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Blow molding electric drives of Mechanical Engineering

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Abstract. The article considers the questions about the analysis of new possibilities, which gives the use of adjustable electric drives for blowing mechanisms of plastic production. Thus, the use of new semiconductor converters makes it possible not only to compensate the instability of the supply network by using special dynamic voltage regulators, but to improve (correct) the power factor. The calculation of economic efficiency in controlled electric drives of blowing mechanisms is given. On the basis of statistical analysis, the calculation of the reliability parameters of the regulated electric drives' elements under consideration is given. It is shown that an increase in the reliability of adjustable electric drives is possible both due to overestimation of the electric drive's installed power, and in simpler schemes with pulse-vector control.

1. Introduction

The blowing mechanisms of plastic manufacture have a fan-like nature of the load, so for a long time they were unregulated and fed on a network with a fixed voltage and frequency [1]. The installation of frequency converters extends the regulatory parameters of these mechanisms (speed and torque control ranges, new possibilities for reactive power compensation). In the case of frequent operation in the start-brake modes, the reserves of energy savings appear [2,3]. Thus, an increase in the number of elements in the system (the appearance of a frequency converter) in some cases leads to a reduction of the electric drive's reliability parameters [4]. In this regard, the article makes an attempt to quantify the effects of energy saving and reliability parameters. The ways of increasing reliability are defined.

2. Analysis of new possibilities of blowing mechanisms' controlled electric drives

The economic development in the industrial world leads to the increase of the industrial production, an essential part of which is power engineering. Semiconductor voltage converters, which take an important part in power engineering, are being used in all spheres of production, transfer, distribution and consumption of electric energy [5.6]. The major part of the produced semiconductor converters is intended for power supply and control of the electric drives (about 70-80% of overall amount of converters). Separately, one can distinguish semiconductor converters, which are used as correcting devices. The semiconductor converters classification in terms of application is shown in figure 1 [8].

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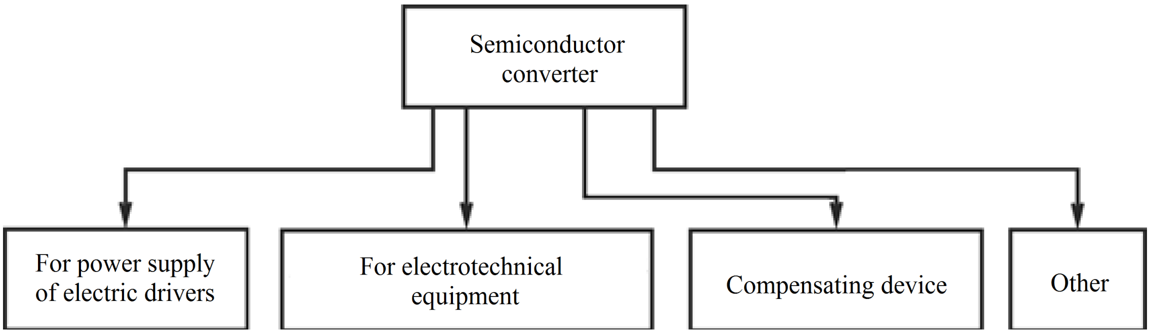

Figure 1. Semiconductor converters classification

Among the compensating converters, the most promising type are dynamic voltage regulator (DVR). The functional diagram of such converter is given in figure 2.

