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VECTOR CONTROL METHODS FOR VARIABLE SPEED OF AC MOTORS

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Abstract - *This research paper gives the information and result about the vector controlling methods, using vector control methods what parameters are obtained. These vector controlling is used for A.C .motors. The three phase alternating current (AC) induction motor are mechanically simple, rugged, highly reliable, lower in cost per horsepower than DC motors and capable of more torque and efficiency than single-phase A.C. motors. Vector control, also called field-oriented control (FOC), is a variable-frequency drive (VFD) control method in which the stator currents of a three-phase AC electric motor are identified as two orthogonal elements that can be visualized with a vector. One element defines the magnetic flux of the motor, the second the torque. The control system of the drive analyzed the equivalent current element places from the flux and torque places set by the drive's speed control. Normally proportional-integral (PI) controllers are used to keep the measured current elements at their reference values. The pulse-width modulation (PWM) of the variable frequency drive defines the transistor switching according to the stator voltage references that are the output of the PI current controllers. Doubly Fed Induction Generator (DFIG) wind turbines are nowadays increasingly used in large wind farms because of their ability to supply power at constant voltage and frequency. Modern control techniques such as vector control and MFC (magnitude and frequency control) are studied and some of proposed systems are simulated in MATLAB-SIMULINK environment.*

Key Words: Doubly Fed Induction Generator (DFIG), Alternating Current (AC), Pulse Width Modulation (PWM), Proportional Integral (PI), Wind Energy, Spectral Analysis, Electrical Drives (E.D).

1. INTRODUTION

The control strategy of the machine is distributed in two ways, one is scalar control and the second is vector control. The limitations of scalar control give a importance to vector control. However the scalar control strategy is uncertain to implement but the natural coupling effect gives sluggish response. The inherent problem is presence solved by the vector control. The vector control is invented in the beginning of 1970s. Using this control strategy an induction motor can be performed like dc machine. Because of dc machine like performance vector control is also known as orthogonal, decoupling or Tran's vector control. FOC is used to control AC synchronous and induction motors. It was originally developed for high performance motor applications that are required to operate smoothly over the full speed range, generate full torque at zero speed, and have high dynamic performance including fast acceleration and deceleration. However, it is becoming gradually attractive for lower performance applications as well due to FOC's motor size, cost and power consumption reduction superiority. It is predictable that with increasing computational power of the microprocessors it will eventually nearly universally displace single-variable scalar volts-per-Hertz (V/f) control Altered vector control strategies have been proposed to control the active and reactive power of an induction motor. The basic of the vector control theory is d-q theory. To understand vector control theory information about d-q theory is essential.

1.1 D-Q THEORY

The d-q theory is also known as reference frame theory. The history states in 1920, R. H. Park suggested a new theory to overcome the problem of time varying limitations with the ac machines. He expressed a change of variables which replace the variables related to the stator windings of a synchronous machine with variables related with fictitious winding which rotates with the rotor at synchronous speed. Basically he changed the stator variables to a synchronously rotating reference frame fixed in the rotor. With such transformation (Park's transformation) he presented that all the time varying inductances that occur due to an electric circuit in relative motion and electric circuit with varying magnetic reluctances can be eliminated. Later in 1930s H. C. Stanley showed that time varying parameters can be eliminated by transforming the rotor variables to the variables associated with fictitious stationary windings. In this case the rotor variables are transformed to the stationary reference frame fixed on the stator. Later G. Kron proposed transformation of stator and rotor variables to a synchronously rotating reference frame which moves with rotating magnetic field. Latter, Krause and Thomas had shown that the time varying Inductances can be eliminated by mentioning the stator and rotor variables to an arbitrary reference frame which may rotate at any speed.

