إستعراضات تحليلية وعملية لنظم إدارة ذاتية التزامن

ANALYSIS AND EXPERIMENTAL INVESTIGATIONS OF SELF-SYNCHRONIZED DRIVES

By

M. M. I. El-SHAMOTY

Electrical Power & Machine Department

Faculty of Engineering

Mansoura University

EGYPT

الخلاصة: يقدم البحث استعراضات تحليلية وعملية لخواص تشغيل نظامى اداره ذاتى التزامن حيث تم اشتقاق النماذج الرياضية التى ترجمت فى برامج بلغة ++C لمحاكاة تشغيل النظامين وقد تم الحصول على منحنيات تشغيل كثيرة تحليلياً وعملياً.

تم استخدام جديد لقنطرة توحيد فى نظام إدارة ذاتى بسيط يتكون من محركين استنتاجين يعمل كل منهما كمحرك متزامن فى نفس الوقت. يستخدم النظام البسيط عندما يكون العزم المنقول بين الوجهين صغير. يستخدم نظام الإدارة ذاتى التزامن العادى عندما تكون هناك الحاجة لنقل عزم كبير بين وحدات النظام. البحث يقدم آفاقاً جديدة للدراسة المستمرة.

Abstract:

Operational characteristics of two different self-synchronized drives are experimentally investigated. Accurate mathematical models are derived and analyzed using software programs. Computer- aided analysis and experimental results are compared. Many operational functional graphs are obtained.

Analysis of obtained graphs resulted in the following conclusions. Introducing a chopped rectifier bridge in the rotor circuit provides an economical mean to get synchronized drives when unit loads are approximately equal. Common synchro-tie systems are used when considerable differences of unit loads are present. At each loading case exact synchronized running is assured without additional electronics or servo controls. Unstable operation occurs at a specific speed which can be avoided during normal operation.

1. Introduction :

Self-synchronized or selsyn drives are used in modern position control and industrial machine drives. Self synchronized drives are also known as power selsyns or synchro-tie systems.

Selsyns drives are used in operations where different parts of a structure have to be moved or lifted by the same distance. A self-synchronized drive makes use of two or more, 3-phase wound-rotor induction motors. Wide field of applications of power selsyns is found [1]. Operating characteristics of power selsyns have not received enough attension where limited references are available upon the subject [1-5].

The present study is devoted to clarify the different operation characteristics of selsyn drives. It aims to give an enhanced understanding of theory and operation of power selsyns.

Comprehensive laboratorial studies have been carried out to achieve the aimed objective.

2. Basic Structures of a Synchro-tie System :

A synchro-tie system may have two different basic structures as shown in figures (1) and (2). Fig. (1) represents the common synchro-tie system used when large-torque transmission is required. Fig. (2) represents a chopped synchro-tie system used when small torque transmission is needed. The simplified synchro-tie system which is called system (II) is more economical than system (I) because the induction motors are used as drives and synchronizers at the same time.

Using the chopping rectifier bridge in system (II) is a new technique is used in this field. The control rheostat is to make the slip not smaller than 0.25 . System (II) is used on account of its simplicity for carding machine drives in the textile industry, machine tools , conveyor plants and others.

In both structures self-synchronized operation is obtained by two identically 3-phase wound-rotor induction motors. Its stators are connected to the same 3-phase supply and its rotors are electrically connected together through the slip rings.

If the two rotors are electrically occupying the same position relative to the axis of rotating nagnetic field, the induced voltages in the two rotors, while equal in magnitude, will be in direct opposition. When one of the rotors is turned from neutral position of the standstill through an angle θ, the induced voltages in the rotors will be shifted by the same angle. Because of this phase shift, current will flow in the rotor circuits, and torque will be created in each machine by the interaction of its

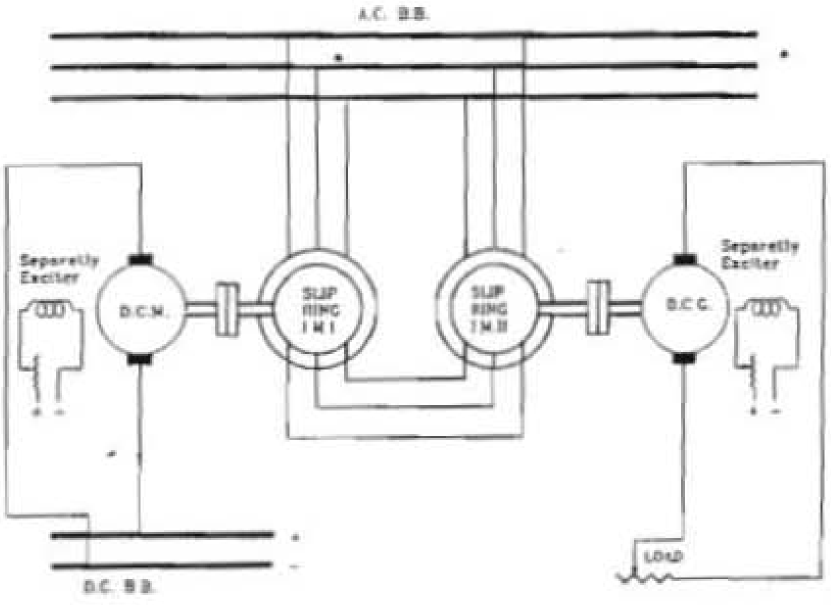

Fig.(1) : Connection Scheme of Synchro-tie System (I).

