ELECTRIC MACHINES OLDER CONSTRUCTION FED FROM FREQUENCY CONVERTERS

The working life of electrical machines of great power (over 1MW) averages generally several decades. By the reconstruction of production aggregates due to saving of power in industrial or power enterprises and societies, the reconstruction of drive is often required but only with the existing electric motor. It goes for example about feeding of DC motor from rectifiers, use of slip-ring induction motor in subsynchronous cascade, feeding of asynchronous or synchronous motor from frequency converter with current or voltage intermediate circuit. Keeping of the same or slightly increased rated output and torque is supposed. The presentation of project, realization and practical operation experiences of such reconstructed drives in great enterprises should be the subject of this paper. Saving of power, EMC problems etc. will be presented.

1. INTRODUCTION

Electric machines, whose development is apparently finished, are set to new operational areas evoking electrodynamics effects, which classical theory of electric machines did not encounter with. Drives expecting stepless, fast and accurate speed regulation create such area for AC motors. These controlled drives were till this time practically exclusive matter of DC motors. The line of workability of great power DC motors is limited by acceptable size of reactive voltage (then by product \( l \times n \)), it comes by current commutation without troubleshooting, further by mechanical strength especially of commutator, inertial matter of the rotor, transport possibility etc. As it is known the maximum output power of these machines vary to 7 MW by maximum voltage 1200 V and low speed about 100–180 min\(^{-1}\). For often demanded speed at least to 1500 min\(^{-1}\) the maximum possible output power used to be about 1500 kW.

AC asynchronous and synchronous motors come into regulation drives more and more with semiconductor technology development. AC commutator motors are pushed out from industrial applications. These motors are practiced now at single-phase consumers for house and at hand tools.
It is possible to advance markedly limits of electric drives by usage of AC motors supplied from semiconductor converters namely as for power output (ten MW) and speed \((5000 \text{ min}^{-1})\). Next there are possible applications for inexplosive ambient, which by DC drives were almost impossible. Current commutation remains as limiting factor however also by AC drives. Difference between DC and AC motor is at that, where the commutation is accomplished. A mechanical commutator is by DC motors, whilst there is a power part of static converter by AC motors. Current commutation was transferred to static converter and it goes on contactless, but no without problems.

2. PRODUCTION AGREGATES AND TECHNOLOGY MODERNIZATION

Series of electric drives out of use exist at industrial plants with considerably energy demanding speed control or input medium parameters of driven aggregate. Rising price of electric energy, expensive and very discussed construction of new energy sources are the main reasons which push every operator, electric equipment user, but also managers and politicians to be engaged in possibility to prevent of evident waste of all energy types or to limits consumption when it is possible. Evidently it would not be accepted that economic development needs to be bound with proportional rise of energy consumption. Therefore new production technologies minimizing energy consumption are searched at all areas. Objective example can be metallurgical industry with introduction of new technology of continuous casting or mini-iron works. We must be able to judge, if contemporary electric machines and other appliances already used or only offered on the market, are modern from the viewpoint of efficiency that is advantageous for operator and no e.g. from the viewpoint of weight and material consumption that is often advantageous for producer.

Energy savings develop mostly by fan and rotary pump drives applications. Energy losing method of regulation of transported quantity by the help of throttle-valve in pipe system or by bypass is replaced by speed regulation of AC motor of the pump. Power consumption of the motor goes down with third power of speed. Our experiences with realization of those projects (heating rotary water pumps of delivery stations for commuterland supplying, turboexhauster drive of agglomerating etc.) indicate, that is possible to save 30% of electric energy (in the case of heating water pumps more quantity of heat energy). A little slower there is penetration of these applications to crane and hoist drives, where uneconomic control of starting, braking and also speed control are replaced. On the contrary the converters expanded more by roller conveyors.

