the fuel elements at a pressure of approximately 90 bars. It then passes to a steam generator, which is very similar to that used in PWR. CANDU reactors have not experienced the same steam generator problems as the PWRs. Experts suppose that it happens possibly because of the lower operating temperature [2.P.48].

The fuel elements consists of bundles of natural UO_2 pellets clad in zirconium alloy cans; individual bundles are about 50 cm long, about 12 of such bundles are placed into each pressure tube. Another fact about CANDU is that the average volumetric power density in the core is approximately one-tenth of that in a PWR.

Although the CANDU has operated with remarkable success, difficulties have been experienced with hydrating of the zirconium alloy pressure tubes. Even though it has a lower fuel cost, CANDU needs considerable amounts of expensive heavy water, which makes its capital cost higher. For this reason the CANDU reactor is less demanded than the PWR and the BWR.

Conclusion

It is undeniable that science has been developing fast nowadays. Progress has influenced the nuclear energy: several new nuclear reactors have been designed and built. These reactors are safer but have higher capital costs, which prevents their large-scale exploitation. Despite this fact, experts are convinced that the number of nuclear power plants will increase in the next 50 years and nuclear power energy will be able to compete with other types of energy.

References:

1. Hore-Lacy I., Nuclear energy in the 21st century. World Nuclear University Press, 2010. 133 p.
2. Hewitt G.F., Coiler J.G., Introduction to nuclear power. London, 2000. 304 p.
3. Антонова А.М., Воробьев А.В. Атомные электростанции: учебное пособие. Изд-во Томского политехнического университета, 2009. 275 с.

Leonov, A.V., Nizkodubov, G.A.

Synchronization of Two Induction Motors

National Research Tomsk Polytechnic University.

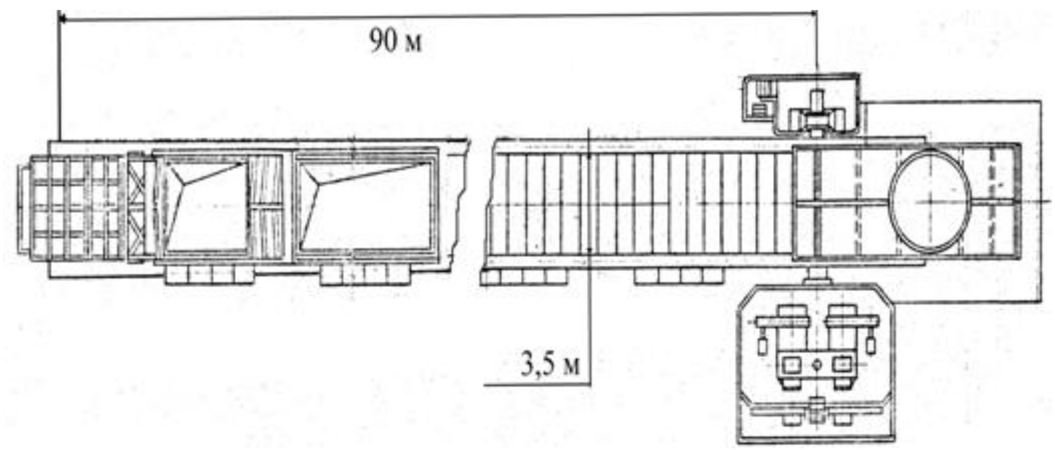

Figure 1 – General view conveyor.

This article is devoted to development of a control system of asynchronous electric motor drive conveyor with two electric motors.

A **conveyor system** is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Many kinds of conveying systems are available, and are used according to the various needs of different industries. There are chain conveyors (floor and overhead) as well. Chain conveyors consist of enclosed tracks, I-Beam, towline, power and free, and hand pushed trolleys.

Conveyor systems are used widespread across a range of industries due to the numerous benefits they provide.

- Conveyors are able to safely transport materials from one level to another, which when done by human labor would be strenuous and expensive.
- They can be installed almost anywhere, and are much safer than using a forklift or other machine to move materials.
- They can move loads of all shapes, sizes and weights. Also, many have advanced safety features that help prevent accidents.
- There are a variety of options available for running conveying systems, including the hydraulic, mechanical and fully automated systems, which are equipped to fit individual needs.