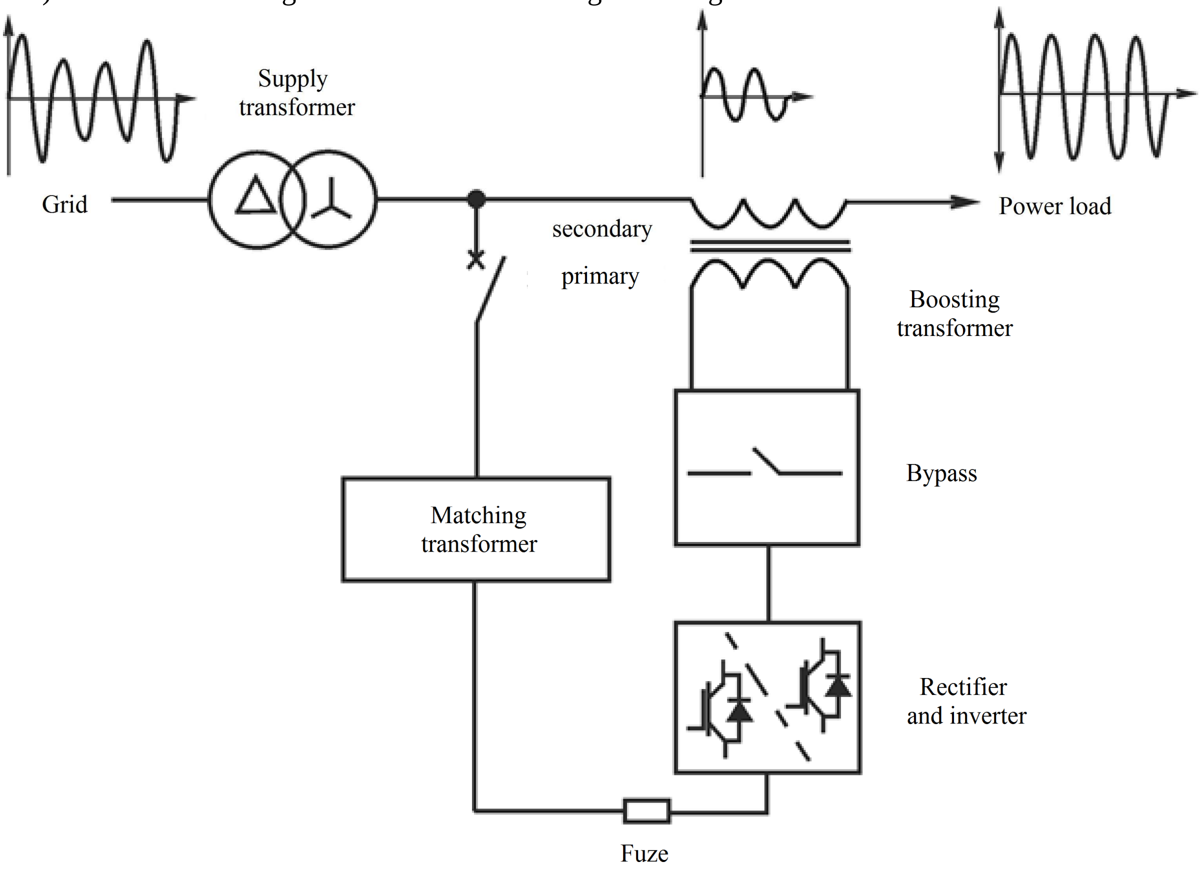

Figure 2. Functional scheme of dynamic voltage regulator

Dynamic regulators are being used to provide reliable and continuous consumer power supply in case of voltage dip in electrical networks. DVR is a semiconductor voltage converter (invertor unit consists of IGBT modules), which is connected to the consumer's power network and through the auxiliary transformer redistributes power in such way that the voltage addition on the secondary winding of the transformer completely compensates the voltage dip at external short-circuit or voltage draw down.

The power range of existing semiconductor converters is close to 10^{12}: from units of μW in instrument systems to tens of MW for electric drives of pumps and compressors at pumping stations [10].

Analysis of the statistics [11] provided by the specialists of the service department of STC

"Privodnaya Tekhnika" Ltd. showed that the overwhelming number of failures (more than 85%) of semiconductor converters occurs due to the failure of the power transistor module [12]. The causes of failures can be different: short-circuit currents, overvoltages, disturbance of thermal condition, mistakes in engineering and exploitation, etc. No more than 15% of the failures of semiconductor converters are accounted together on the rectifier module and the DC link (Figure 3).

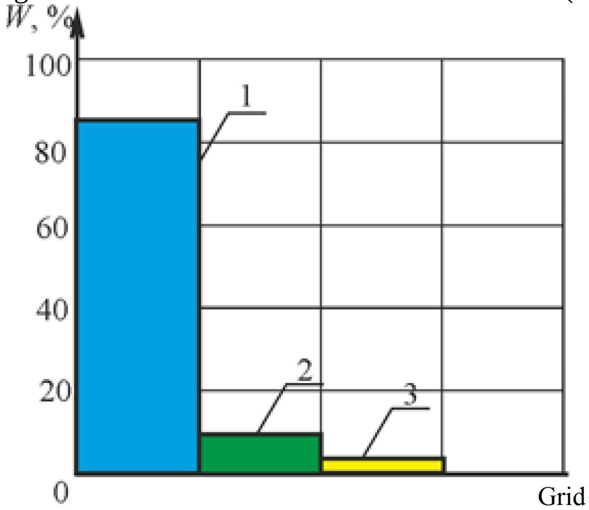

Figure 3. Percentage of malfunction of the voltage converter due to failures of the nodes of semiconductor converters: 1 – power unit "transistor-driver"; 2 – rectification unit; 3 – filter capacitors block.

