COMPARISON OF INFORMATION TECHNOLOGY OF ENERGY CONTROLLED CURRENT SOURCE INVERTER DRIVES

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ABSTRACT

A new induction motor drive control strategy is introduced for current source inverter. The so-called contact energy model is used. The contact energy control diagram is presented that is the base of the strategy. Speed or torque control can be realized without measurement or calculation of mechanical speed. Laboratory experimental results are also presented. Change in contact energy shows the energy need in the future. In this way the control of contact energy is a control for the future, and it results high dynamics and no oscillations. The paper presents the information technology of two control process (CBEC and EBCC).

1. THEORETICAL APPROACH AND OPERATION

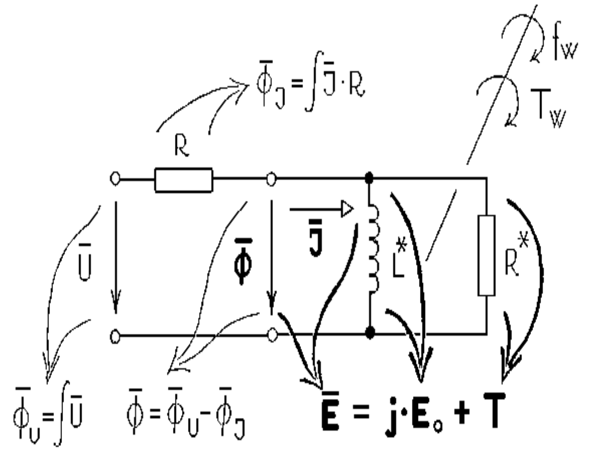

Fig.1. Induction machine energy model

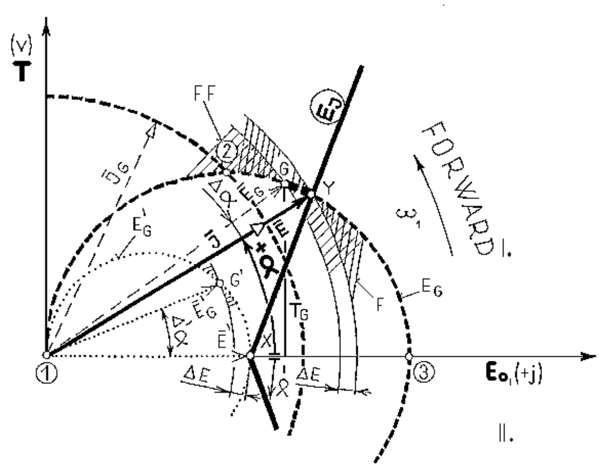

Fig.2. Induction machine combined Contact Energy and Contact Energy Control diagram

The generally used induction machine model consists of resistances and inductance. A modified "Energy Model" is used during the research work, where only the stator resistance is taken into consideration with its original value. The motor remainder part is represented by the L^* and R^* equivalent elements, as it is shown in Fig. 1. The vectors of stator voltage space vector $\overline{U}$, the stator current space vector $\overline{I}$, and the stator resistance R are derived continuously from the motor. Therefore the flux $\overline{\phi}$ and stator current $\overline{I}$ space vectors are equal to the actual motor values, that means that the used main field and leakage values are errorless, and the equivalent L^* and R^* values are not calculated. The electromagnetic energy E_0 inside the motor represents the energy of the magnetic wave field produced by voltage or current compulsion and is considered as a potential energy. The contact energy and contact energy control diagram of induction machine is shown in Fig.2. The flux space vector is fixed to the real axes. The Contact energy diagram in the case of $\bar{I}_G$ current limit is represented by broken line. The set points for this current value is determined by the $\bar{I}$ and $\bar{E}$ space vectors driven by thick line. If we determine the set points for every current value, the series of set points gives the Contact-Energy control diagram (continuous thick curved line). In position *3*, the total energy input is equal to the E_0 component, and $f_{rot} = 0$. In position *2*, $E_0 = T$ that is the breakdown torque value, and the rotor frequency is the breakdown value. In position *1*, ($E_0 = T = 0$) the frequency has an infinite value. The no-load point is signed by X. The controller works on the interval $X - Y$. ΔE energy difference develops on the interval $Y - G$, that results frequency seeking and tracking. Other special positions on the diagram are: $F - FF$: error surface, ω_1: forward rotational direction, $I.$: motor mode, forward, $II.$: generator mode forward, $\Delta\alpha, \Delta\alpha$': load angle difference, $\bar{E}_G, \bar{E}_G$': contact energy with energy limit, T_G: torque limit. Knowledge about the correlation between the I current and E contact energy are given in literature [2].

