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DTC-SVM CONTROL STRATEGY FOR INDUCTION MACHINE BASED ON INDIRECT MATRIX CONVERTER IN FLYWHEEL ENERGY STORAGE SYSTEM

M Laxmana Rao[1], G.Venkataratnam[2]

[1]*Assistant Professor, Department of EEE, Dhurva institute of Engineering and Technology*

[2] *Assistant Professor, Department of EEE, Sree Rama Insitute of Technology & Science*

ABSTRACT

Flywheel energy storage system (FESS) improves the quality of the power transmitted to the grid by wind generators. Presently, FESSs, containing back to back converter and a direct torque control (DTC) that controlled induction machine (1M), are mainly considered for this kind of application.This paper investigates a low-speed FESS with DTC_SVM control strategy for an 1M based on indirect matrix converter (IMC). In this system, DTC-SVM increase efficiency of the energy storage system and facilitate the active power output of the wind farm by providing situation to shift quickly and repeatedly between motoring and generating operation modes in induction machine. The space vector modulation (SVM) strategy in indirect matrix converter provides full control of both the output voltage vector and the instantaneous input current displacement angle. The reference power of the FESS that used as the input of the system can be obtained by calculating the active power of wind farm and the target power. The model of the system is simulated in SIMULlNK MATLAB software for different FESS operations such as: charge, discharge and standby modes and observe the simulation results

II. LITERATURE REVIEW

[1]Flywheel energy storage system is the energy storage device that can convert electric power into kinetic energy which stored mechanically by rotating the flywheel rotor. The FESS is coupled to an electric generator that produces electricity when the flywheel brakes. According to the different operating speeds, flywheel can be classified as highspeed flywheel and low-speed flywheel [I]. The rotate speed of low-speed FESS is about thousands RPM, mainly used in renewable energy generation and uninterruptible power supply (UPS) and for the high-speed flywheel it's more than ten thousands RPM and mainly used in space and military fields[2]. FESS is well adapted due to their high efficiency, long lifetime, low cost, environmentally friendly, high dynamic speed, etc. They constitute have been considered storage systems, which is generally sufficient to improve the power quality. This system is able to deliver a very high power, which is limited only by the rating of the generators and power electronics. The response time is limited to a few milliseconds, and the number of

charge and discharge cycles of a flywheel is constrained only by the efficiency of the electric and power electronic systems cooling. Although mechanical losses in FESS is more than battery energy storage systems, flywheel systems would eliminate many of the disadvantages of existing battery energy storage systems, such as low capacity, long charge times, heavy weight and short usable lifetimes[4].With the development of the wind power technology, the relevant issues of wind power connecting to grid receive a lot of attention. The real problem with wind turbines is the variation of output power with respect to wind velocity. As a result of this, energy storage systems were used in wind power farms in order to keep a balance between the production, consumption power and the exploitation of the maximum power of farms. In recent decades, the FESSs have thus found a specific application in enhancing the electric power quality, as far as voltage and frequency are kept within preset limits. The storage device is charged and convert electric energy into kinetic energy when wind power is surplus. Conversely, the device is discharged when wind power is lower than the power required for grid [1-3].

Presently, FESSs containing a direct torque control (DTC) controlled induction machine (1M) and back to back converter are mainly considered for this kind of application. In this paper, a low-speed FESS that control by DTC-SVM induction machine based on IMC is investigated [I]. Fig. I provides a block diagram of the FESS assembly under study. Direct torque control is a control strategy of 1M with a fast dynamic and high performance. The general principles of DTC-SVMcontrol strategy is the direct selection of a proper space voltage vector in order to immediately adjust electromagnetic torque to the flux range of stator within the specified area. In this method, the amount of linkage flux and electromagnetic torque at the authorized bandwidth, previously defined, are controlled by choosing voltage-appropriate vectors in each sector of samplings [6], [7]. By means of the indirect matrix converters, the energy generation and storage systems can be coupled via an AC-link circuit. The low-speed FESS manages transfer between network and the wind generator and makes smooth the power generated by the wind. The reference value generated or of the FESS power, which yields the energy

