# An Algorithm for Synchronized Control of Multi-Motor Drive Systems

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*Abstract* – **A general-mode algorithm for synchronized control of multi-motor drive systems is presented in this paper. Application of the offered control algorithm to speed synchronization has been investigated and discussed. The developed computer simulation models and the results obtained can be used in optimization and final tuning of such types of drive systems.**

*Keywords* – **fault diagnosis, analytical redundancy**

## I. Introduction

Automation of a number of production lines requires control of multi-motor electric drive systems. By technological reasons it is often necessary to maintain exact synchronization of the main controlled variables such as position, speed and acceleration.

The required synchronization can be achieved applying a common reference signal and individual stabilization of the regulated variables for all the electric drives.

In order to realize more precise synchronization control, some corrections of the slave electric drive reference signals may be introduced, in accordance with the respective differences between the master and slave drives controlled variable values [1].

A method and relevant device for control of dual-motor electric drives aiming at synchronized maintenance of the regulated variables have been proposed in [2]. The performance of some dual-motor electromechanical systems with synchronized speed and position control applying this method has been presented in [3].

This paper describes and discusses a general-mode control algorithm for multi-motor drive systems, which provides the possibility to maintain reference synchronization accuracy of the respective controlled variables. Results from the investigation of such a drive system where the offered algorithm has been applied for synchronized speed control, are also represented.

## II. Control Algorithm

The simplified block diagram of the multi-motor drive system under consideration is shown in Fig. 1, where the following notations have been used: LC – logical control block; ED1, ED2, ..., ED$n$ – electric drives; S1, S2, ..., S$n$ – sensors for the controlled variables; L1, L2,..., L$n$ – loads of the electric drives; $x(t)$ – the input common reference signal for the main controlled variable; $x_1(t)$, $x_2(t)$, ..., $x_i(t)$, ...,$x_n(t)$ – the reference signals for the respective electric drives; $y_1(t)$, $y_2(t)$, ..., $y_i(t)$, ...,$y_n(t)$ – the feedback signals; $z_1(t)$, $z_2(t)$, ..., $z_i(t)$, ...,$z_n(t)$ – the disturbances applied to the electric drives; $\triangle y_r$ the reference dead zone determining the synchronization accuracy.

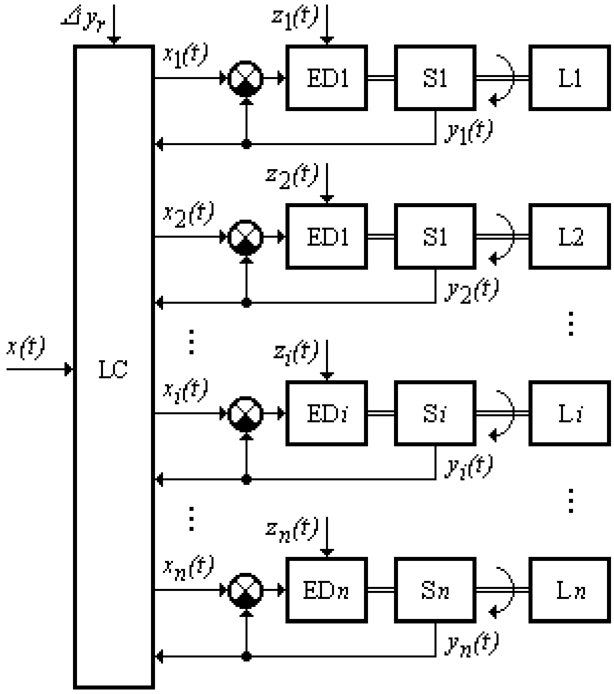


Fig. 1. Simplified block diagram of a multi-motor drive system

In this system the respective feedback signals are being used for both individual stabilization of the controlled variables and realization of synchronized control of the electric drives.

Fig. 2 shows a simplified flowchart of the proposed control algorithm in its general-mode. The algorithm provides for synchronization of the principal controlled variables in multi-motor drive systems such as speed or position.