1.1. Determination of torque

From the relation of the directed fields $\bar{\phi}$ and $\bar{I}$ results the torque T_w. It is defined by the following form:

$$\vec{T}_w = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \phi_x & \phi_y & 0 \\ I_x & I_y & 0 \end{vmatrix} = \vec{k} \cdot \left(\phi_x \cdot I_y - \phi_y \cdot I_x \right) \tag{1}$$

$$\vec{T}_w = \vec{k} \cdot T_w \text{ (VAs), (Nm)} \tag{2}$$

The value of variables $\bar{\phi}$ and $\bar{I}$ can be determined from the induction machine model.

1.2. Contact energy space vector

The following form can determine the Contact energy space vector:

$$\begin{aligned} \bar{E} &= \left(\bar{\phi} \cdot \bar{I}^*\right)^* \cdot j = \\ &= \left(\left(\phi_y + j \cdot \phi_x\right) \cdot \left(I_y - j \cdot I_x\right)\right)^* \cdot j = \\ &= \left(\phi_x \cdot I_y - \phi_y \cdot I_x\right) + j \cdot \left(\phi_y \cdot I_y + \phi_x \cdot I_x\right) = \\ &= T + j \cdot E_0 \qquad \left(\text{VAs}\right). \end{aligned} \tag{3}$$

In this approach the potential effective energy (T) is equal to the motor torque measured on the shaft of the machine (T_w), i.e. $T = T_w$. The (E_0) potential magnetic energy.

2. CONTACT ENERGY CONTROL - CURRENT BASED ENERGY CONTROL (CBEC)

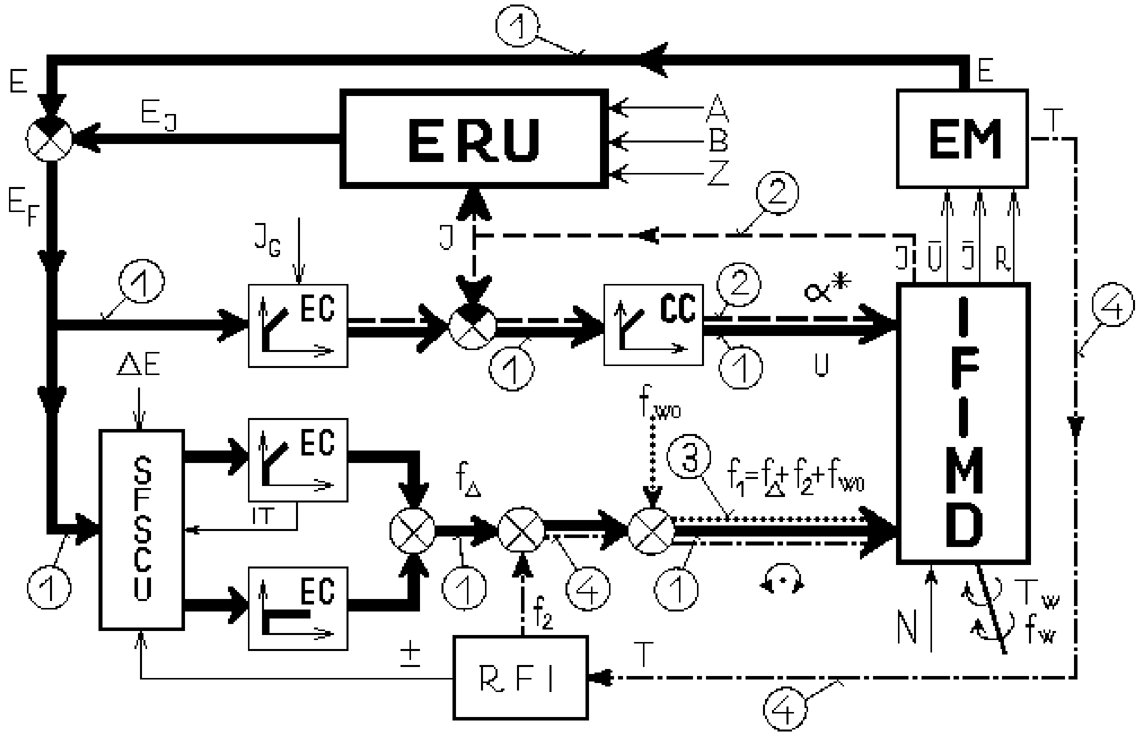

Fig.3. Current Based Energy Control (CBEC)