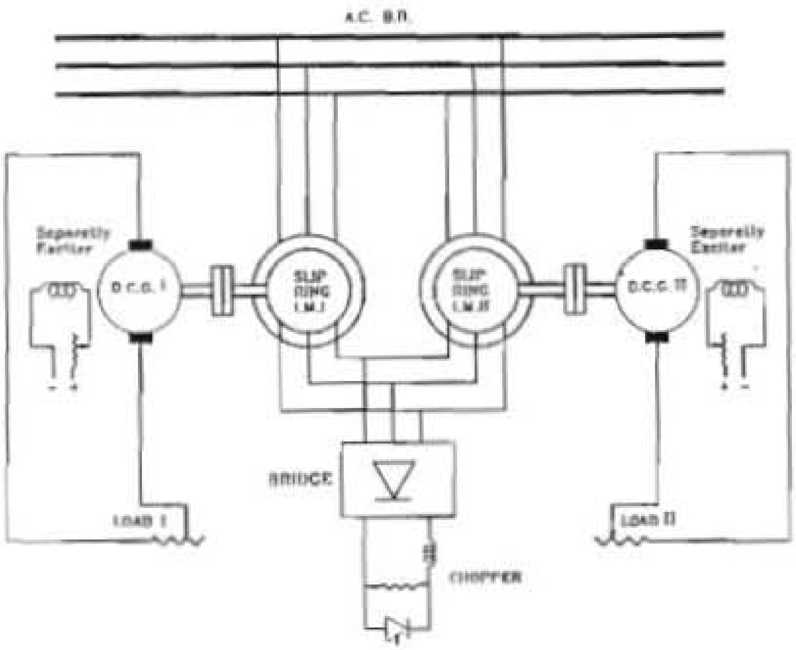

Fig.(2) : Connection Scheme of Simplified Synchro-tie System (II).

air-gap flux and rotor emf-waves. These torques act in directions to tend to reduce the unbalance angle θ. Thus, one machine will follow the other and the two rotors are tied by an Electric Shaft through which an angle or position will be remotely transmitted. Rotation may be either in the direction of the rotating magnetic field or in the opposite direction. This scheme of synchro-tie system is not limited to two units, as many units as desired may be tied together.

3. Torque Transmission in a Synchro-System :

Torque transmission T_{in} a synchro-tie system is a function of the unbalance angle θ and the slip. To find relation between T , θ , and the slip , the per phase equivalent circuit of the two systems is considered as shown in Figs. (3) and (4). The procedure to find this relation is as follows :

1. Using simple circuit laws to find the per-phase current in the rotor circuit referred to stator I_r.
2. Calculate the transmitted power across the air-gap ;
   $P_{g1} = 3E_1 . \text{Real } (I_{r1})$, $P_{g2} = 3E_2 . \text{Real } (I_{r2})$
3. Compute the electromagnetic torque as ;
   $T_{g1} = \dfrac{0.975}{n_s} . P_{g1}$, $T_{g2} = \dfrac{0.975}{n_s} . P_{g2}$
4. The synchronizing action of the system is determined by the difference in the torques of the two machines and hence is termed as the equalizing torque ;
   $T_{eq} = T_{max} . \sin \theta$

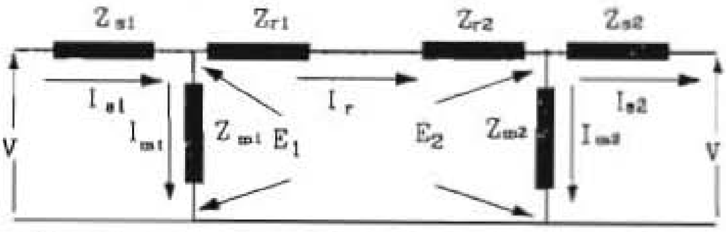

Fig.(3) : Per-Phase Equivalent Circuit of System (I).

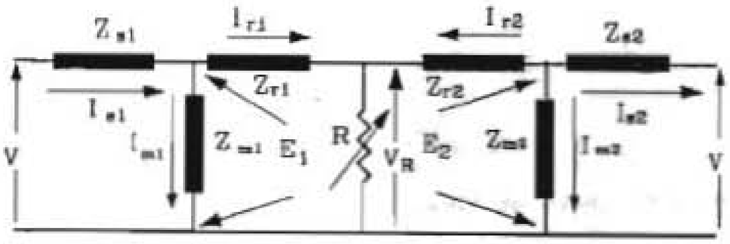

Fig.(4) : Per-Phase Equivalent Circuit of System (II).

When The displacement angle δ equals 90 electrical degrees, the equalizing torque will reach a maximum value. Since, in practice, the displacement angle does not exceed 25 → 30 electrical degrees. This procedure is visualized by the flow chart of Fig. (5) and Fig.(6).