III. RESEARCH METHODOLIGES

1. Mathematical analsis
2. Simulinkand matlab
3. Experimental analysis

IV. SIMULINK AND MATLAB

In Simulink, it is very straightforward to represent and then simulate a mathematical model representing a physical system. Models are represented graphically in Simulink as block diagrams. A wide array of blocks are available to the user in provided libraries for representing various phenomena and models in a range of formats. One of the primary advantages of employing Simulink (and simulation in general) for the analysis of dynamic systems is that it allows us to quickly analyze the response of complicated systems that may be prohibitively difficult to analyze analytically. Simulink is able to numerically approximate the solutions to mathematical models that we are unable to, or don't wish to, solve "by hand." In general, the mathematical equations representing a given system that serve as the basis for a Simulink model can be derived from physical laws. In this page we will demonstrate how to derive a mathematical model and then implement that model in Simulink. This model is then employed in the Introduction: Simulink Control page in order to demonstrate how to employ Simulink to design and simulate the control for a syst

V. OBJECTIVE OF THE THESIS

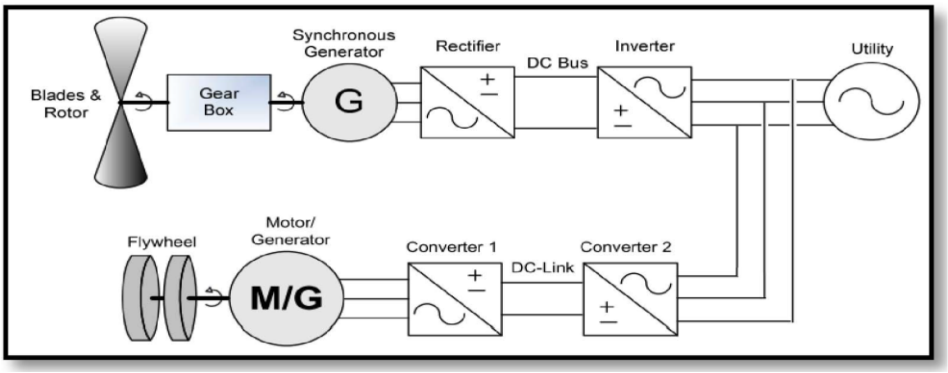
Direct torque control with space vector modulation (DTC-SVM) based on indirect matrix converter is applied to the induction machine of the FESS. The direct torque control has high operation speed. The results indicate that the power FESS follow reference power with fast dynamic. The THD for both the input current of matrix converter and stator current was obtained 6.23 and 2.09 respectively. In addition, the phase form of the input current and the input voltage of matrix converter indicate unit shift coefficient on the input of the system as well as low loss of the method for FESS. The recommended operation of an participation is a future challenging task In flywheel energy storage system.

HYPOTASIS

VI. CONTROL OF FESS

The connection structure of a wind farm with the FESS and grid is shown in "Fig. 1". The system studied is constituted of a, an induction generator, an indirect matrix converter, and flywheel. Flywheel is a kind of mechanical battery, by which energy is saved by rotating the flywheel rotor. The stored energy is adjusted to flywheel mass and square of IM speed, which is obtained from equation

1 Ee = -jw2 2(1)



Block diagram of wind generator connect to FESS and grid [II].

