1): control strategy applied to the DFIG model The diagram representing the complete system with the control strategy applied is given by figure (7
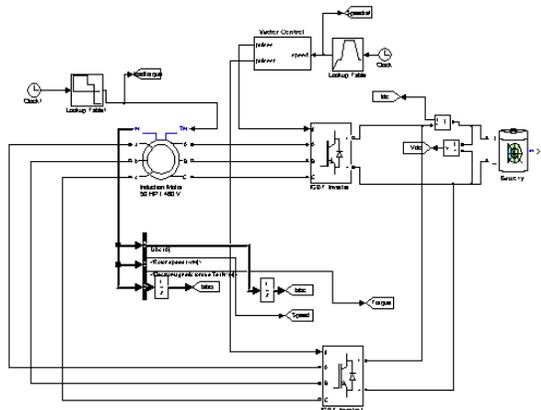

Fig (4): Control diagram of the electric vehicle drive train

8. Simulation results

A speed control with pulses repartition is applied to the DFIM for a path of a road with variable slopes. The overall system simulation is performed on the MATLAB / Simulink; the following figures show the simulation results
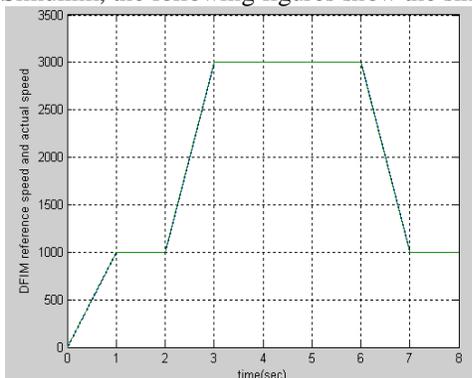

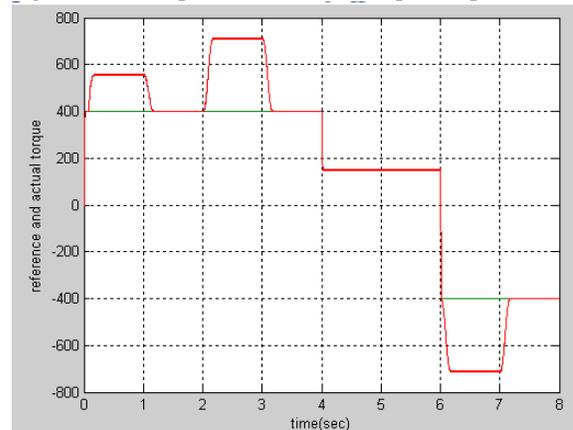Fig (5): DFIM speed and reference speed (rpm)
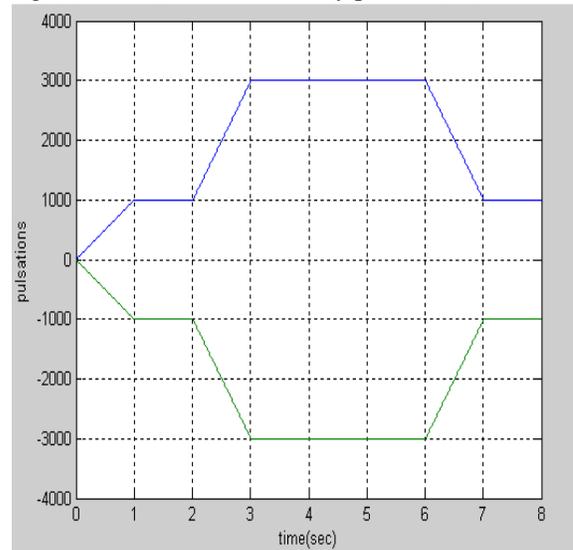

Fig (7): Stator, rotor and battery powers (W)