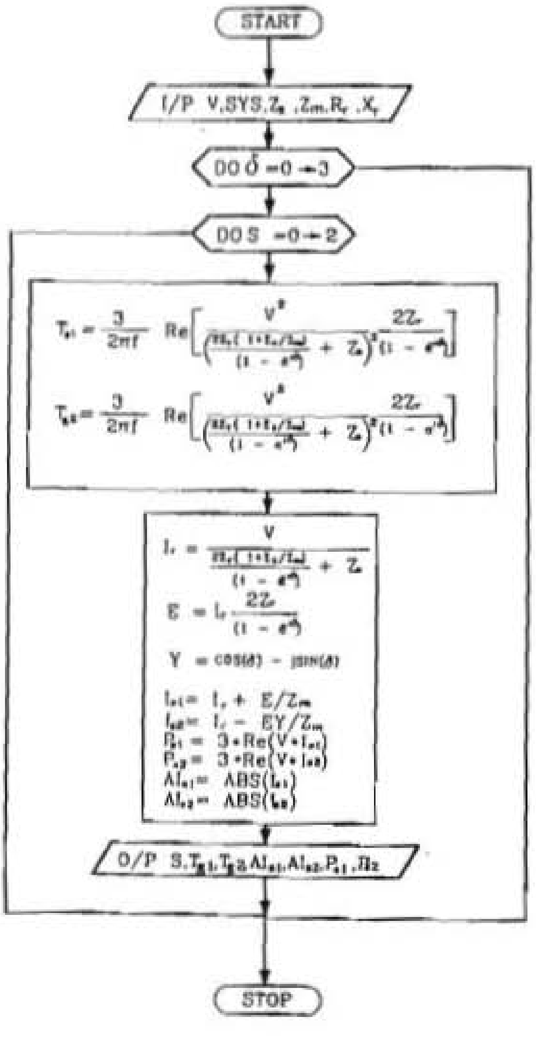

Fig.(5) : Mathematical Model of Synchro-tie System (I).

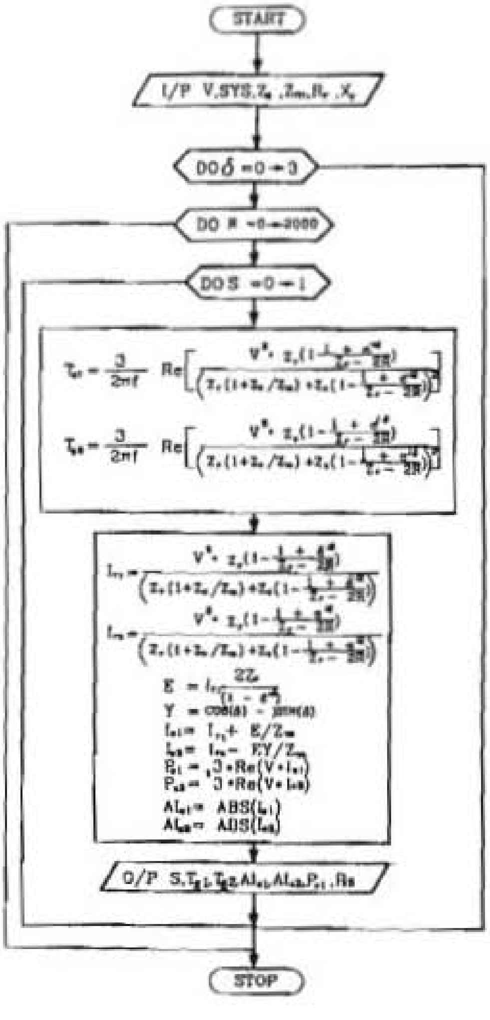

Fig.(6) : Mathematical Model of Synchro-tie System (II).