As well known, the wind speed is very fluctuant, and therefore, the wind generator will deliver a variable electric power. To overcome this drawback, an auxiliary energystorage system is installed in order to produce an additional energy and regulate the electric power delivered to the grid. FESS is designed to smooth wind power fluctuations by releasing or absorbing stored energy during wind

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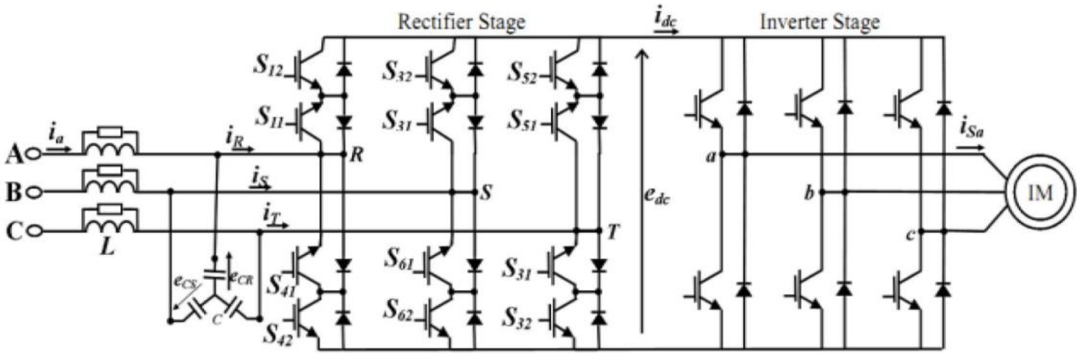
fluctuations [1], [3], [10]. The reference value of the active power exchanged between FESS and AC-link circuit is determined as follows:

Pret = Pgrid – Pwind (2)

VII. INDIRECT MATRIX CONVERTER

In "Fig. 3", is shown the indirect matrix converter (IMC) topology. The converter includes a current source rectifier with bidirectional switches, which is directly, without a DC link capacitor, connected to a voltage source inverter. For the input converter, soft switching commutation is obtained by synchronizing the input and output converter pulse widthmodulation patterns. This commutation is simpler thancommutation of direct matrix converter [11].



The following sections demonstrate the step modulation strategies of the indirect matrix converter. First, the modulation strategies which can be used to produce a DC
voltage are presented. Second, the procedure to obtain the output converter duty cycles is shown. Eventually, synchronizing the commutation of the input IMC to output converter is presented.

3. a Direct Torque Control with n space vector modulation for Induction Machine drives In FESS

The block diagram of the DTC-SVM control is showed in "Fig.2". In this method, 1M torque and stator-flux amplitudes are controlled by two PI controllers [1],[3]. According to the
section II the reference electromagnetic torque is determined as a function of FESS reference power and flywheel speed. The flux reference is calculated as follow [I]: In addition, the torque and flux of the motor are estimated using the equations of the induction machine. Then the estimated values of the torque and flux were compared with respectively the torque and flux of its corresponding reference, as the errors are applied to two PI controller. The output of the PI flux and torque controllers can be interpreted as the reference stator voltage components Vd's and Vq□. Then voltage components in rotating d-q system of coordinates are transformed to a□ stationary coordinates using the flux position angle[8], [9]. With the values Vpand Va , the angle and magnitude reference voltage (Vref and8rer) can be obtained
by(5)

$$\psi_{ref} = \begin{cases} \psi_{rat} & , |\Omega| > \Omega_b \\ \psi_{rat} \dfrac{\Omega_b}{\Omega} & , |\Omega| > \Omega_b \end{cases} \qquad (4)$$

Where ψrat is the 1M-rated stator flux and Ωb is the base speed of induction machine.

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$$V_{ref} = \sqrt{v_\alpha^2 + v_\beta^2} \quad (5)$$

The sector number of reference voltage vector is determined by angle8ref. The angle is determined as follows:

$$\theta_{ref} = \tan^{-1}\left(\frac{V_\beta}{V_\alpha}\right) \quad (6)$$

The stator flux vector is given by:

$$\frac{d\psi_S}{dt} = V_S - R_S I_S \quad (7)$$

$$\psi_{ds} = \int (v_{ds} - R_S I_{ds})dt \quad (8)$$

$$\psi_{qS} = \int (v_{qS} - R_S I_{qS})dt$$

Where Rs is the stator resistance and subscripts ds and qs stand for the d-axis and q-axis components of the voltages urrents of the stator windings of the inductioand cn machine.