3. DURABILITY OF LIFE OF ELECTRIC MACHINES

As by every equipment, system or production aggregate as by electric machine we must try to determine durability life or time to its necessary modernizing or replacement by new equipment. Working life of electric machines is largely given by working life of insulation system of winding. As end-time of function ability of this system it is possible to consider a moment, when the value of breakover voltage its arbitrary element (winding, coil or phase insulation) goes down
under value of operating voltage. A breakover voltage is various at different parts of the machine. Aging process of insulation system proceeds mainly owing to temperature and mechanical stress under presence of electric field, influence of the climate and other factors. Failures of the winding insulation system belong to the most frequently failures of the machine and therefore the winding is changed even several times during lifetime mainly by the machines of small and medium output. Frequent exchange can concern also bearings and current collector mechanism (except standard exchange of brushes). Magnetic circuit of the machine and other mechanical and constructional parts of these machines stay without change during all technical life. So the machines older than 40 years are common by the machines of great output.

4. REASONS FOR USE OF EXISTING MOTORS BY MODERNIZATION OF PRODUCTION AGGREGATES

Efficiency of electromechanical conversion proceeding in electric motor and energetic and economic efficiency can be influenced by these factors:

- optimal project, technology and production quality of electric motors,
- use of a motor suitable type, power output, speed, loading factor etc. for driven aggregate or nodal point,
- time, power and speed utilization of the motor.

It is often mentioned, that electric motors consume 35–50% of all producing electric energy. By reason of that the energy index of electric motors have essential signification by evaluation their operational economy and also economy of the whole production equipment. Let us deal with their economical, technical and technological aspect of the production, operation and repairing.

Electric machines are industrially used more than 100 years. During these years the basic regularities of electric machines were theoretically elaborated and very quickly mastered in industrial production. The development proceeded basically without sensational inventions but with systematic perfection of all machine details. So it was able to happen that specific weight of electric machines went down swiftly. This is documented very well on squirrel cages asynchronous motors representing major part of today produced electric machines. If the specific weight of the typical representative of these machines had value 82kg/kW in 1891 then did only 6.75 kg/kW in 1985. From 20th the weight of the motors per 1 kW went down approximately 0.8× every 10 year. A modern computer technique lately contribute to specification of calculation of electric and magnetic circuit and especially mechanical parts of the machines, losses calculation, temperature rise and ventilation. This fact lead to optimization of all parts of electric machines.

Producers of electric machines were concentrated lately more on reducing of material consumption and operation time than on the reliability of used features of their products and as a result of this the users of electric machines often found the progressive decrease of reliability of electric machines.

From the view of economy several different ways exist to make an optimal design of electric machine:

- production costs minimization including costs for active construction materials,
minimization of machine dimension and weight,
• operational costs as lower as possible where the important role do the machine price, efficiency or costs relative to consumed energy by operational state and lifetime of the machine (time of use),
• maximum possible reliability of the machine and minimum requirement of maintenance.

It is obvious from above mentioned that motors made before time were not strike by hunting for the minimum of unit weight to 1 kW of power and so their efficiency could be suitable. If the mechanical parts and magnetic circuit of the machine are in good trim it is no reason why we could not keep these machines by appropriate modernizing in next operation. This is of course useful only by drives with rating above 1 MW supplied from network 6 kV.

The following modifications must be made on selected motors for use on modernized aggregate:
• to pull down stator and rotor winding and renew their insulation systems in class F,
• stator winding must be often modified for D-connection (3.46 kV),
• short connected rotor winding and dismounted rings by slip ring motors,
• mechanically modified shaft, bearings and bearing stands,
• metallic bandage must be removed and replaced by fibreglass laminate bandage.

By such modernizing of electric machines older construction the decision must be made if the pull down winding will be used again or if the new winding will be produced. These facts must be considered carefully before this decision:
• by use pull down winding:
  - cost saving for purchase of new conductors and for production of coils,
  - increase of the machine thermal reserve proportionally to difference of thermal classes of a new and an old insulation system or proportionally to this difference the rating power of the machine may be increased,
  - increase of a labour consumption because there are difficult a removal of old coil and especially of winding insulation;
• producing of new winding will be more expensive, but modern insulating systems permit to reduce insulation thickness and so an arise of the slot space for use of conductors of bigger cross-section and by this it is possible to increase the rating power of the machine or its thermal reserve than in the previous example.