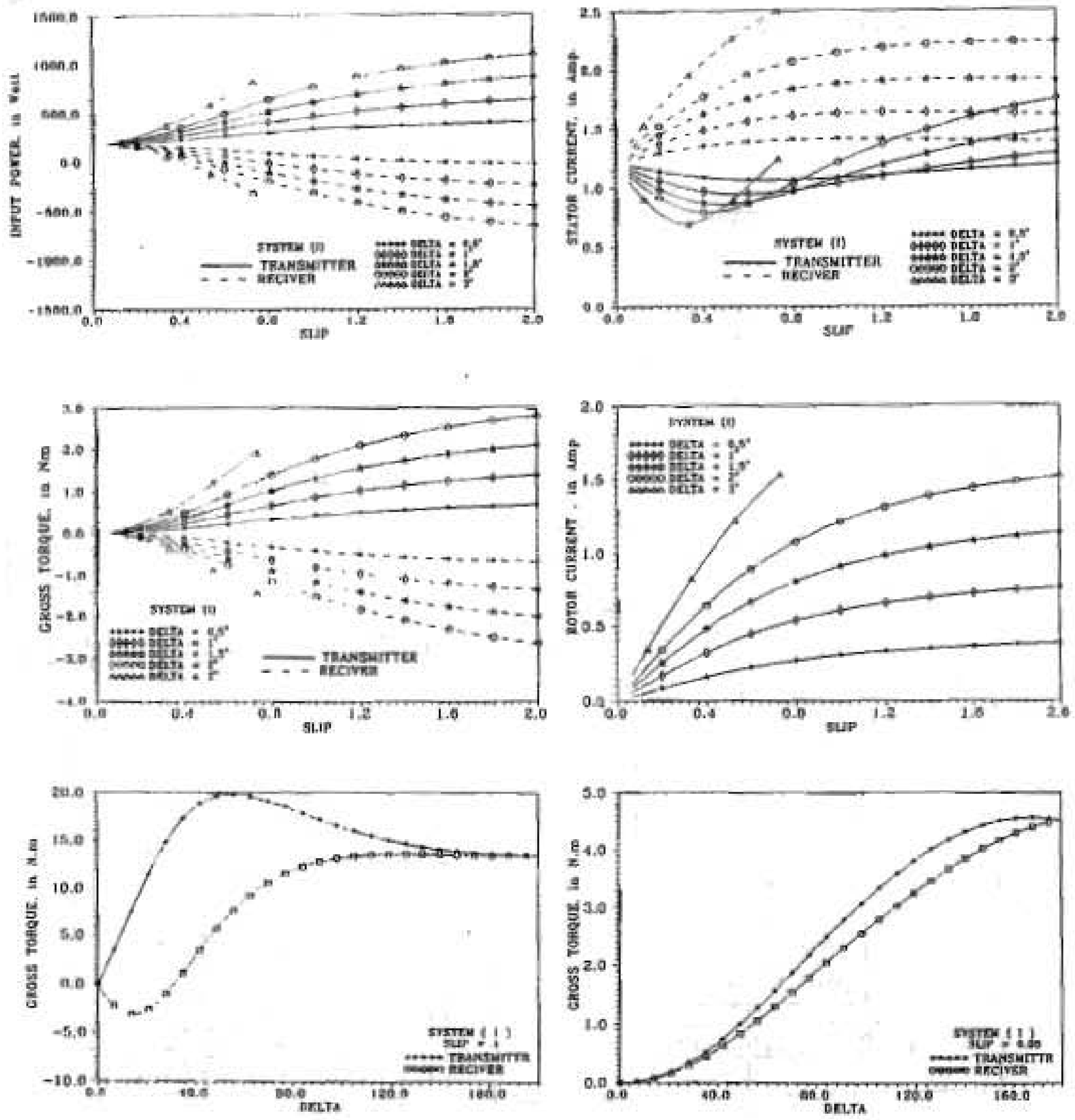

Fig.(7) : Simulation Results Using Mathematical Model of Synchro-tie System (I).

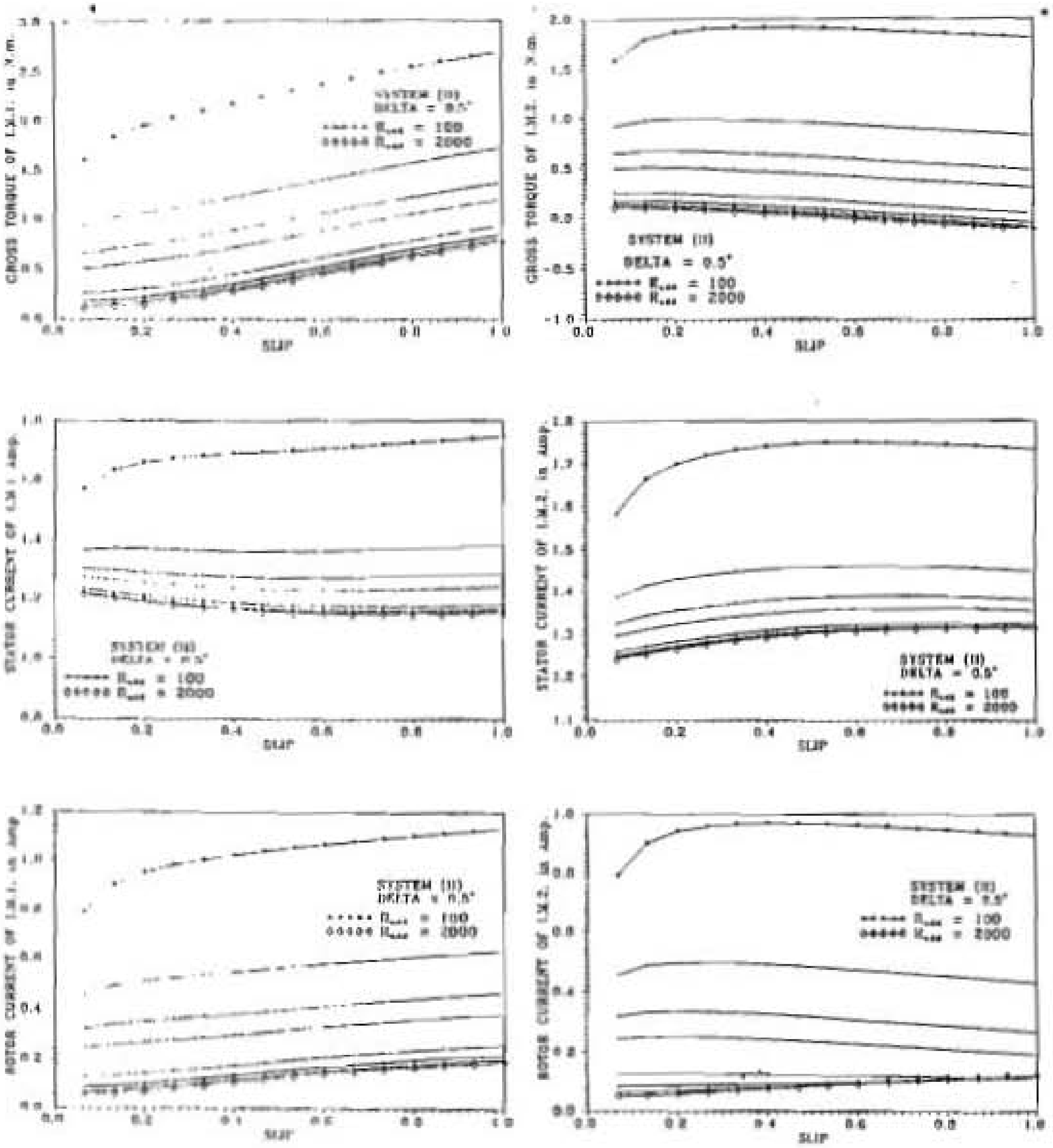

Fig.(8-a) : Simulation Resultes Using Mathematical Model of Simplified Synchro-tie System (II).