According to the adopted control strategy, at the beginning of the starting process, as well as during operation in steady-state regimes, the reference signals for the electric drives are as follows:

$$x_1(t) = x_2(t) = ... = x_i(t) = ... = x_n(t) = x(t) \qquad (1)$$

The control continues in relation to Eq. 1 while the maximum error is within the limits of the reference error

$$\Delta y_{max} \leq \Delta y_r \qquad (2)$$

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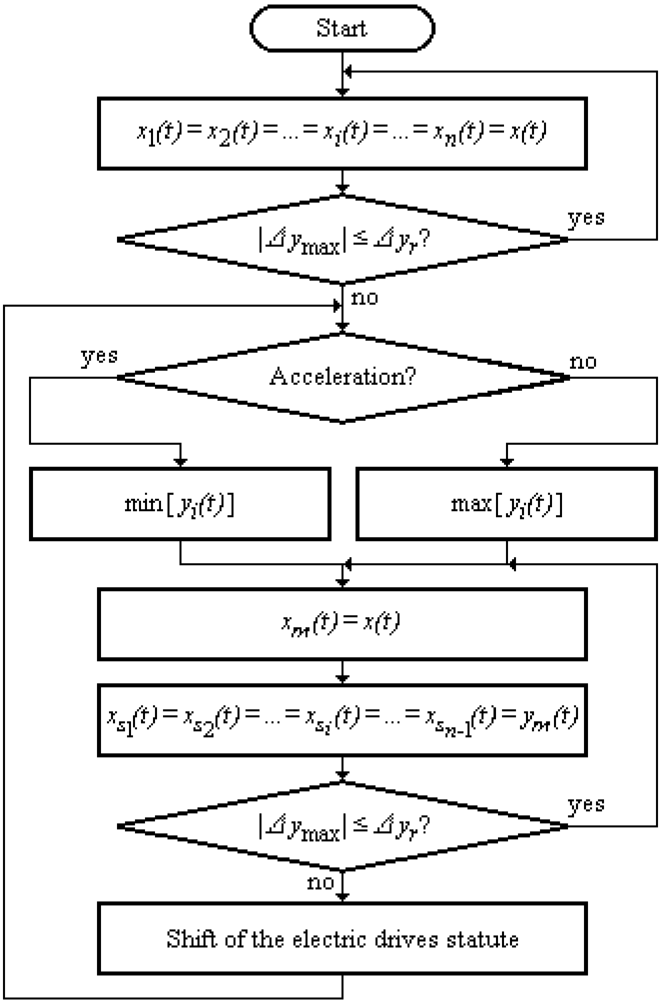


Fig. 2. Simplified flowchart of the proposed control algorithm

The respective feedback signals $y_i(t)$ are compared to determine the smallest value signal. The electric drive that for the given moment appears as most lagging assumes the statute of a master one, while the rest of $n-1$ electric drives become slaves. Therefore, the master drive is the one limiting the performance of the multi-motor system.

The master electric drive continues to be synchronized by the input reference signal

$$x_m(t) = x(t) \tag{3}$$

while the reference signals for the slaves are determined by the feedback signal of the master electric drive:

$$x_{s1}(t) = x_{s2}(t) = ... = x_{si}(t) = ... \\ = x_{sn-1}(t) = y_m(t) \tag{4}$$

The subscripts used are as follows: $m$ – for the master drive and $s$ – for the all slave drives.

When a new lagging occurs, the slowest electric drive automatically becomes the master and the control continues in compliance with Eq. 3 and Eq. 4 respectively.

During acceleration the electric drive that has the lowest level of the controlled variable is assumed as a master - $\min[y_i(t)]$, but at deceleration the master drive will be the one that has the highest controlled variable value - $\max[y_i(t)]$. Therefore, the shifting conditions for the electric drives statute are as follows:

$$y_m(t) = \min[y_i(t)] \text{ – for acceleration} \tag{5}$$

$$y_m(t) = \max[y_i(t)] \text{ – for deceleration} \tag{6}$$

This way the required accuracy is achieved as in the transient regimes (accelerating and decelerating) with different loads, so in cases of disturbances applied to the respective electric drives.

To verify the offered control algorithm functionality a number of computer simulation models have been developed using the MATLAB/SIMULINK software package. Various electric drives have been modelled including both DC and AC motor types. The respective models allow study of a wide range of multi-motor electromechanical systems with different controlled variables.