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1.2 MAKING DEVELOPMENT

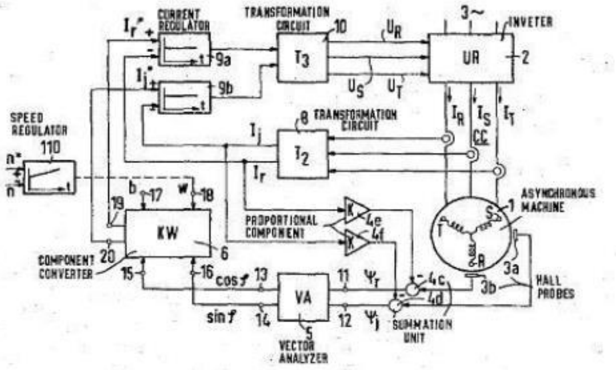


Fig-1: Block diagram from Blaschke's 1971 US patent application

Technical University Darmstadt's K. Hasse and Siemens' F . Blaschke founded vector control of AC motors starting in 1968 and in the early 1970s.Hasse in positions of suggesting indirect Vector control, Blaschke in positions of suggesting direct Vector control. Technical University Braunschweig's Werner Leonhard further developed FOC techniques and was instrumental in opening up opportunities for AC drives to be a competitive other to DC drives. However it was not until after the commercialization of microprocessors, that is in the early 1980s, that general purpose AC drives became available. Barriers to use FOC for AC drive applications included higher cost and complexity and lower maintainability compared to DC drives, FOC having until then required many electronic components in terms of sensors, amplifiers and so on. The Park transformation has long been widely used in the analysis and study of synchronous and induction machines. The transformation is by far the single most important concept needed for an understanding of how FOC works, the concept having been first conceptualized in a 1929 paper authored by Robert H. Park. Park's paper was ranked second most important in terms of impact from among all power engineering related papers ever published in the twentieth century. The novelty of Park's work involves his ability to transform any related machine's linear differential equation set from one with time varying coefficients to another with time invariant coefficients.

2. OVERWIEW

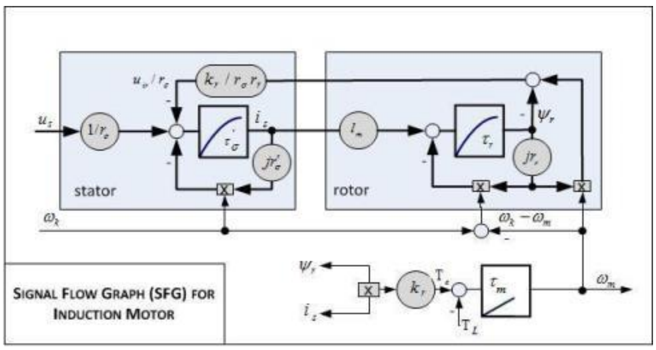
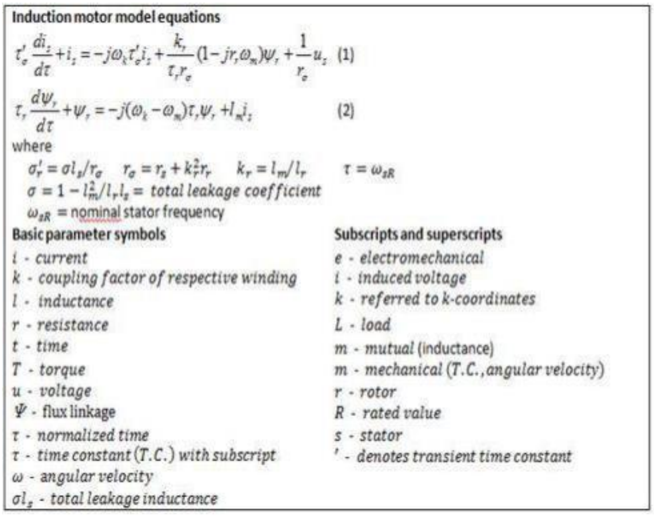


Fig-2: Signal Flow Graph (SFG) for Induction Motor


Induction motor model equations

$$\tau'_\sigma \frac{di_s}{d\tau} + i_s = -j\omega_k \tau'_\sigma i_s + \frac{k_r}{\tau_r r_\sigma}(1 - j\tau_r\omega_m)\psi_r + \frac{1}{r_\sigma}u_s \quad (1)$$

$$\tau_r \frac{d\psi_r}{d\tau} + \psi_r = -j(\omega_k - \omega_m)\tau_r\psi_r + l_m i_s \quad (2)$$

where

$\sigma'_r = \sigma l_s / r_\sigma$ $\quad r_\sigma = r_s + k_r^2 r_r$ $\quad k_r = l_m / l_r$ $\quad \tau = \omega_{sR}$

$\sigma = 1 - l_m^2 / l_r l_s =$ total leakage coefficient

ω_{sR} = nominal stator frequency

Basic parameter symbols
- i - current
- k - coupling factor of respective winding
- l - inductance
- r - resistance
- t - time
- T - torque
- u - voltage
- Ψ - flux linkage
- τ - normalized time
- τ - time constant (T.C.) with subscript
- ω - angular velocity
- σl_s - total leakage inductance

Subscripts and superscripts
- e - electromechanical
- i - induced voltage
- k - referred to k-coordinates
- L - load
- m - mutual (inductance)
- m - mechanical (T.C., angular velocity)
- r - rotor
- R - rated value
- s - stator
- $'$ - denotes transient time constant