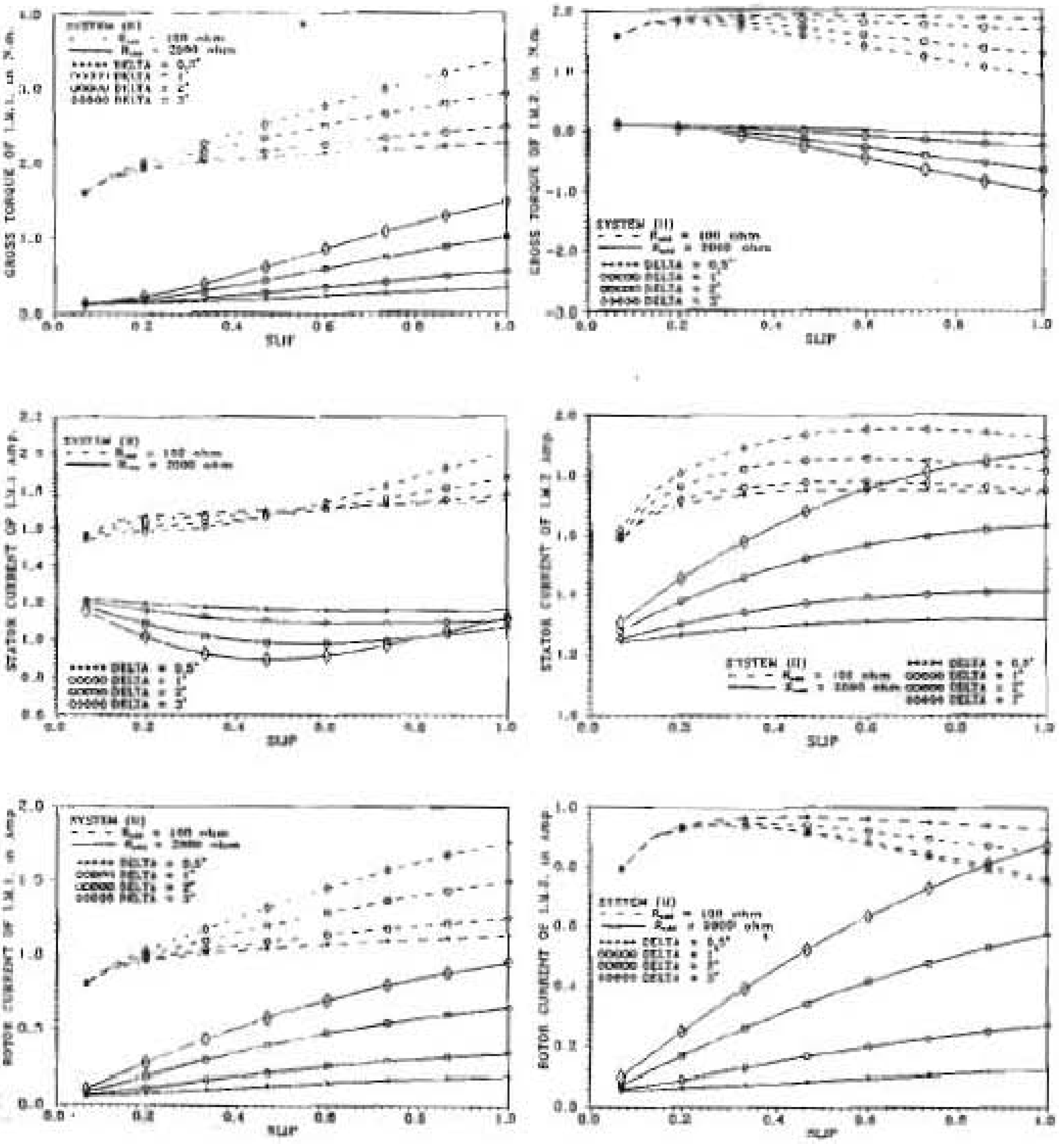

Fig. (8-b) : Simulation Resultes Using Mathematical Model of Simplified Synchro-tie System (II).

The mathematical models and flowcharts of figures (5) and (6) have been translated into a C-langauge program to simulate different operating cases (different displacement angles δ and different operating slips S).

4. Computer Simulation Results :

Flowcharts of figures (5) and (6) have been coded in C-langauge programs in which a Grapher software has been included.

Different operating conditions have been simulated considering different values of slip and displacement angle δ for synchro-tie system I and II. Equivalent-circuit parameters of machines used referred to the stator side are :-

$$Z_s = Z_r = 4.33 + j\ 4.24 \quad \text{and}$$
$$Z_m = 38.0 + j\ 171.78 \text{ Ohms}$$

Simulation results are visualized in figures (7) and (8). In figures (8-a) and (8-b) up-to-down curves are obtained for chopper resistance values of 100, 200, 300, 400, 800, 1200, 1600 and 2000 ohms respectively.

