

VECTOR CONTROL OF INDUCTION MACHINES

Ilie Borcosi¹, Alina Dincă², Daniela Nebunu³, Antonie Nicolae⁴

¹ "Constantin Brancusi" University of Tg-Jiu, Geneva Street, Nr. 2, Gorj, ilie_b@utgjiu.ro

² Constantin Brancusi University, Tg. Jiu, alina@utgjiu.ro

³ Constantin Brancusi University, Tg. Jiu, dana@utgjiu.ro

⁴ Constantin Brancusi University, Tg. Jiu, antonie.nicolae@utgjiu.ro

ABSTRACT. The vector control which consists of maintaining the orthogonality between the flux and active current, strengthens the advantages of using the induction motors, compared to the continuous current motors.

ВЕКТОРЕН КОНТРОЛ ПРИ ИНДУКЦИОННИТЕ МАШИНИ

Илия Боркоз¹, Алина Динча², Даниела Небуну³, Антони Николае⁴

¹ Университет "Константин Бранкуш", Търгу Жиу, ул. Женева № 2, Гордж, ilie_b@utgjiu.ro

² Университет "Константин Бранкуш", Търгу Жиу, alina@utgjiu.ro

³ Университет "Константин Бранкуш", Търгу Жиу, dana@utgjiu.ro

⁴ Университет "Константин Бранкуш", Търгу Жиу, antonie.nicolae@utgjiu.ro

Резюме: Векторният контрол, който представлява поддържане на ортогоналност между потока и реалния ток дава предимство на използването на индукционните електродвигатели в сравнение с електродвигателите на непрекъснат ток.

1. Introduction

For a long time, the induction motors were not a technical solution for adjustable control (driving), even though they are superior to the continuous current motor considering dimensions, weight, rotor ineptness, effective power, cost, reliability, exploitation expenses, etc.

Along with the recent developments in the power industrial electronics domain, with applications in variable speed driving, the adjustable driving with induction motors are used in a wide scale.

I talk about two development directions: one connected to the semiconductor devices (electronic valves) and the other one connected to their command circuits.

From the point of view of the automated speed adjustments systems with alternative current motors, a different approach must be considered, compared to the case with continuous current motors. At the continuous current motors, the flux and current in the induced circuit are independent (not coupled) and because of this, simple adjustment schemes have been designed, fully controllable and with good dynamic performances.

2. Asynchronous motor control principles

Until recently, the most used revolution adjustment method for an asynchronous motor was "Scalar Control" (or "V/Hz").

For this method, the motor works in an area in which the rotor flux is constant (volts proportionally to speed).

In case of the asynchronous motor with short-circuited rotor, the static converter must ensure the motor with the necessary active and reactive power for magnetization, because it external sources for excitation don't exist. They must be found in the statoric coiling of the asynchronous motor, both currents: excitation (reactive) and couple generator (active).

Field oriented control uses the spatial phases for modeling the AC motors, their complex structure being able to be transformed in one similar to the CC motor, characterized by the orthogonality between flux and current. As a consequence, the electromagnetic couple developed by the motor has permanently an expression of scalar product between flux and current, similar to the couple developed by the continuous current motors with separate excitation and so, maximum value. Adjustment of the couple through this method is done through decoupling the active and reactive components of the statoric currents, generators for couple and flux.

Because the expression of the electromagnetic couple may be written in different referential systems, solidary with the statoric, rotoric or magnetization flux, there are a lot of variants for adjustment schemes for each type of command.

Field control is made in a referential system which is solidary with the flux we need information about. The components of

The C2812 is generating six pulse width modulation (PWM) signals by means of space vector PWM technique for six power – switching devices in the inverter. Two input currents of the AM (i_a and i_b) are measured from the inverter and they are sent to the c218 via two analog – to – digital converters. The current on the third phase is not necessary to be calculated because it is obtained from the relation:

$$i_a + i_b + i_c = 0$$

The rotor position is required for variable transformation from stationary reference frame to synchronously rotating reference frame. The rotor position is obtained from the encoder. As a result of this transformation, the so called Park transformation, the q-axis current will be controlling torque while the d-axis current is forced to zero. In this case “d” means direct and “q” means Quadrature.

The Park transform has been around for 78 years. This theory requires very much mathematical calculations (matrix multiplications), which can be made in real-time with the help of DSPs.

This theory is not limited to sinusoidal distribution and can be applied to any kind of vector.

We start from the alimentation voltages' vector (V_s) of the stator (the voltage vector applied to the stator):

$$V_s = \begin{bmatrix} v_{s1} \\ v_{s2} \\ v_{s3} \end{bmatrix}$$

In fig. 2 is shown the change of the reference through Park transformation.