To increase the capacity two electric motors are used. It is cheaper than buying a powerful motor. However, two motors must be synchronized.

There are two types of synchronized drives of two or more mechanically independent shafts commonly known: one is the "power selsyn" or "synchro-tie;" and the other might be called the "simplified selsyn." The first system uses, besides one or more prime movers, individual selsyn motors for synchronizing. The analysis and application of this type is very well covered in literature. With the simplified-selsyn system, each single shaft is driven by its individual motor, a wound-rotor induction motor, and these motors themselves are used for achieving a synchronized drive, without any additional selsyn motors. So far, the published analyses of this system are very poor and very little information, if any, can be obtained from the literature, which could be used as a guide for planning of such drives. Recognizing this situation, the Armour Research Foundation of the Illinois Institute of Technology made possible the performance of a series of tests which should furnish more basic information on the subject.

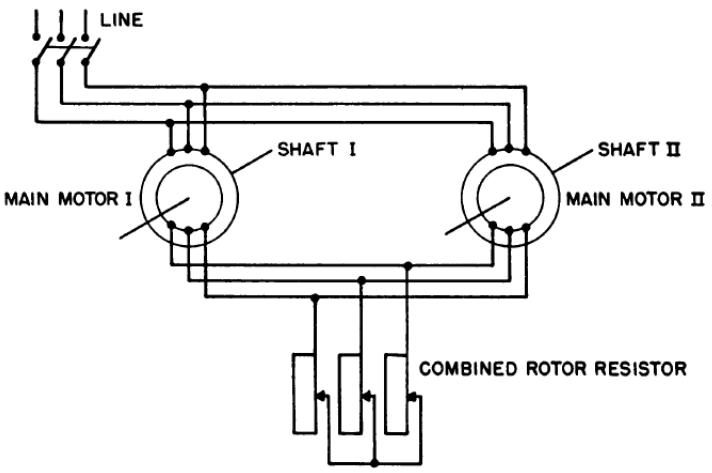

Figure 2 (left) – Diagram of a synchronized drive with two duplicate wound-rotor induction motors.

Figure 2 shows the wiring of two wound-rotor motors for such a synchronized drive. The slip rings of both motors are interconnected, tying the equivalent rotor phases together and a combined secondary resistor is inserted between the tie leads. The ohmic value of this resistor is important for obtaining a satisfactory operation. The two extreme values of resistance are zero (resistor short-circuited) and infinite (no connection between the rotor tie leads). In the first case, the two motors act as two independent squirrel-cage induction motors without any synchronizing torque, and under different loads the slip of the motors will be different. In the second case, with no connection between the ties and with the rotors in synchronized position, both rotor voltages are in opposition and cancel each other. No rotor current can flow, no torque can be developed, and the motors do not start. The proper size of this secondary resistor is important. Defining *BR* as the base rotor resistance, $BR = E^2 / \sqrt{3} I_2$, where E_2 is the rotor voltage across rings; I_2 is the rated secondary current. The optimum value of this secondary resistor is around 0.23 *BR*. With the transmitter motor fully loaded and this resistor, *0.23BR*, inserted, a synchronized run is secured if the load of the receiver motor is between a maximum 1.95 rated torque and a minimum 0.2 rated torque. With a greater load, the receiver motor will be stalled, and with a load smaller than minimum, the receiver will speed up to almost synchronous speed.

The customary stopping by disconnecting the motor primaries from the line is inconvenient, because there is no synchronizing action during the deceleration period. It is recommended that the drive be stopped by opening the combined resistor circuit and leaving the primaries line-connected. The drives come to rest under the influence of the load, friction, and stop brakes, and an appreciable synchronizing torque is maintained during the deceleration period.

To avoid failures in operation, the shortcomings of this system have to be realized. In the first place, the synchronized run is secured, as previously indicated, only if the load differences between the two shafts do not exceed the permissible limit. However, there are very few cases where the normal or accidental load differences (due to frozen bearings, jammed gears, or the like) safely can be predicted. Furthermore, in case of failure of the power supply, there is no synchronizing torque developed and a displacement is very likely. Consequently, in cases where proper alignment is paramount, the following arrangement of safety devices is necessary:.