5. Experimental Results :

Experimental investigations on the two synchro-tie systems have been carried out. Name-plate information of the two three phase slip-ring induction motors and the two dinamometer used are:

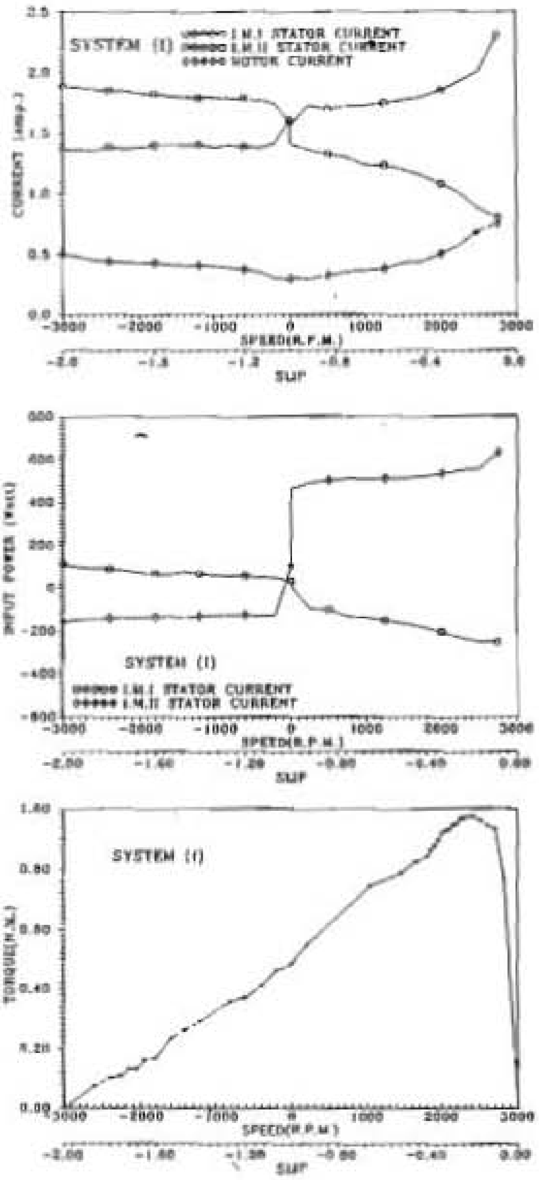

Fig.(9) : No-Load Operating Characteristics of SyStem (I). (Experimental Results)