2.1. The following control loops are used in the controller

1 Energy controller, *2* Current controller, *3* Shaft-frequency controller, *4* Rotor-frequency controller.

2.2. The signals and the main parts of the controller are

I dc current value, I_G dc circuit current limit value, $\bar{I}$ current space vector, $\overline{U}$ voltage space vector, R stator resistance, α^* firing angle, U voltage reference value, N three-phase power network, E contact energy, E_I contact energy reference value, E_F contact energy error signal, A dc circuit current value at $\alpha = 0^0$ load angle, B dc circuit current value at $\alpha = 45^0$ load angle, Z transfer factor, ΔE contact energy difference, IT integrator inhibit, f_1 stator frequency, f_2 rotor frequency, f_w shaft frequency, f_{wo} shaft frequency reference value, f_Δ frequency compensation, T effective energy, T_w shaft torque. *IFIMD* Inverter-Fed Induction Motor Drive, *EM* Energy Model, *ERU* Energy Reference Unit, *EC* Energy Controller, *CC* Current Controller, *SFSCU* Shaft Frequency Seeking and Controlling Unit, *RFI* Rotor Frequency Interface.

More information about control process showed in parts 2 and 3 are presented in literature [1], [2], [3].

3. CONTACT ENERGY CONTROL - ENERGY BASED CURRENT CONTROL (EBCC)

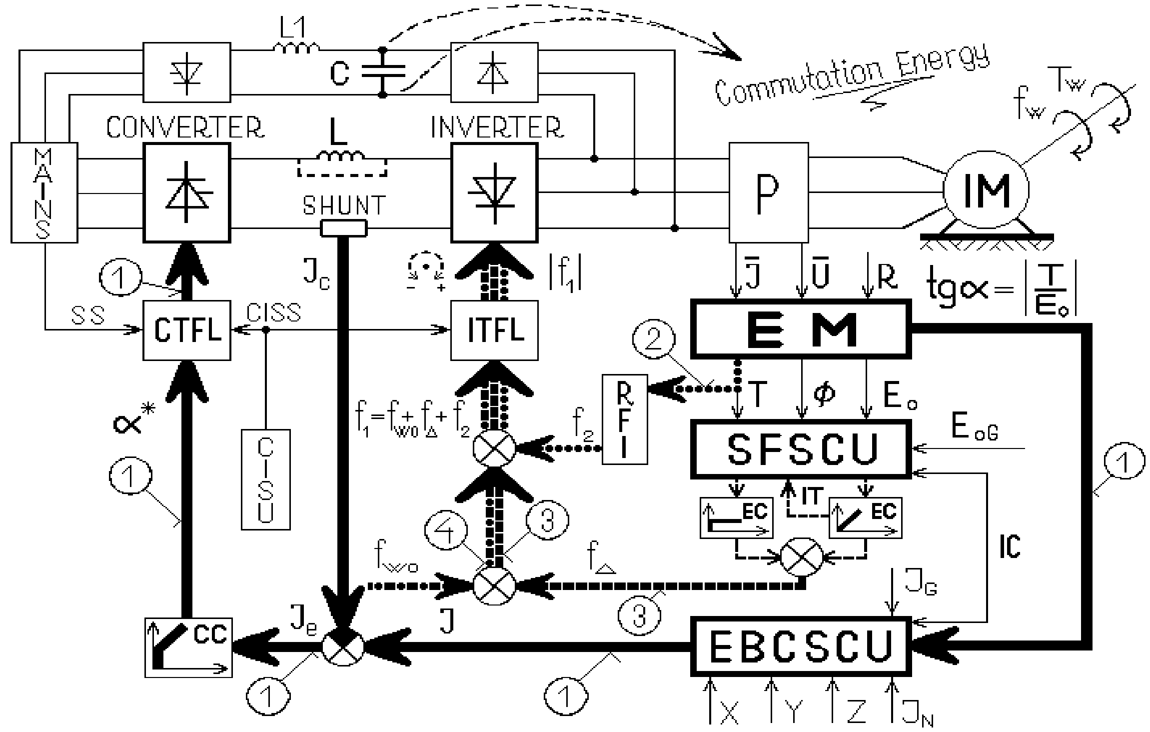

Fig.4. Energy Based Current Control (EBCC), tgα Control

3.1. The following control loops are used in the controller