1. Automatic control of the angular displacement between the two rotors can be achieved easily by two small selsyns, each rigidly coupled to one motor, and a conventional differential selsyn between the two. The differential selsyn permits observation of the angular displacement at rest and while running, and develops ample torque for control purposes. For example, it can actuate a sliding contact, which opens, through a contactor, the combined resistor leads, in case the angular displacement exceeds the preset limit.
2. Control of displacement also can be achieved by limit switches.
3. The correct arrangement of the motor overload protection is also important. In case just one of the overload relays trips, all motors have to be stopped. As previously mentioned, it is very convenient not to interrupt the motor primaries with these safety devices, but to disconnect the leads to the secondary tie resistor.
4. Another requirement is provision for realignment. This is achieved by arranging a key-locked switch, which permits operation of only one motor in both directions, and which bypasses all the alignment controls.

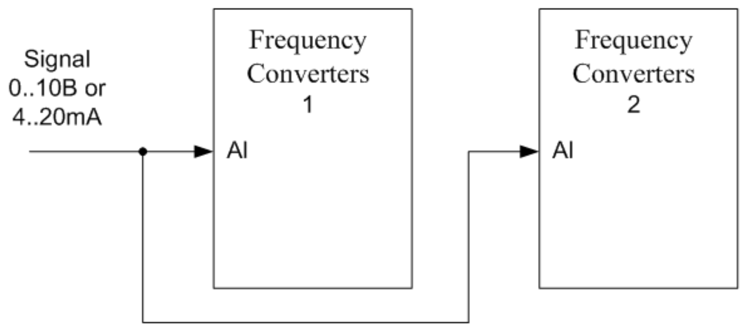

Figure 3 (left) – Synchronization on the parallel interface.

However, another system must be used for the conveyor, the system is more expensive but it is more efficient at the same time. It consists of two motors, two frequency converters and a controller. This system was the goal of my research.

It is possible to adjust the offset velocity by scaling an analog input frequency converter 2 or analog output of the frequency converter 1. It can be implemented almost on any models of frequency converters with a good analog output (bit digital-to-analog converter not less than 10).

In its simplest form, you can just give a parallel task like that:

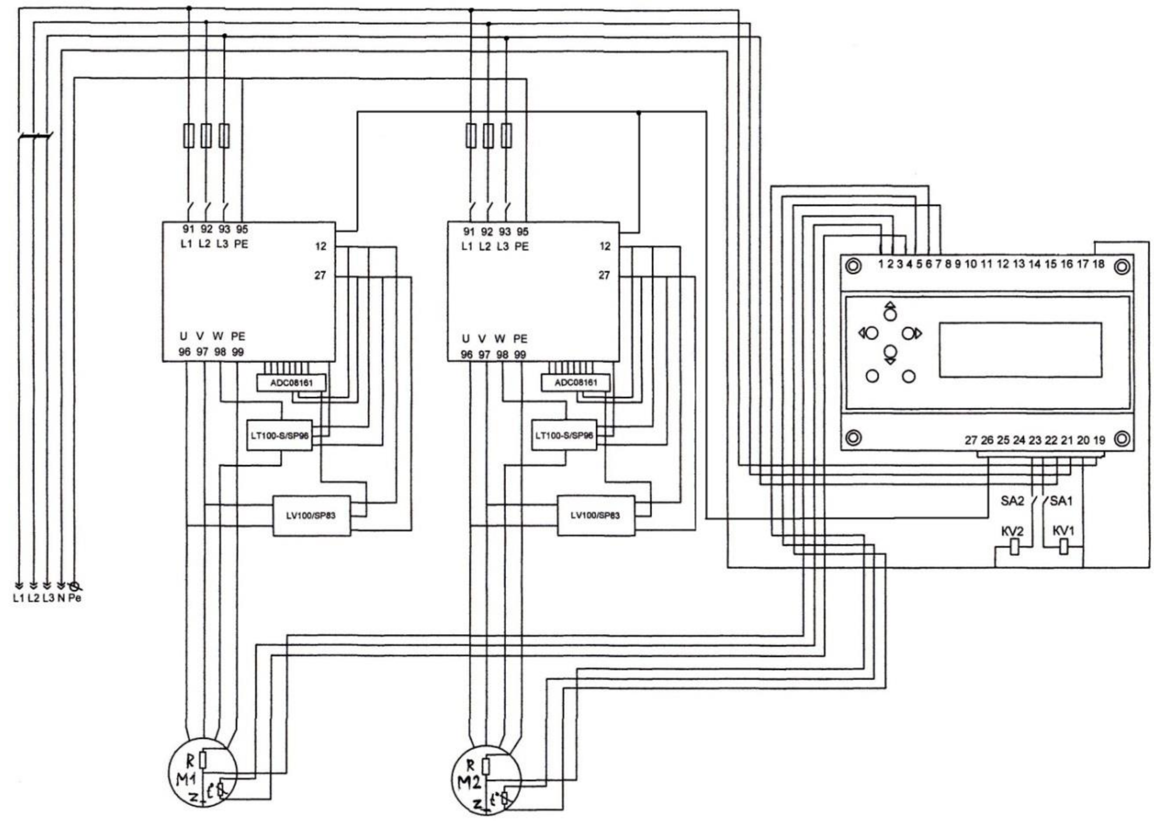

Figure 4 – Schematic diagram. A circuit diagram which shows: a control device two frequency converter and two motor, and various sensors has been introduced.

In Figure 5 we see the mechanical characteristic. On the characteristic 1+2 summed moments electric motors.

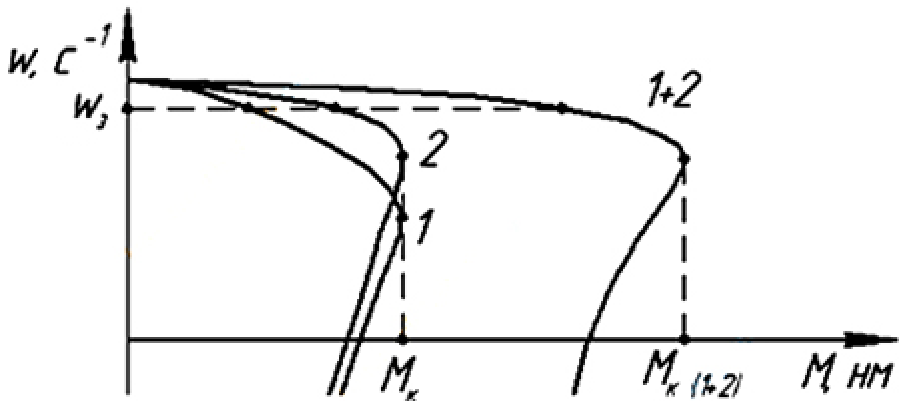

Figure 5 (left) – Teamwork electric motor operating in different modes.

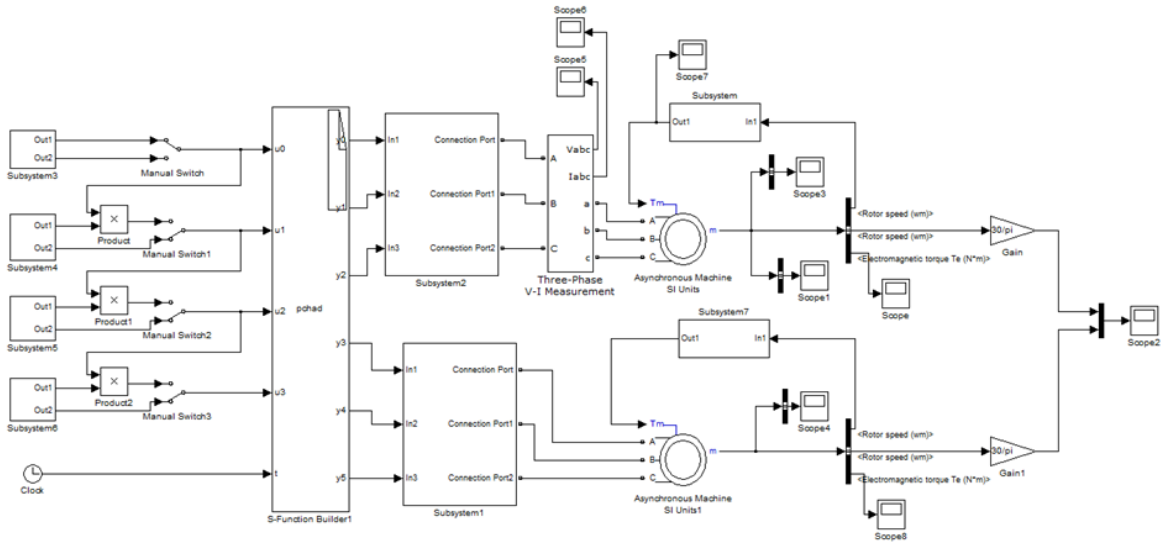

Figure 6 – Simulation model in Matlab program.