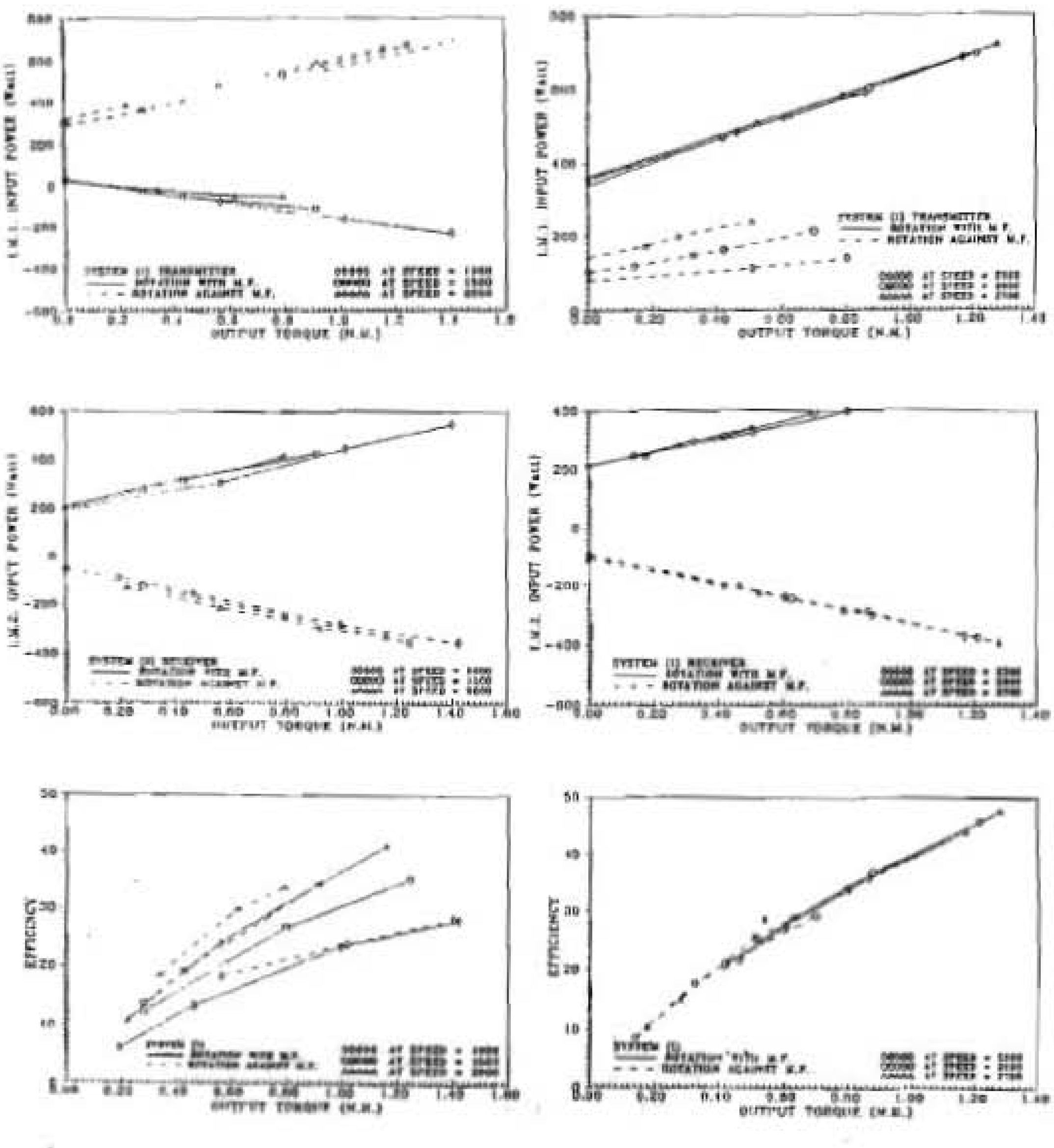

Fig.(10-a) : Load Operation Characteristics of Synchro-tie System (I) - Experimental Results.

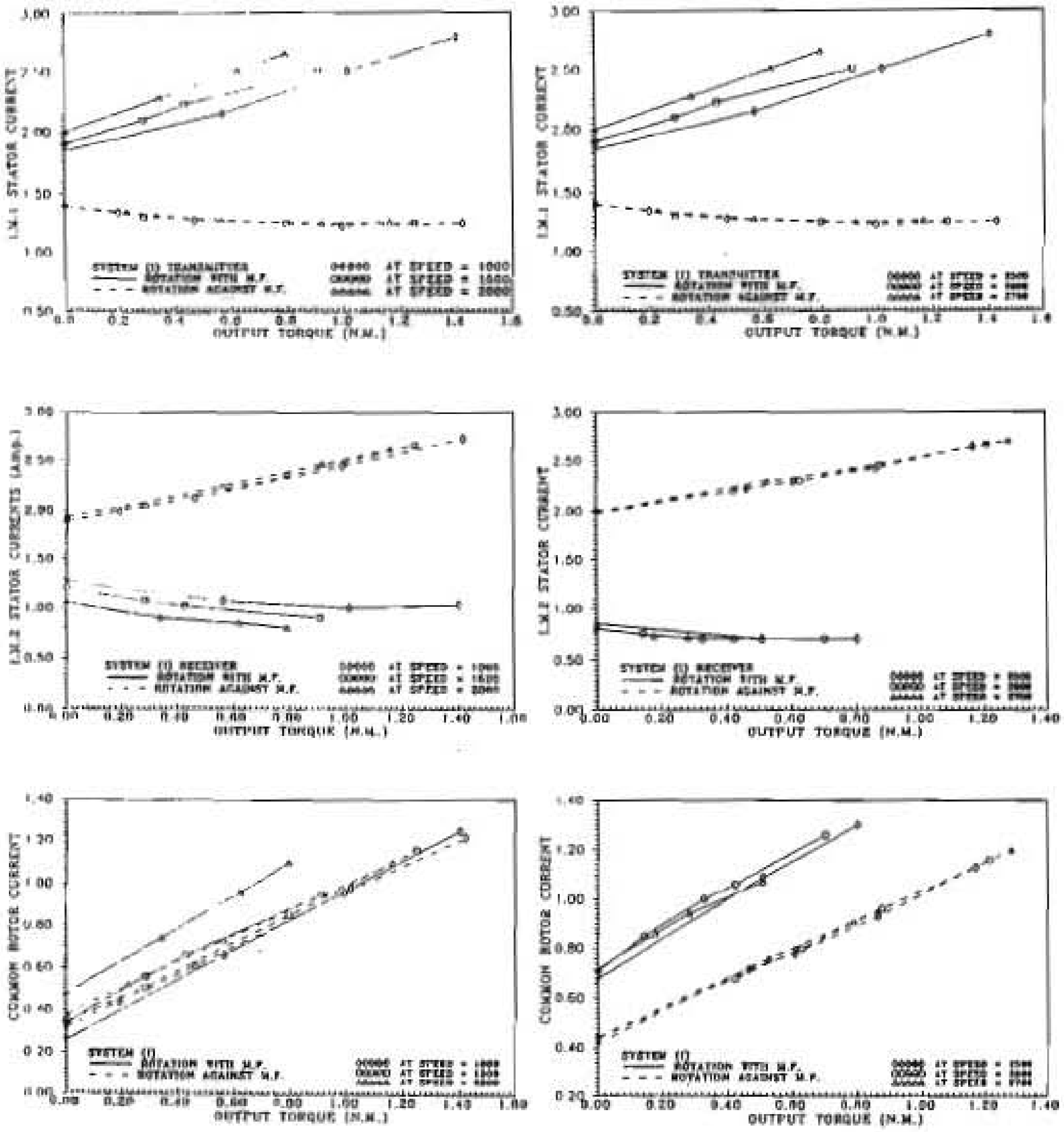

Fig.(10-b) : Load Operation Characteristics of Synchro-tie System (I) - Experimental Results.