Thus, the transition to regulated electric drives of the plastic production's blowing mechanisms allowed one to expand the adjusting characteristics of the electric drive, and also the reduction of the unstable supply network influence was achieved [13,14]. At the same time, the calculation showed that the use of more elements can reduce reliability parameters.

3. Estimation of energy saving due to the transition to regulated AC electric drives

Mostly synchronous machines are installed on the electric drives of the blow molding machines. This is due to a number of factors, the most important of which is the ability of synchronous machines to operate in the reactive power compensation mode [15]. As the blow molding machines must work throughout the molding process, the process of returning reactive energy to the network also takes a long time (stops are only made in emergency situations and for preventive events), which significantly reduces the cost of electricity for the entire production.

For a long time, the electric drive of the blow molding machines remained unregulated [16]. This situation was explained by the insufficient development of semiconductor to create powerful and reliable converters and exciters for synchronous machines [17]. It is advisable to shift the electric drive mechanism of the gas trap to a reduced speed at specified intervals. The stop of the electric drive of the blow molding machines during the auxiliary operations is economically inefficient, since the energy losses at start-up are very high. For preventing the backward emission of generated gases from the reservoir into the working space of the workshop, a complete deactivation of the gas cleaning system is also impossible.

The estimation of the energy-saving effect in the electric drives of the blowing mechanisms was carried out indirectly in terms of the losses magnitude in the start/deceleration sections (Table 1)

Table 1. Results of calculation of losses in an asynchronous motor with different start-up methods with different types of loads

№	Mode	The amount of loss, W	The amount of loss, a.u.
Start/deceleration of the electric drive from the supply network			
1	Idling	275	0,12
2	Rated torque	2336	1
3	Pumps loads	1016	0,43
Start/deceleration of the electric drive from the frequency converter			
1	Idling	1,08	0,005
2	Rated torque	210	0,11
3	Pumps loads	153,5	0,065

According to a survey of specialists, the blow molding machines's malfunctions on blow molding mechanisms occur at an average frequency of once every two months [18]. The reason for the stops in the tuned drive system is the disconnection of the frequency converter from overcurrent, as well as malfunctions in the synchronous motor excitation system.

Installing frequency converters will provide speed control in a given range. In addition to speed regulation, frequency converters can provide smooth start-ups of drives, which will provide a positive impact on the energy of work processes. However, as already noted above, there is no need for frequent start-ups and shutdowns of the electric drives of the blow molding machines. In the work of such mechanisms, the established operating modes prevail. Thus, frequency converters have excessive control capabilities, for which one has to pay an inflated cost. At present time, there is no evaluation of the benefits from using simpler schemes in control systems of electric drives of such mechanisms without decreasing the quality of work. Therefore, an attempt to create a management system that is characterized, on the one hand, by low cost, and on the other hand, satisfice a large number of requirements is very actual.

4. Ways to improve the reliability of electric drives of plastic production’s blowing mechanisms

There are several methods to improve the reliability of electric drive systems. One of the main methods for increasing the reliability of any system is the insertion of "internal redundancy" of the system. This way of reducing the malfunction flow is the simplest: it is necessary to select elements designed to work with a larger load and use them in a system loaded with less efforts. The technique of "internal redundancy" is considered in detail in the works of [19,20].

Another common method is the technique of increasing reliability based on the criterion of minimizing the capital expenditures, proposed by [21,22]. All industrial electrical installations can be conditionally divided into three categories based on the required level of plant reliability, its responsibility, and the amount of the capital and operating expenses on the equipment. Both methods have a number of drawbacks, particularly overestimation of capital expenses on the established power of the semiconductor converter.

The most promising way to improve the reliability of the electric drive system is the use of new, non-traditional technical solutions for both power circuits and for the machine itself.

To the greatest extent, reliability requirements are met by electric drives with new, non-traditional types of electrical machine designs. Such electric drives are characterized by a wide variety of schemes and solutions. Electrotechnical complexes based on gate-inductor electric drives or reactive machines have been widely used in recent [21,23]. The study of the variants of such schemes of electric drives should be considered insufficient for a confident and successful application in practice, in particular in electric drives of mechanical engineering mechanisms characterized by severe operating conditions. One example of such system can serve as a pulse-vector control (PVC) synchronous reactive machine with independent excitation (SRMIE)[24]. The machine itself is characterized by the simplicity of the rotor design and the high manufacturability of production. In the initial case, the scheme of the power circuits is made multiphase with individual power supplies. The rejection of individual sources in favor of a simpler scheme leads to a structure with pulse-vector control (Figure 4).