## III. Investigation of a Sample Drive System

The block diagram of a sample multi-motor drive system of the investigated type is shown in Fig. 3. The used notations are as follows: LC – logical control block; SC1, SC2 and SC3 – speed controllers; CC1, CC2 and CC3 – current controllers; PC1, PC2 and PC3 – power electronic converters; M1, M2 and M3 - electrical motors; SS1, SS2 and SS3 – speed sensors; SF1, SF2 and SF3 – speed feedback blocks; CF1, CF2 and CF3 -current feedback blocks; L1, L2 and L3 – loads of the motors; $\omega_2$, $\omega_2$ and $\omega_3$ – angular speeds; $T_1$, $T_2$ and $T_3$ – motor torques; $T_{l_1}$, $T_{l_2}$ and $T_{l_3}$ – load torques applied to the motors; $J_1$, $J_2$ and $J_3$ – summary inertias referred to the motor shafts.

The corresponding signals and variables for this tri-motor drive system are as follows:

$$\begin{aligned} &x(t) \to V_{sr}\,; \\ &x_i(t) \to V_{sr_i}\,; \\ &y(t) \to V_{sf_i}\,; \\ &z(t) \to \triangle T_{l_i},\, \triangle J_i\,; \\ &\triangle y_r \to \triangle\omega_r\,; \\ &i = 1,\, 2,\, 3 \end{aligned} \tag{7}$$

The system input includes the common reference signal for the main controlled variable $V_{sr}$ as well as the reference dead zone determining the synchronization accuracy $\triangle\omega_r$. Both load torque and inertia changes in the drive system can be considered as disturbances.

In the electromechanical system under consideration all the electric drives are of the same type and act as dual-loop cascade control structures.

Fig. 4 represents some simulation results illustrating the performance of one of the electric drives. The transient start and stop processes are shown, as well as the drive response to the disturbances, expressed in changes of the load torque acting upon the motor shaft. The starting current is limited to the maximum admissible value $I_{a\max}$, which provides a maxi-mum starting motor torque. The load torque is equal

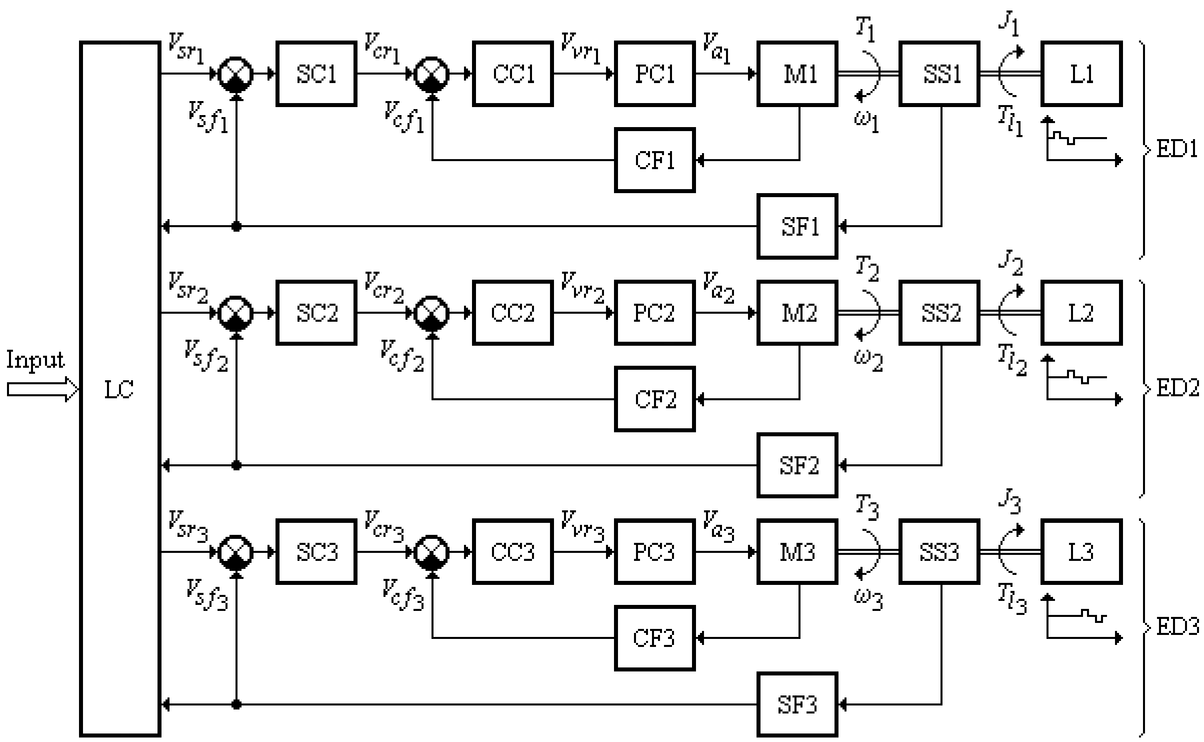


Fig. 3. Block diagram of the investigated multi-motor drive system with synchronized speed control

to the nominal value, while the disturbances applied sequentially are $\triangle T_l$=+25% and $\triangle T_l$=-25%, respectively. The motor cur-rent value at the steady-state regimes is $I_a = I_{a\text{nom}}$

