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Power Conversion

CONFERENCE

JUNE 6 - 8, 2000
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POWER SYSTEMS AND EVOLUTION FACTORS FROM THE STATE OF THE ART TO FUTURE TRENDS

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Abstract- Power electronic systems and electric drives are often considered as out-of-date techniques, no more evolving. As most techniques, electrotechnics would disappear without evolution. Many factors influence this evolution and will be developed : the demand; when the electric power system becomes the weakest point in a machine, it becomes automatically the key factor for the performances; the electronic components; the control systems and devices; the communication systems; the materials (ferrites, permanent magnets); the design optimization according to the applications; the integration of the power system components and the integration into the global systems.
An example in the field of contactless energy transmission for electric vehicles will illustrate this presentation.

I. INTRODUCTION

For 25 years, the most important developments and progresses in the field of power systems, including electric drives, power electronics, energy conversion, etc., have been initiated with low power applications. Electronics played a key role, not only by introducing more flexible solutions, but also thanks to mass cost reductions.

By taking mainly the example of electric drives, including their peripheral components, the recent evolution is already far away from the situation from 25 years ago. In the past, there were only three popular motor types :

- the DC motor in a wide range of power, centered on speed control;
- the collector motor for high speed low power applications (and electric traction for some countries);
- the induction motor at constant frequency, in a wide power range.

The synchronous motor was only used in combination with asynchronous starting.

At the end of the years 1960's, the stepping motor revolution introduced the first synchronous motor, controlled by electronic commutation. This motor was mainly and first developed and applied to computer mechanical systems like printers, plotters, card readers, etc. Such motors make it possible to execute energy and information conversion. This solution brought a very important impulsion in the domain of motor control and electronic drive integration.

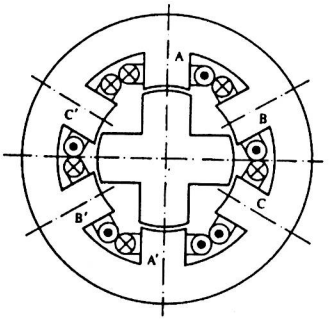


Fig. 1 Reluctance step motor

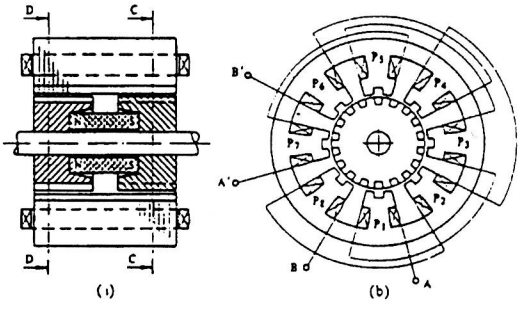


Fig. 2 - Hybrid step motor

In Figures 1 and 2, the most popular step motors are presented : the reluctance and hybrid motors. The most popular current application is

the one-phase step motor for quartz watches (Figure 3).

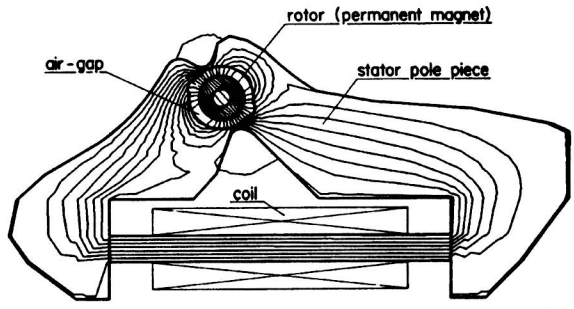


Fig. 3 - Watch step motor

The step motor technique opened the door to the brushless DC motor development, for many applications such as fans, disk drives, machine tool axis control, robotics, etc. Two main structures have been developed :

- the brushless DC motor, with a trapezoidal back EMF, supplied by a 6 transistor bridge (Figure 4), commutated in a 120 or 180 degree mode (Figure 5). This kind of motor is a relatively low cost solution, used mainly for torque and speed control:
- the synchronous self-commutated motor, with a sinusoidal back EMF and a driver generating 3 phase sine wave currents. It is associated to a high resolution numerical (optical) or analog (resolver) encoder. This motor type is used for torque, speed and position control.