In figure 4, L1 ... L6 - phase windings of the machine, the power part of the semiconductor converter is a three-phase diode bridge rectifier; there is only one transistor (regardless of the number of phases of the system). The presence of only one IGBT transistor in the converter leads, first of all, to the increased reliability of the circuit (the less the number of elements in the circuit, the more reliable it is), and the second - to the relative cheapness of this system. The pulse-vector circuit can provide the required speed range for the mechanism of the blow molding machines 1:2 or 1:3.

Nowadays, the electric drive of the blow molding machines is implemented on a frequency-controlled synchronous electric drive. As it has been already noted above the existing solution has its advantages and disadvantages. At the same time, low reliability of the frequency-current control of the synchronous machine gives a great chance for us to improve the electric drive of the blow molding machines .

Increasing the reliability of the mechanism of the electric drive is proposed to be carried out in two directions: 1) changing the type of the electromechanical converter 2) simplifying the power converter circuit.

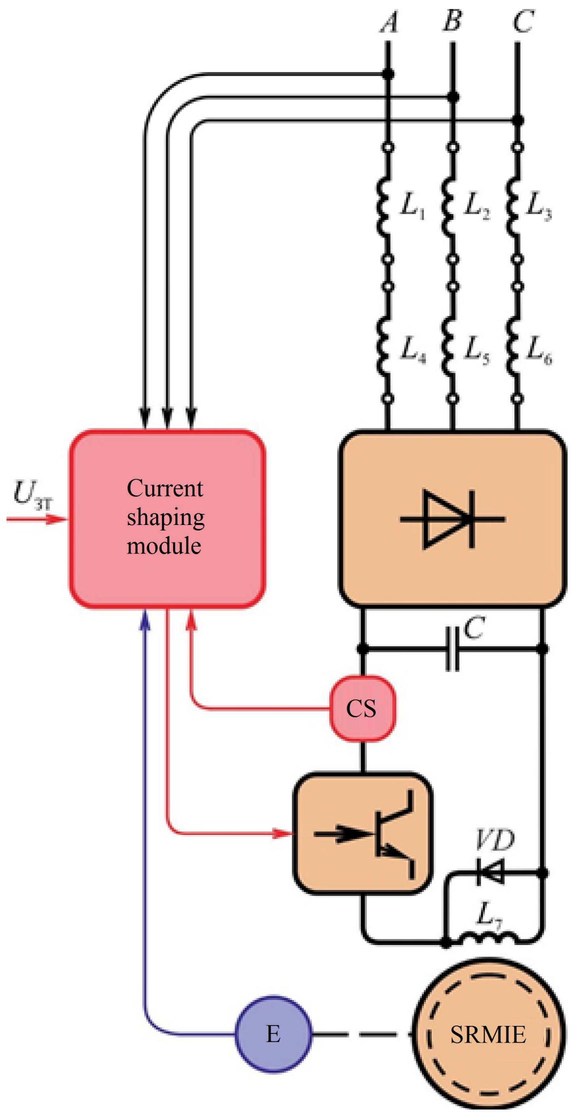

Figure 4. An example of a simplified scheme of pulse-vector control of the SRMIE.

5. Conclusion

1. The analysis of the requirements and conditions for conducting the technological process of the electric drive of the blow molding machines for the production of plastic products made it possible to determine the weakest places of the existing electric drive system in terms of reliability: the presence of the excitation system of the synchronous machine in the power section of the electric drive, the large number of controlled semiconductor elements in the power circuit schemes of the voltage converters, the presence of a contact motor in an electric drive operating under severe conditions.

2. It is established that the transition to a regulated electric drive in blowing mechanisms can significantly reduce electrical losses (up to 20%).

3. One of the main methods of increasing the reliability nowadays is the method of introducing "internal redundancy". This way of reducing the malfunction flow is the simplest: it is necessary to select elements designed to work with a larger load and use them in a system loaded with less effort. However, this technique has a number of drawbacks, particularly overestimation of capital expenses on the established power of the semiconductor converter.

4. It is shown that the application of simpler structures of pulse-vector control makes it possible to increase the reliability of the electric drive system while maintaining performance indicators (to retain the range of speed and moment control).

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