1 Current controller, *2* Rotor-frequency controller, 3 Magnetic energy controller, *4* Shaft- frequency controller.

3.2. The signals and the main parts of the controller are

I_C current control signal, I_e current error signal, I current reference or principal signal, I_G current limit value, I_N rated current, X p.u. relative current value, if $\alpha = 45^0$, Y p.u. relative current value if $\alpha = 0^0$, Z transfer factor, IC communication, SS synchronous signal, $CISS$ converter-inverter synchronous signal, $\bar{I}$ current space vector, $\bar{U}$ voltage space vector, R stator resistance, α^* firing angle, T effective energy, T_w shaft torque, ϕ flux, E_{0G} magnetic energy limit, IT integrator inhibit, f_1 stator frequency, f_2 rotor frequency, f_w shaft frequency, f_{wo} shaft frequency reference value, f_Δ frequency compensation, $L, L1$ inductances, C capacitor. *EM* Energy Model, *SFSCU* Shaft Frequency Seeking and Controlling Unit, *EBCSCU* Energy Based Current Signal Computation Unit, *CTFL* Converter Thyristor Firing Logic, *ITFL* Inverter Thyristor Firing Logic, *CISU* Converter-Inverter Synchronizing Unit, *RFI* Rotor Frequency Interface, *CC* Current Controller, *EC* Energy Controller, *P* Park-vector presentation circuit, *IM* Induction Motor.

4. THE INFORMATION TECHNOLOGY OF CBEC AND EBCC CONTROLS

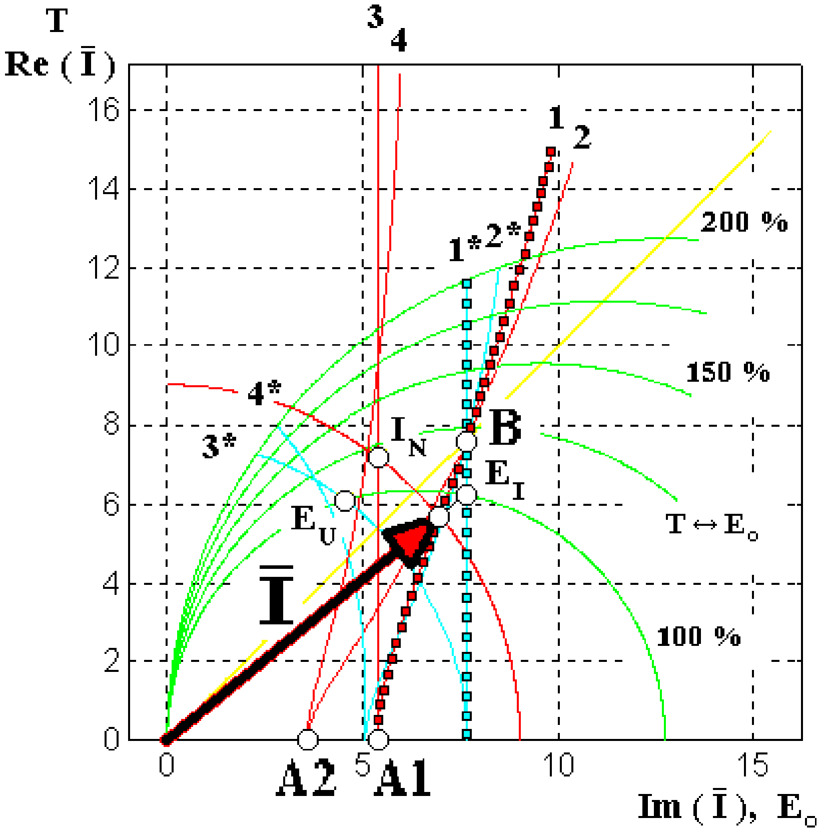

Fig.5.