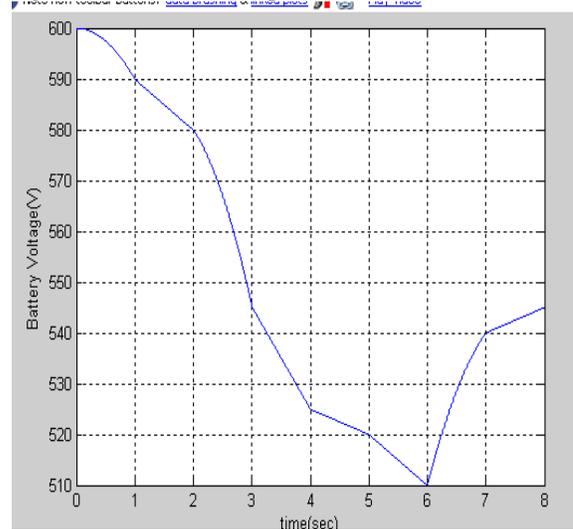Fig (8): Stator and rotor pulsations (rd/s)

Fig (9): Battery voltage (V)

9. Results interpretation

According to the simulation results it is noted that the DFIM operates over a wide range of speed variation (twice the nominal speed), while following the reference imposed. The distribution of pulses applied for control of DFIM has allowed to have the distribution of stator and rotor actives powers, however, there is a slight difference and this is due to the stator resistance that is greater than the rotor resistance, and we note that the total power exchanged between the battery and DFIM equal to the sum of the stator and rotor actives powers. Indeed, when the driver requests the machine to beat a rib with a given speed the, DFIM can provide power equal to twice its rated power. So for positive slopes the driver requests the DFIM to provide the torque required to overcome the resistive torque imposed by the vehicle, so the machine is operating in motor mode, and absorbs power from the battery, for negative slopes (braking) the DFIM operates in generator mode and recharges the battery.

10. CONCLUSION

The aim of this work is to integrate DFIM in a drive train of an electric vehicle and show its performances. Indeed, the simulation results obtained show that the DFIM can operate over wide range of speed variation, which allows to reduce the size of gearbox which is complicated and very expensive systems. And the power of the machine rises up twice of its rated power, which allows to increase its

Power density. Seen these benefit the DFIM is a very good alternative for use in a drive train of electric vehicles

.

Nomenclature

: Frontal area of the vehicle
: Battery capacity
: Aerodynamics coefficient
 : Aerodynamic force
: Gravitational strength
: rolling force
: Open circuit voltage
g: Earth gravity
: Battery current
 : Direct and quadrature of stator and rotor currents
,: Stator and rotor inductances

M: Mutual inductance
 : Vehicle total weight
R: Internal battery resistance
r: Wheels radius
 : Stator and rotor resistances
 : Electromagnetic torque

References

[1]: R.Campagne, L-A.Dessaint, H.Fortin-Blanchette. Real Time Simulation of Electrical Drive. Mathematique and computers in simulation 63 (2003), 173-181.

[2]: A. CHAIBA, R. ABDESSEMED, M.L. BENDAAS et A. DENDOUGA. Controle of torque and unity stator side powefactor of the doubly-fed induction generator. Conferences sur le génie électrique CGE'04, EMP Alger, 2005.

[3]:GhaniaMouna,Chaffaa,Khirddine,Benmahammed Khier. Adaptive Type-2 Fuzzy Control For Induction motor. secondinternational conference on electricalsystems, ICES'06, 2006, Oum El Bouaghi, Algeria.

[4]: Lota Gidwania*, Harpal Tiwanib, R.C.Bansalc.Improving power quality of wind energy conversion system withunconventional power electronic interface. Electrical Power and Energy Systems 44 (2013) 445-453.

[5]: Joris Soens, Karel de Brabondere, JohanDriesen, Ronnie Belmans, .Doubly Fed induction Machine: Operating Regionsand Dynamique Simulation. EPE 2003-Toulouse, ISBN:90-

P SHILPA GAYATRI currently pursuing her M.Tech in Electrical Power Systems in Bajaj institute of Technology and Sciences, Warangal, Telangana, India affiliated to JNTU University, Hyderabad. She has done her B. Tech degree from SR engineering college, affiliated to JNT University, Hyderabad, Telangana, India in 2007 and her fields of interest include Renewable Energy Sources, Power Systems and Industrial Drives.