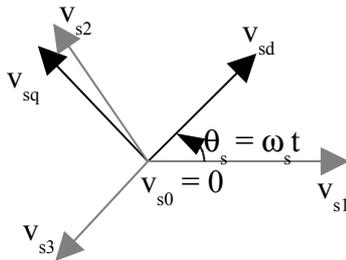


Fig. 2

This referential change transforms the V_s vector in a new vector as written below:

$$\begin{bmatrix} v_{s1} \\ v_{s2} \\ v_{s3} \end{bmatrix} = \begin{bmatrix} \cos \theta_s & -\sin \theta_s \\ \cos(\theta_s - \frac{2\pi}{3}) & -\sin(\theta_s - \frac{2\pi}{3}) \\ \cos(\theta_s - \frac{4\pi}{3}) & -\sin(\theta_s - \frac{4\pi}{3}) \end{bmatrix} \begin{bmatrix} v_{sd} \\ v_{sq} \\ v_{s0} \end{bmatrix}$$

or

$$\begin{bmatrix} v_{s1} \\ v_{s2} \\ v_{s3} \end{bmatrix} = \mathcal{P}(\theta_s) \begin{bmatrix} v_{sd} \\ v_{sq} \\ v_{s0} \end{bmatrix} \text{ and } \begin{bmatrix} v_{sd} \\ v_{sq} \\ v_{s0} \end{bmatrix} = \mathcal{P}(\theta_s)^{-1} \begin{bmatrix} v_{s1} \\ v_{s2} \\ v_{s3} \end{bmatrix}$$

For a three-phase balanced system the following relations

can be written:

$$\begin{aligned} v_{s1} + v_{s2} + v_{s3} &= 0 \\ v_{sd} \cdot v_{sq} &= 0 \\ v_{sd} \cdot v_{s0} &= 0 \\ v_{sq} \cdot v_{s0} &= 0 \end{aligned}$$

where:

- (v_{sd}, v_{sq}, v_{s0}) are called the Park coordinates;
- v_{sd} – is direct Park component;
- v_{sq} – is squaring Park component;
- v_{s0} – is homo-polar Park component;
- v_{s0} is null for a three-phase balanced
- each pair of components is perpendicular to each other.

In specialty literature is used the normalized Park transform for which the inverted matrix is much easier to calculate and which allows building an orthogonal referential change:

$$\mathcal{P}(\theta_s) = \begin{bmatrix} \cos \theta_s & -\sin \theta_s \\ \cos(\theta_s - \frac{2\pi}{3}) & -\sin(\theta_s - \frac{2\pi}{3}) \\ \cos(\theta_s - \frac{4\pi}{3}) & -\sin(\theta_s - \frac{4\pi}{3}) \end{bmatrix}$$

The normalized Park can be seen as a result of the combination of the Clarke transform combined with a rotation.

Clarke transform converts balanced three-phase quantities into balanced two-phase orthogonal quantities, as in fig. 3:

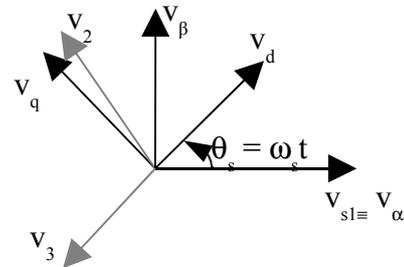


Fig. 3

Combining the Clarke and Park transforms as defined above, we move from the three-phase rotating domain to the stationary domain: we just need to control DC quantities in real-time.

To drive the power switches with new values we have to re-transform these stationary control values back into the three-phase rotating domain. This is done with a similar transform function called “Inverse Park”, as in fig. 1. The control itself is done with 3 instances of a C-cellable function “PID”.

3. Conclusions

The vector control offers to the asynchronous motors major advantages in report to the CC motors for the revolution adjustment systems.

Actual evolutions from the power electronics domain and the apparition of DSPs make possible the real-time control. In addition to this, Texas Instruments, world's leader for DSP production, puts at anyone's disposal for free all the necessary drivers.

4. References

1. I. Borcoși, Olaru Onisifor, Luminița Popescu, Cureleanu Sorin – “*Three Phase Inverter with U/f report constant*”,

Conference with international participation “Gorjeanul in mileniul III”, Tg-Jiu, 18-19 November 2005.

2. I. Borcoși, Luminița Popescu, Florin Grofu, Nicolae Antonie – „*Inverters with rectangular output voltage*”, the XIth edition of the scientific conference of the Faculty of Engineering, with international participation, 3-4 november, 2006, Tg-Jiu.
3. Sergiu Iovanov, *Vector adjustment of the electronic control systems*, Craiova University Printing House, Craiova, 2000.
4. www.ti.com

Recommended for publication of Editorial board