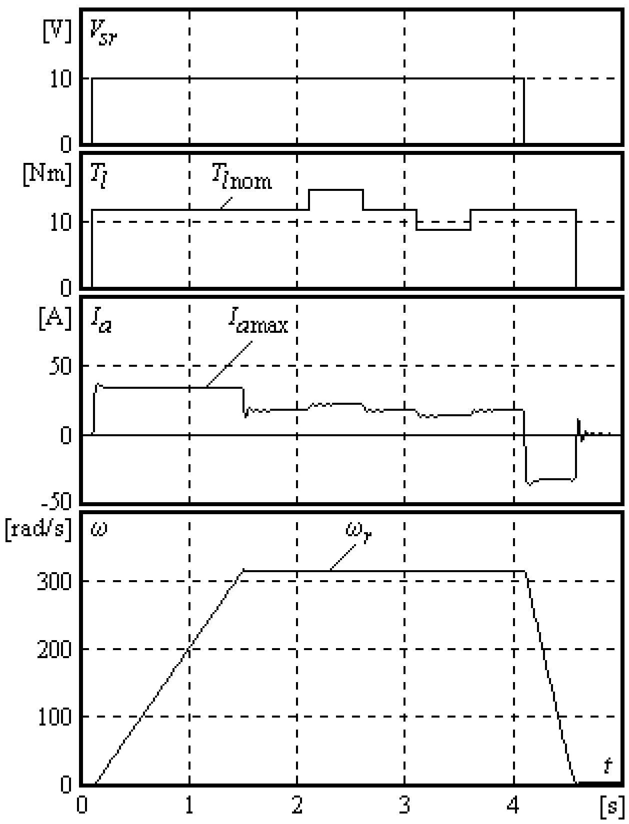


Fig. 4. Simulation results for one of the controlled electric drives

and it conforms to the nominal load torque $T_{l\text{nom}}$. The setting electric drive parameters in this case are as follows: reference speed $\omega_r = 314$ rad/s; maximum current $I_{a\max}$=35.2 A.

Fig. 5 shows the time diagrams of speeds and relative speed errors obtained as simulation results for non-synchronized control. The speed errors $\triangle\omega_1(t)$, $\triangle\omega_2(t)$ and $\triangle\omega_3(t)$ are calculated with respect to the slowest electric drive (in this system it is ED1). Because of that the respective error is $\triangle\omega_1(t)$. The rather large speed discrepancies are due to the differences between the load inertias $J_1$, $J_2$ and $J_3$ of the controlled electric drives. The reference speeds are as follows: $\triangle\omega_{r_1}(t)$=157 rad/s; $\triangle\omega_{r_2}(t)$=314 rad/s.

The respective time diagrams of speeds and relative speed errors at synchronized speed control are represented in Fig. 6. The working conditions at which this investigation has been carried out are exactly the same as those of non-synchronized control but the resulting speed errors $\triangle\omega_i(t)$ have been represented in a different scale. As evident, the errors of synchronized control are considerably reduced and the accuracy achieved in this case is $|\triangle\omega_{\max}| = 0.5\%$.

## IV. Conclusion

A general-mode algorithm for synchronized control of multi-motor drive systems has been represented. Relevant models for computer simulation of such systems with control utilizing the described algorithm have been developed. The possibilities for application of this algorithm to speed control have been investigated and discussed.

The study has been carried out for electromechanical systems with controlled rectifier DC motor drives. The basic parameters of the used motors are as follows: $P_{\text{nom}}$=

3.4 kW; $V_{nom}$= 222 V; $I_{anom}$= 17.6 A; $\omega_{nom}$= 314 rad/s; $T_{lnom}$= 11.76 Nm.

The detailed analysis of the drives performance at the respective transient and steady state regimes bring us to the following basic conclusions:

- the control algorithm presented here provides for a good electric drives synchronization at different loads and disturbances;
- except for speed, this algorithm for synchronization control is suitable for other basic regulated variables of multi-motor electromechanical systems, such as position and acceleration;
- this type of synchronization control can be applied also in maintaining reference ratios of the respective regulated variables.