From the "equation (7)", for the omitted voltage drop on the stator resistance, the stator flux can be expressed as:

$$\Delta\psi_S = V_S \Delta t \quad (9)$$

The electromagnetic torque can be estimated starting from the estimated sizes of flux linkage vector and the calculated size of motor current vector.

$$T_e = \frac{3}{2} P \left(i_{qs}\psi_{ds} - i_{ds}\psi_{qs}\right) \quad (10)$$

Where P is the number of pole pairs,l/Jds, l/Jqs, ids and iqsare the stator fluxes and currents respectively along the d and q axis.

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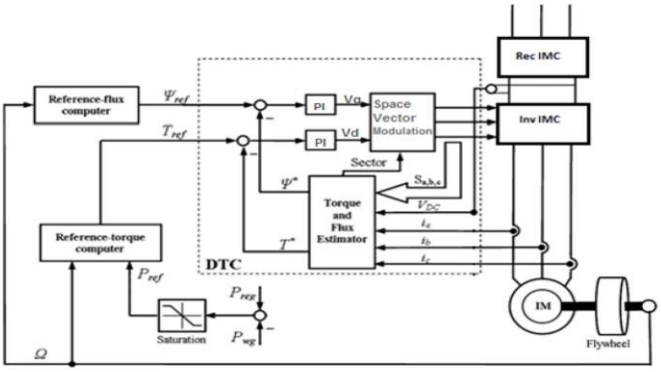

Block diagram of FESS control shame using DTC-SVM for the 1M based on IMC[7].

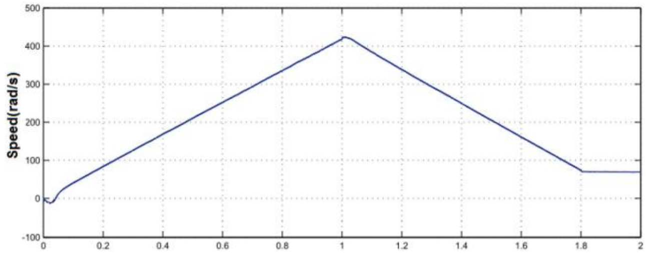

Fig1.Flywheel speed.

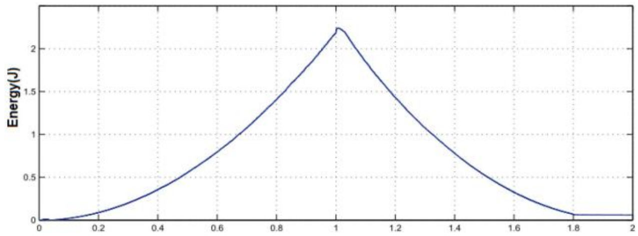

Fig2.Electrical Energy.

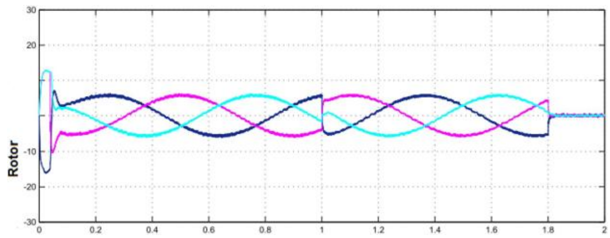

Fig3.Three phase rotor currents of induction machine.

VIII. CONCLUSION

When a FESS is applied in a wind farm, two parameters are important; high dynamic velocity and the high efficiency of control method. In this paper, direct torque control with space vector modulation (DTC-SVM) based on indirect matrix converter is applied to the induction machine of the FESS. The direct torque control has high operation speed. The results indicate that the power FESS follow reference power with fast dynamic. The THD for both the input current of matrix converter and stator current was obtained 6.23 and 2.09 respectively. In addition, the phase form of the input current and the input voltage of matrix converter indicate unit shift coefficient on the input of the system as well as low loss of the method for FESS. The recommended operation of an participation is a future challenging task In flywheel energy storage system.

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