A simulation model which is under development has been introduced as well. It will investigate such modes as jam mechanism jams, maximum load start, as well as the failure of a single drive.

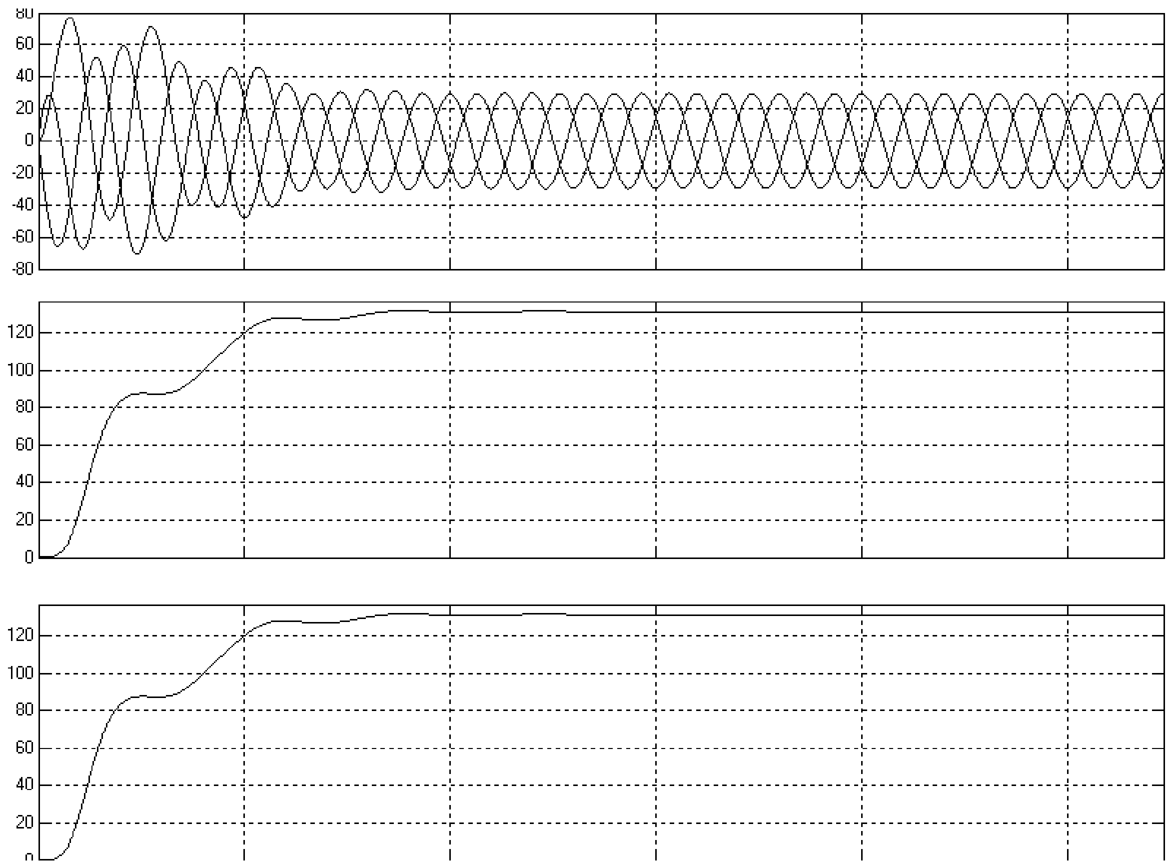

Figure 7.

In Figure 7, we see two synchronized engine speed. This is the result of synchronization in Matlab program.