The developed computer simulation models and the results obtained can be used in optimization and final tuning of such types of multi-motor drive systems.

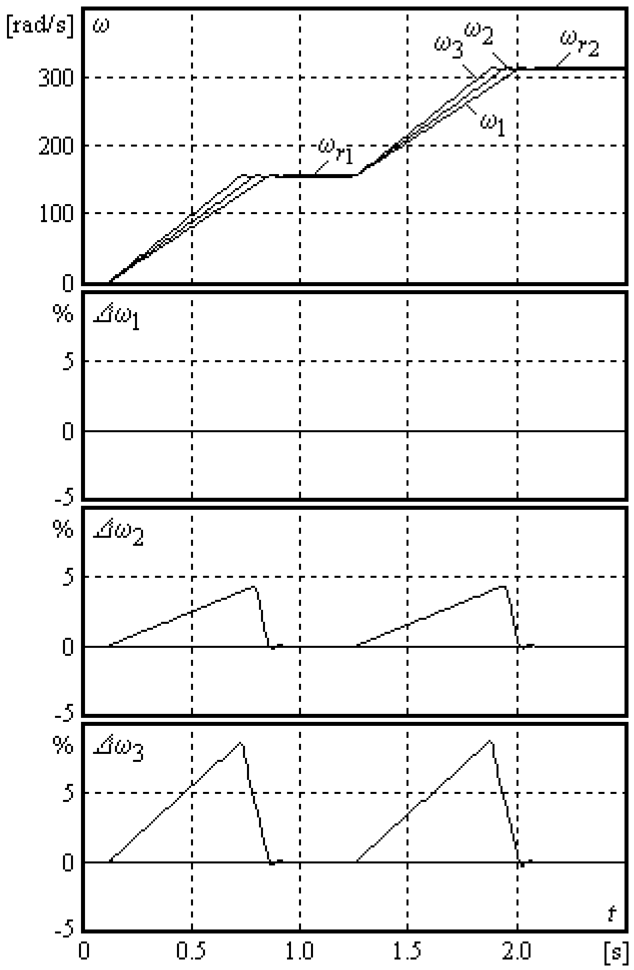


Fig. 5. Time diagrams at non-synchronized speed control

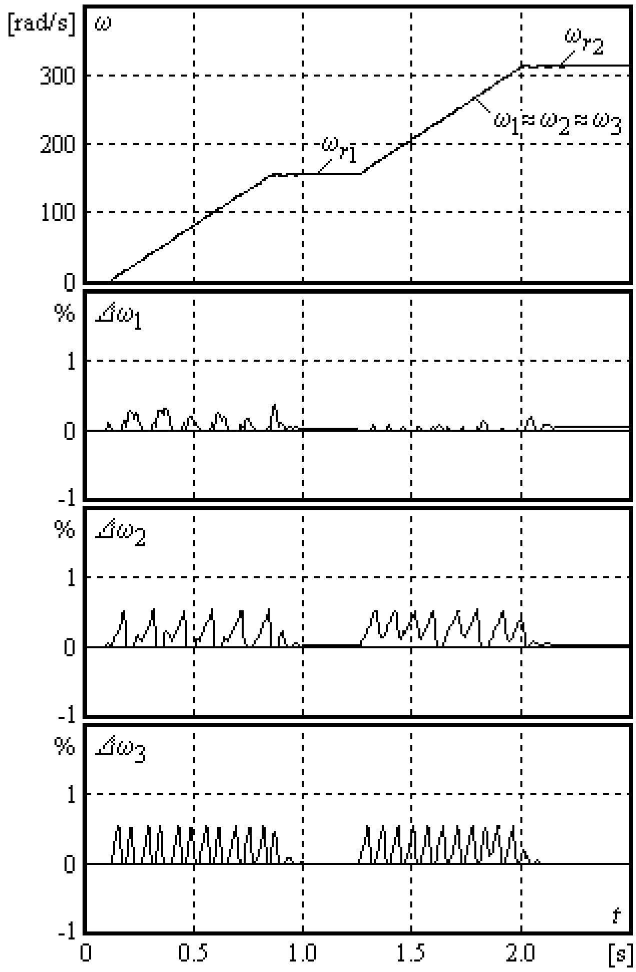


Fig. 6. Time diagrams at synchronized speed control

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