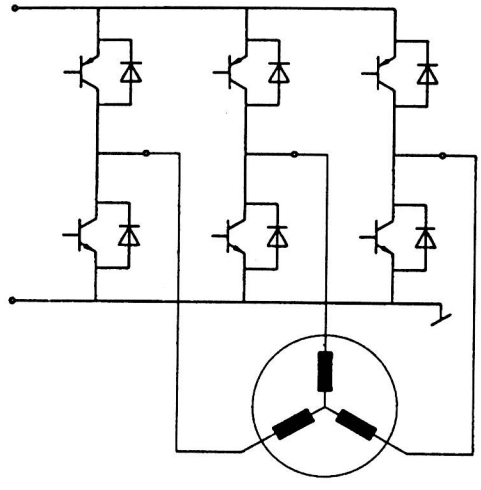
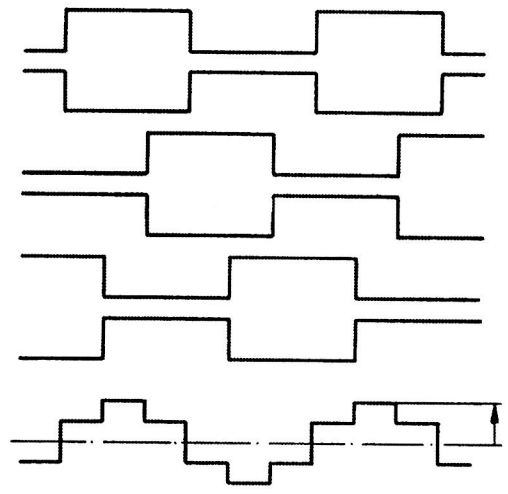
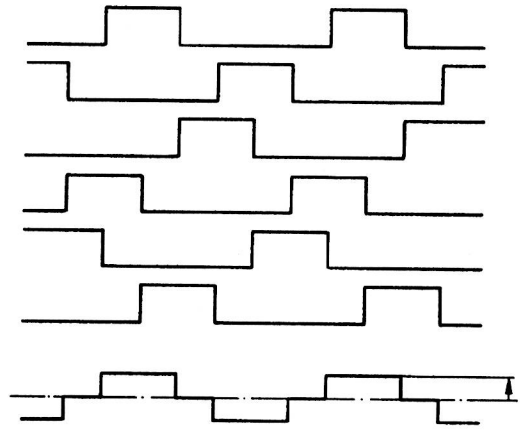


Fig. 4 - 6-transistor bridge



180° commutation



120° commutation

Fig. 5 - 120 and 180 degree commutation mode

Two other developments appeared during the last 20 years, mainly based on power electronic drivers :

- the induction motor supplied by a variable frequency driver, mainly used as a high speed or power motor; a torque regulation is possible thanks to vector control;
- the switched reluctance motor (Figure 6) has a very simple rotor structure, without any PM or winding and a low inertia; like a BLDC motor, it is commutated as a position function, with a phase control; the main specific problem is the noise due to the high flux transition.

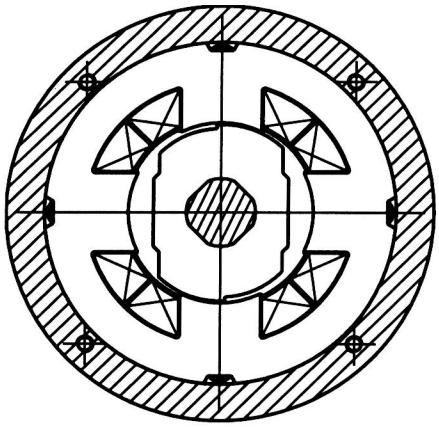


Fig. 6 – Switched reluctance motor, 2 phases

In Figure 7, a classification of the main present electric drives is presented. Two main characteristics can be distinguished :

- the synchronous motors, with mechanical (DC motors) or electronic (BLDC motors) commutation;
- the induction motors.

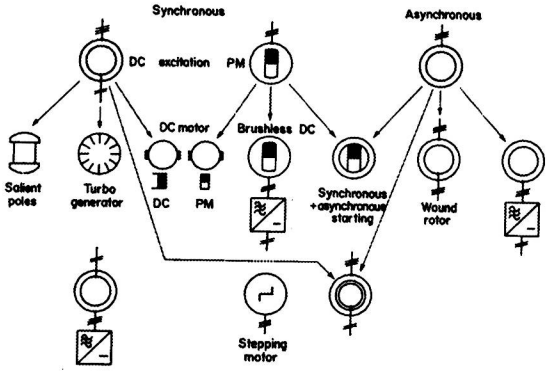


Fig. 7 – Main electric motors

II. EVOLUTION FACTORS

Looking at the future trends in the field of electric drives, different factors can be foreseen :

- the most important is the *demand*, creating tendencies and pressure for new developments;
- among the main trends created by the demand, the need for *direct drives*, rotating or linear is a sure evolution factor;
- as a consequences of the former tendency, the motor *integration* to the load.

Evolution in other domains have influenced and will still influence the electric drive performances; among them :

- the *power electronic* devices and integrated drives, including their cost aspects;
- the integrated control circuits such as *microcontroller and DSP's* offering more and more flexibility, calculation rapidity and specific functions;
- the *material* evolution, for PM, magnetic circuits, including materials such as ferrites;
- the *communication* capacity of electric drives, using field buses and specific IC to exchange information.

But, in order to reach the best solutions using the up-to-date technologies, two other conditions will be necessary :

- to dispose of efficient *design and modeling*, tools such as finite element methods, dynamic simulation, design software under constraints, etc.;
- to evolve towards totally integrated electric drives or *smart drives*, integrating electromechanical, power electronics, control electronics, communication, sensing and adaptive functions in one component; this implicates a good global thermal model and specific solutions for this aspect.

III. THE DEMAND

III.1 Main trends

When, for a machine tool or a robot, the different components evolve, becoming stiffer (mechanics), faster (CNC) and more flexible (control), as a consequence the key factor for further improvements remains the electric drive. The demand pressure increases and steers the motor evolution towards new structures. For old or traditional techniques, one of the main evolution factor is the demand, the needs for more performing solutions. Two main trends exist and will still be reinforced in the future :

- the request for more direct drives, rotating (torque motors, high or low speed motors) or linear;
- motors more often integrated into the application system.