Induction machine Contact Energy Control diagram ($I_N = 9A$, $\cos\varphi = 0.8$), Control Strategy – (CBEC)

$$B = 1.2 \cdot I_N,$$
$$A1 = 0.6 \cdot I_N,$$
$$A2 = 0.4 \cdot I_N.$$

1, 1*, 2, 2* curves: $Z(CBEC) = 1.$

3, 3*, 4, 4* curves: $Z(CBEC) = 2.$

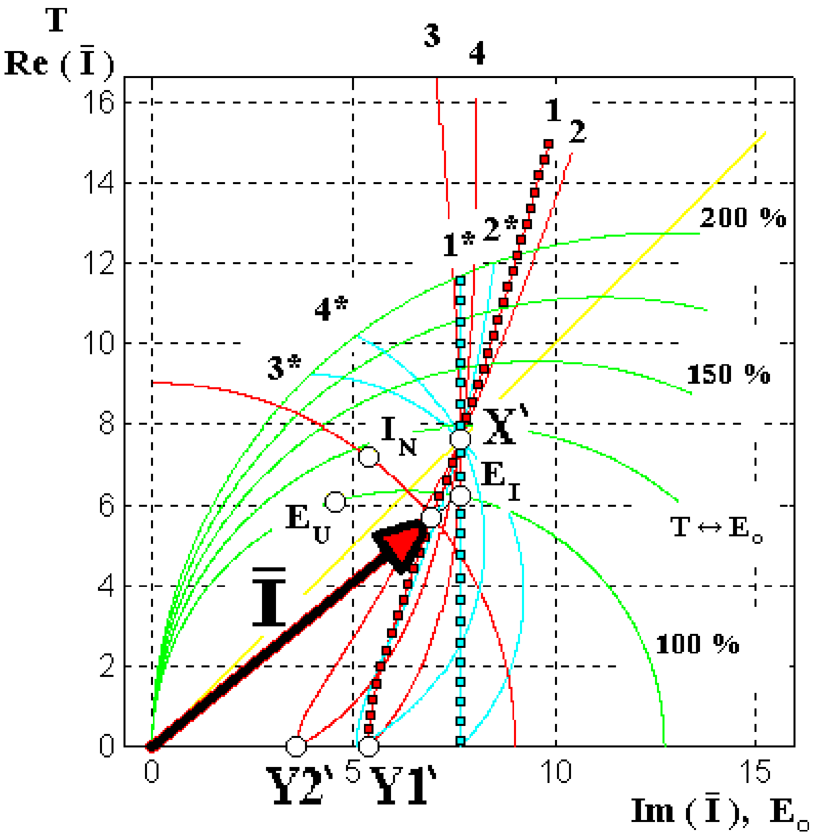

Fig.6.

Induction machine Contact Energy Control diagram ($I_N = 9A$, $\cos\varphi = 0.8$), Control Strategy – (EBCC)

$$X = 1.2,$$
$$Y1 = 0.6,$$
$$Y2 = 0.4.$$

1, 1*, 2, 2* curves: $Z(EBCC) = 2.$

3, 3*, 4, 4* curves: $Z(EBCC) = 1.$

The control function of contact energy related to Fig. 3. and 5.:

$$E_I = \sqrt{2} \cdot I \cdot \left(\frac{B - A}{B - 2 \cdot A + I} \right)^{\frac{Z}{2}}. \tag{4}$$

The control function of contact energy related to Fig. 4. and 6.:

$$I = I_N \cdot X \cdot \left(1 + \left(1 - \frac{Y}{X} \right) \cdot \left((\mathrm{tg}\,\alpha)^Z - 1 \right) \right). \tag{5}$$

Fig. 5. and 6. demonstrates that the two different controllers with parameters $Z(CBEC) = 1$ and $Z(EBCC) = 2$ gives the same results. The definition of quantities in relations (4) and (5) are given in parts 2.2. and 3.2. The curves 1, 2, 3, 4 are currents (A), and 1*, 2*, 3*, 4* are contact energies (VAs). The analysis were done using MATLAB.

5. CONCLUSIONS

The experimental tests show that the new sensor-less drive gives good results. The measurement or calculation of rotational speed can be neglected. The knowledge of the machine parameters is not necessary. The control strategy gives high precision and excellent dynamical behaviour. The machine is able to work on any set points with high stability The contact energy control can also be considered as current based energy control strategy (CBEC) and energy based current control strategy (EBCC) with the new strategy. The contact energy control control method is a new control strategy that can be used as general control strategy of converter-fed ac machine. The two contact energy controls with the above applied parameters give the same results.

6. REFERENCES

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