References:

1. Blekhman, I.I., *Sinkhronizatsiya v prirode i tekhnike* (Synchronization in Nature and Engineering), Moscow: Nauka, 1971.
2. Blekhman, I.I., *Sinkhronizatsiya dinamicheskikh system* (Synchronization in Dynamic Systems), Moscow: Nauka, 1971.
3. Pikovskii, A.S., Rozenblum, M., and Kurts, Yu.,*Sinkhronizatsiya. Fundametal'noe nelineinoe yavlenie* (Synchronization: A Fundamental Nonlinear Phenomenon), Moscow: Tekhnosfera, 2003.
4. Gordeev, B.A., Gordeev, A.B., Kovrigin, D.A., and Leont'eva, A.V., Hydraulic Vibrational Bearings in Synchronizing Mechanical Systems, *Provolzhsk. Nauchn. Zh.*, 2009, no. 3, pp. 49 –53.
5. Electric drive: a tutorial / YN Dement'ev, LK Chernyshev, IL Chernyshev, Tomsk Polytechnic University. Tomsk Univ TPU, 2010.-224 with.
6. http://h4e.ru/elektricheskie-mashini/136-rabota-dvukh-elektrodvigatelej-na-odin-val.
7. http://www.elec.ru/market/offer-14937312501.html.
8. http://stroy-technics.ru/article/sinkhronnoe-vrashchenie-dvukh-asinkhronnykh-elektrodvigatelei-v-sisteme-elektroprivoda.
9. http://en.wikipedia.org/wiki/Conveyor_system.

Leonova, V.K., Climova, G.N.

Power balance of the Siberian Federal District: dynamics and prospects

National Research Tomsk Polytechnic University.

Introduction

Issues of energy management and energy efficiency are of high importance in the world.

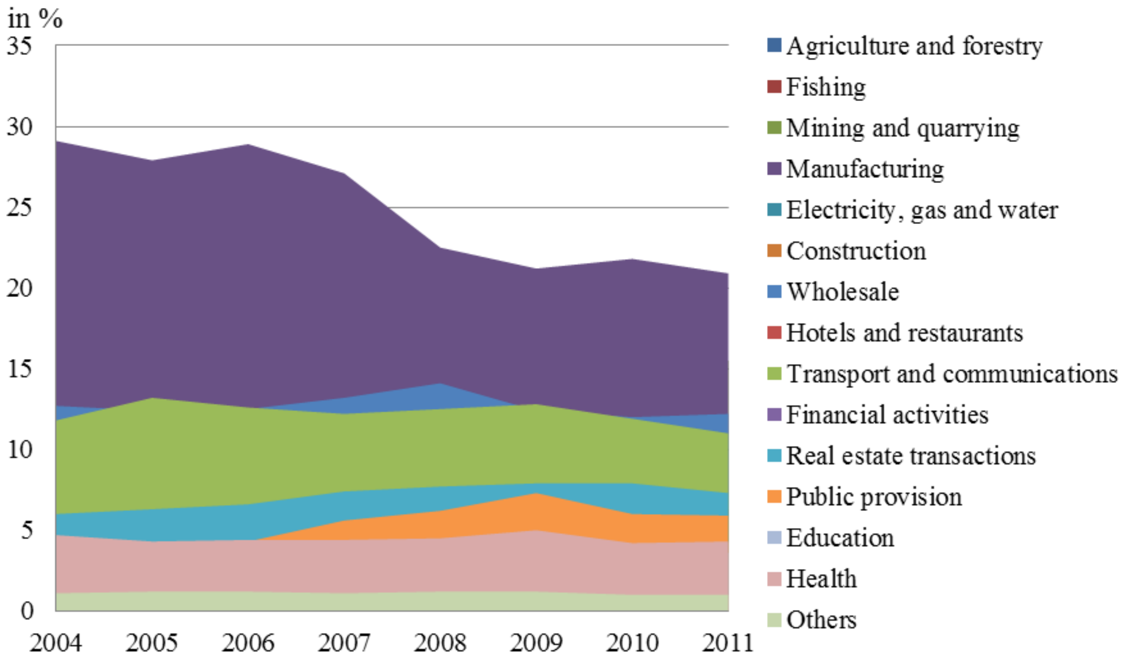

Fig.1 Structural Dynamics of GRP under comparable conditions relative to 2000.