From above mentioned it is obvious that by decision about reconstruction technique it is possible to consider series of technical, economical and technological aspects. It depends also if the repair will be made by own winding work or external corrector.

5. EXAMPLES OF RECONSTRUCTION

a) Subsynchronous cascade

Where the slip ring asynchronous motor is still used and where a too deep speed regulation is not necessary i.e. it is possible to use cascade connection where the speed not differentiating from rating speed about more than 20–25%. Slip energy is then regenerated back to network. The example of such solution is subsynchronous cascade for motor 7.5 MW
driving Ilgner aggregate. The invested costs for reconstruction of this drive are returned in costs on spared electric energy during about 5 years. Properties of this drive are described in [1].

b) Frequency converter with current intermediate circuit

A drive with this 3500 kW converter supplying 6kV synchronous motor was realized by turboexhauster drive. This drive was amortized during about 1.5 year [2] in consequence of considerable saving of electric energy.

c) Frequency converter with voltage intermediate circuit

It is possible to choose following versions for considered reconstruction of HV motors:

- use of two transformers,
- choice of 3.4kV or 6 kV converter.

Because any users do not want to operate HV frequency converters for fear of reliability, it is possible to use two transformers. It means to insert one transformer 6/0.4 kV or 6/0.69 kV etc. between 6 kV network and converter input and second transformer 0.4/6 kV on converter output.

It looks to be that in case of motors to 1000 kW of rating power the investment costs for acquisition of two generally dry transformers should not have had to higher than difference of price of the HV and LV converter. Also costs on higher energy losses by use of two transformers are necessary to implicate in consideration.

![Diagram of the reconstructed drive](image)

Fig. 1. The scheme of the reconstructed drive

There are evidently preferable to use HV converters by drives with asynchronous motors over 1 MW. The converter need not be very often on voltage 6 kV because do these motors have stator winding $Y$ connection. It is possible to make $D$ connection by these motors and supply voltage may be 3.4 kV. Because older motors mostly have insulation system in thermal class B, insulation system of these motors used to be renovated to class F.
A drive of rolling-mill for tube punching can be by example of use of HV frequency converter with voltage intermediate circuit. That rolling-mill was over most 35 years driven by asynchronous motor 3000/2500 kW, 6000 V, 330/245 min\(^{-1}\) with switching of number of poles from 18 to 24. Impossibility of stepless speed control and low load did not correspond to contemporary and coming needs of production technology, and therefore possibilities and techniques of reconstruction and modernizing of these drive were searched. By common rolling there was needed the useful torque of the motor about 140 kNm and e.g. by taken 4600 kW active input power this motor took from network still 4500 kVA reactive input power.

The requirement of use of slip ring asynchronous motor 6200 kW, 6000 V, 730 A, 370 min\(^{-1}\) working several ten years on canceled rotating converter needed next among basic demands for reconstruction.
The scheme of the drive is shown in Figure 1. The motor took reactive power about 4500 kVA by old drive during the rolling cycle. A negligible reactive power take-off is by the new drive fed from frequency converter as shown in Figs. 2 and 4. The course of converter input voltage and current by no load motor run is shown in Fig. 2. Current take off covering only no load loss is obvious. There are the same values under load in Fig. 3 for comparison.

REFERENCES


SUMMARY

Životnost elektrických strojů velkého výkonu (přes 1 MW) činí obvykle několik desítek let. Při rekonstrukci výrobních agregátů kvůli úspěchu energie v průmyslových podnicích a společnostech je často požadována pouze rekonstrukce pohonu se stávajícím elektrickým motorem. Jedná se např. o napájení stejnosměrného motoru z usměrňovačů, použití kroužkového asynchronního motoru v podsynchronní kaskádě, napájení asynchronního nebo synchronního motoru z frekvenčního měniče s proudovým nebo napěťovým meziobvodem. Prezentace projekčních, realizačních a provozních zkušeností takové rekonstrukce pohonu ve velkém podniku je obsahem tohoto příspěvku.