Fig-3: SFG Equations

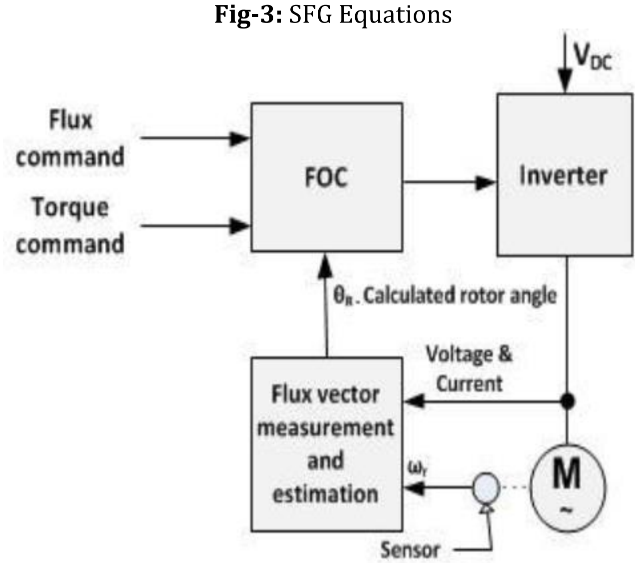


Fig-4: Simplified Direct vector control Block Diagram

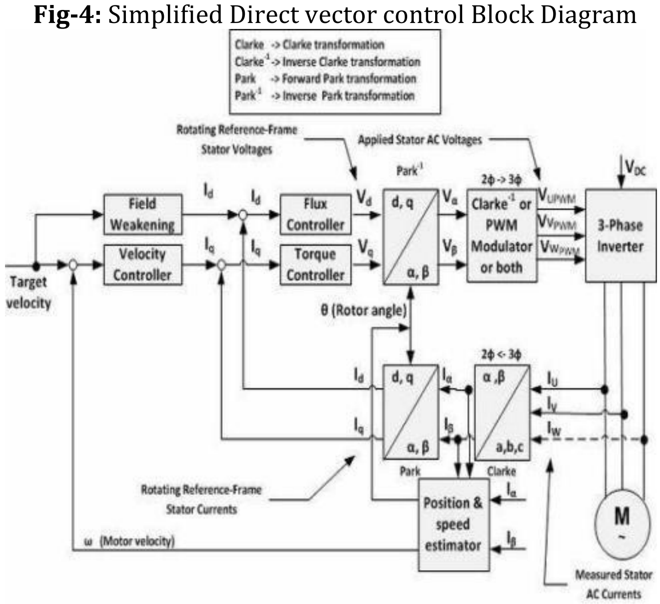


Fig-5: Vector control Block Diagram

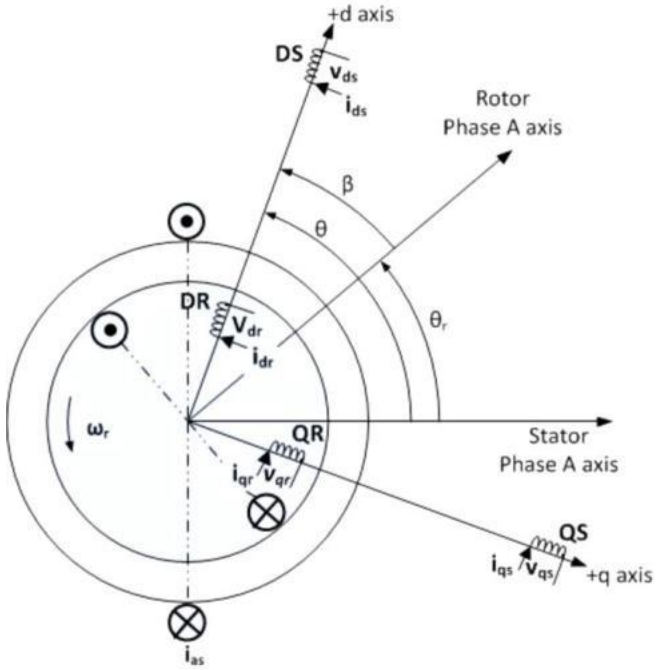


Fig-6: (D-Q) Coordinate System Superimposed on Three-Phase Induction Motor

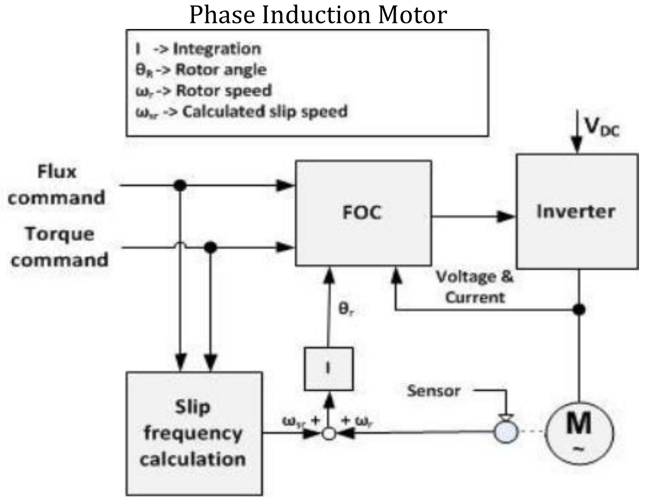


Fig-7: Simplified Indirect FOC Block Diagram

While the analysis of AC drive controls can be technically quite involved ("See also" section), such analysis invariably starts with modeling of the drive-motor circuit involved along the lines of accompanying signal flow graph and equations.[19] In vector control, an AC induction or synchronous motor is controlled under all operating conditions like a Simplified Direct FOC Block Diagram. Vector control Block Diagram separately excited DC motor. That is, the AC motor behaves like a DC motor in which the field flux linkage and armature flux linkage created by the respective field and armature (or torque component) currents are orthogonally aligned such that, when torque is controlled, the field flux linkage is not affected, hence enabling dynamic torque response. Vector control accordingly generates a three-phase PWM motor voltage output derived from a complex voltage vector to control a complex current vector derived from motor's three-phase stator current input through projections