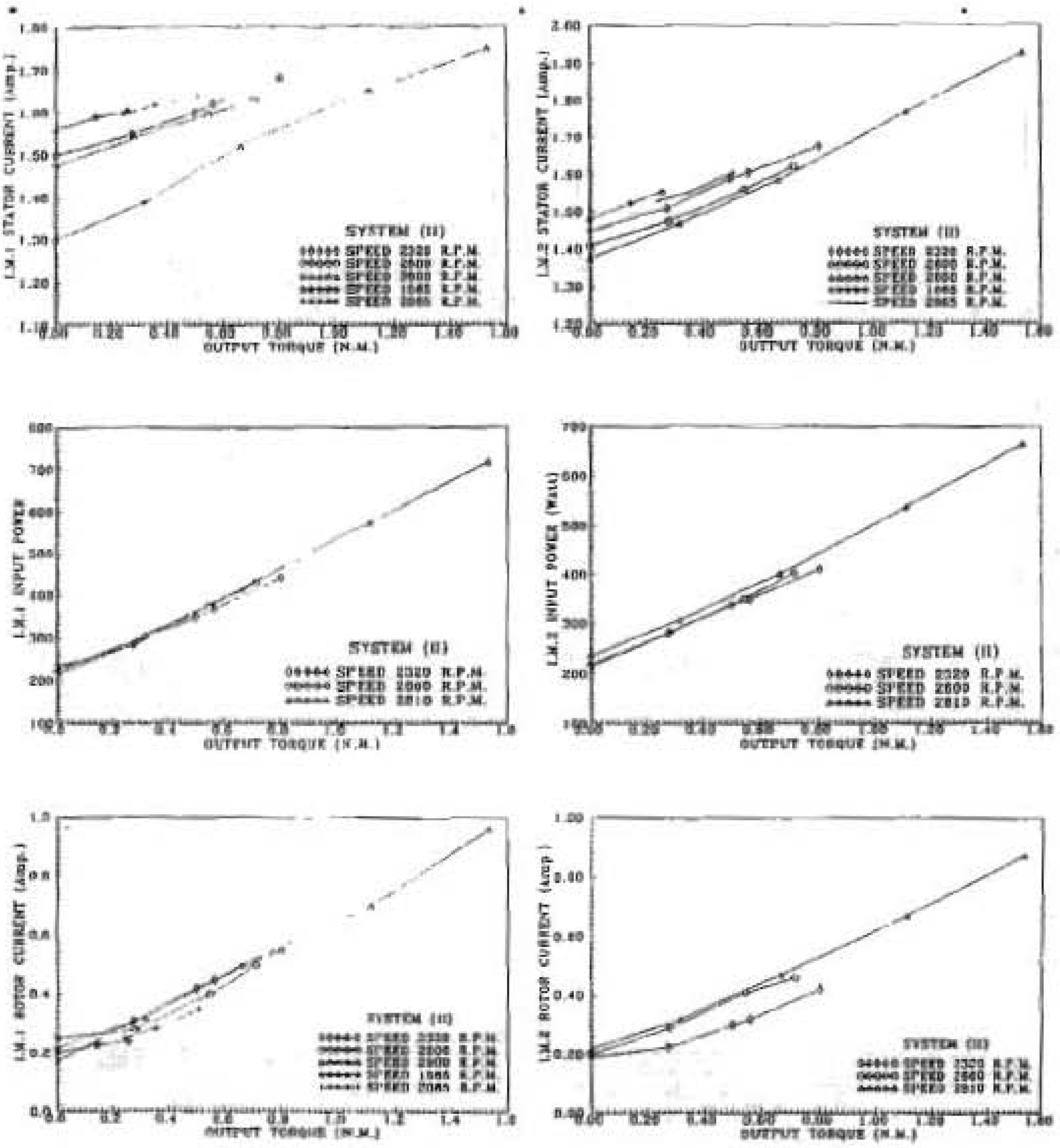

Fig.(11) : Load Operation Characteristics of Simplified Synchro-tie System (II) - Experimental Results.

a. *3-Phase Slip-ring Induction Motor* :

	Stator Winding	Rotor Winding
Connection	Delta / Star	Star
Terminal Voltage	220 / 380 Volt	380 Volt
Full-load Current	4.3 / 2.5 Ampere	2.2 Ampere
Rated Power	1.1 kW	
Rated P.F.	0.9 Lag.	
Frequency	50 Hz	
Rated Speed		2830 r.p.m.

b. *Dinamometer* :

	Armature Windings	Field Windings
Terminal Voltage	220 Volt	170 Volt
Full-load Current	5 Ampere	245 mA
Rated Power	1.1 kW	
Rated Speed	2820 r.p.m.	

The experimental results are shown in figures (9) , (10) and (11).

6. Conclusions :

Comprehensive analysis and experimental investigations of the self-synchronized drives have been presented. Synchro-tie systems provide very good means for torque remote transmission.

The noval approach using a rectifier bridge chopper has an economical simplified synchro-tie system. The induction motors play the role of the driver and the synchronizer at the same time.

Operating discontinuity has been observed at a specified speed during the experimental investigations. Further research work is going on to clarify this observation.

7. References :

[1] Harrison P.F. ; " Synchronized Drives Using Power Selsyns ", Electrical Times No. 4646 pp. 9 - 11, March 1982 , UK.

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