or rotations back and forth between the three-phase speed and time dependent system and these vectors' rotating reference-frame two-coordinate time invariant system. Such complex stator current space vector can be defined in a (D-Q) coordinate system with orthogonal components along d (direct) and q (quadrature) axes such that field flux linkage component of current is aligned along the d-axis and torque component of current is aligned along the q-axis. The induction motor's (D -Q) coordinate system can be superimposed to the motor's instantaneous (a,b,c) three-phase sinusoidal system as shown in accompanying image (phases b & c not shown for clarity). Components of the (D-Q) system current vector, allow conventional control such as proportional and integral, or PI control, as with a DC motor.

3. Result

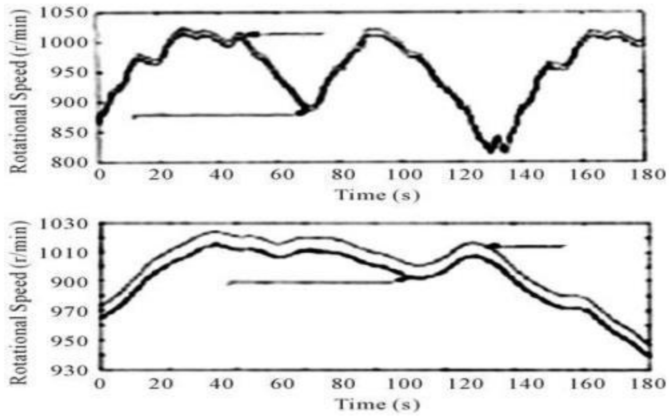


Fig-8: Speed estimation errors

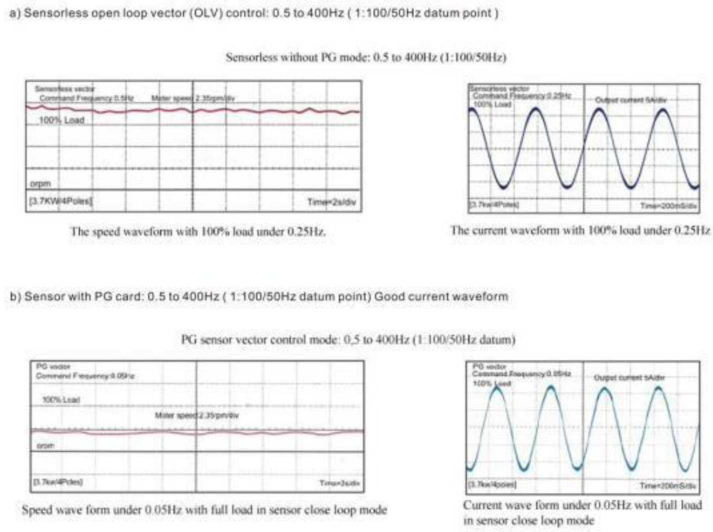


Fig-9: Vector controlling results

4. CONCLUSIONS

The main objective of this paper is accomplished. A three phase AC induction motor is controlled by varying its input according to a mathematical model of the rotor flux field in a complex vector space (Vector Control). Vector Control facilitates us with smooth control of Induction Motor which can be used for various applications in our practical life.

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