

Electric Drives Technology- Part Way to Where?

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Abstract - Power electronic converters have clearly had a dramatic impact on motor drive technology. However, successful applications of this technology have not been all pervasive but relatively selective. This paper attempts to summarize the present status of this technology at to illustrate that, perhaps, the greatest challenges and rewards lie ahead of us.

I. INTRODUCTION

Solid state power electronics and motor drives continue to be a rapidly growing discipline in the field of power engineering. However, the mere fact that this discipline is “growing” suggests that we are only part way to a mature technology which is all pervasive in terms of its potential applications. The question then arises “what constitutes a mature technology?” and consequently under what conditions can we “declare victory” in a technological sense? This paper is intended to illustrate the fact that we are, in reality, a long way from total victory.

II. THE COMPLETE POWER ELECTRONICS PACKAGE

One interesting analogy to the power electronics industry is the concept of a partially finished three dimensional structure as illustrated in Fig. 1. The “walls” of the package encompass four major sectors of commerce: Industry Applications, Defense and Aerospace, Commercial, and Traction and Automotive. The “foundation” of the structure corresponds to Domestic Applications while the “roof” or cover of the structure corresponds to very high power Utility Applications. Hence, the power level of the application increases as we move up the structure from bottom to top. We can contentedly state that when we have completed the entire “package” we will have addressed all of the application field which could benefit from power electronics and motor drives. Let us now examine the various wall (commercial sectors) which make up the complete

power electronics package.

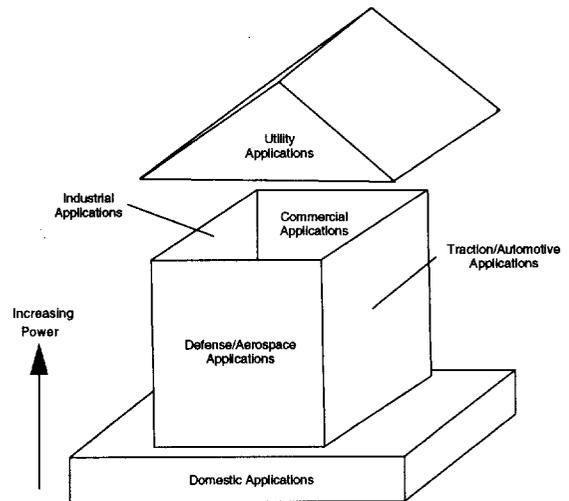


Fig. 1 Complete Power Electronics “Package”

III. THE FOUNDATION - DOMESTIC APPLICATIONS

Laying the foundation for the power electronics/motor drive “package” is the domestic market. The market potential of this market sector is massive as suggested by its location as the “floor” of the power electronic/drive package. The number of single phase motors targeted for such applications in the US has been estimated at about 70 million [1]. At present this area remains almost completely untouched by our technology even though applications are numerous encompassing air conditioners, furnaces, refrigerators, dishwashers, washers and dryers among others. All of these applications could benefit from variable speed, introducing the possibility of improved efficiency, lower noise, and improved comfort. However, at present, nearly all of these applications are serviced by line frequency, single phase induction machines. As single phase motors have been cost minimized by intense competition and evolution

over a 75 year period, the challenge is ominous. The possibility of breaking into this market perhaps hinges on packaging the power electronics and motor as a single unit. A first baby step into this new direction has already been taken [2].

IV. INDUSTRIAL APPLICATIONS

The pervasive use of industrial Ward-Leonard drives predating the emergence of solid state drives in the sixties, formed an easily identifiable, vulnerable target for drive developers during the early period of the power electronics era. These drives were rapidly replaced by dc drives with thyristor bridge armature supply and then subsequently by successive generations of transistor based ac drives that having only a 3-5 year gestation. Indeed, three ac drives ranging from 1 kW to 1 MW have become the dominant technology in nearly all sectors of the industrial market largely supplanting dc drives. Sophistication in the design of such drives have reached the point where, in the lower power range, product offerings are nearly identical.

Overall, the portion of the “package” corresponding to industrial applications can be said to a very firm, solid structure. Indeed, one could state that this surface has already had numerous coats of paint, since, at lower power ratings, because of the uniformity of the product offerings, it is sometimes the color of the paint job that prompts the user to buy one manufacturer’s inverter over another! We can not, however, claim that this part of the package is a completed construction since cracks in the wall have appeared recently as a result of bearing current, dV/dt based winding failure and electromagnetic interference caused by the turn off of the inverter switches.

V. COMMERCIAL APPLICATIONS

Commercial applications of motor drives can be considered as ranging from integral horsepower to the hundreds of horsepower. Opportunities are fewer here than in the industrial sector but numerous successes have occurred ranging from elevators to large, air handling equipment. Nonetheless, the market potential is largely untapped. One need only to count the number of single phase motor/compressors operating the vast amount of refrigeration equipment existing in a modern, supermarket or even a fast food restaurant to recognize the potential. Advantages of higher operating efficiency, lower noise and better regulation of the refrigerating process

are desirable advantages of variable speed in such applications. Cost, of course, prevents many of these applications from migrating to variable speed. These problems can only be addressed by improved packaging concepts, driving down the cost of the power converter to only a fraction of the motor cost [3].

VI. DEFENSE AND AEROSPACE

In contrast to the industrial and commercial work the defense industry needs are focused on small size and weight. Squeezing out extra watts from a fixed volume is far different than squeezing out a few cents from a fixed amount of watts. Defense needs have traditionally been the prime mover in the development of high technology in the US and continues to be today as witnessed by the massive amount of spending on Silicon Carbide semiconductor devices. Navy plans for the a more-electric and all-electric ship featuring power electronic building blocks (PEBS) are typical of the interest in various branches of service in power electronic solutions to problems involving energy conversion.

On the commercial side of this sector, activity has almost come to a standstill while presumed reliability issues are addressed. Clearly the opportunities for motor drives as actuators and as turbine driven variable speed generators exist but have not yet been exploited.

Overall, this sector of the motor drive industry has had an impressive series of successes and failures resulting in a surface within the “power electronic/drive package” having a structure with major holes.

VII. TRACTION AND AUTOMOTIVE

The fourth and last “wall” of the power electronics package concerns primarily the automotive sector. Electric traction has historically been an enabling technology for development of large power converters within Europe. However, electric traction for locomotives is regrettably still in a relatively primitive state in the US with one major manufacturer continuing to use dc traction motors and the other adopting a relatively primitive thyristor technology to vary the speed of their ac induction motor.

The status of power electronics in the automobile is similarly dismal. While good success has been achieved in electric traction for hybrid and electric vehicles, its ultimate success will be dictated primarily by the econom-

ics of the power source. The emergence of small, clean fuel cells has been most encouraging in this regard.

While the use of power electronics in the remainder of the vehicle is minimal, this lack is expected to change dramatically in the future as demand for electric power in the auto continues to mount. It has been shown that the current demand in a typical auto has increased by a factor of six times from 1955 to 1999 and will increase by an additional 65% in the next 15 years [4]. This clearly places an intolerable burden on the cabling and interconnects in car. Higher voltage batteries are the obvious solution to this problem, but the process of stepping the voltage up and down will be needed to server various applications. These applications will undoubtedly involve power electronics with variable speed ac starter/alternators, fuel pumps, water pumps and A/C compressors being only a few of the possibilities. However, the cost driven nature of the application coupled with an onerous temperature range (-50 to 150°F) make this a very challenging task. Hopefully the continuous progress in semiconductor material, for example Silicon Carbide, will provide the breakthrough needed.

In view of its massive potential, this sector of power electronic/drive applications could be considered as in its infancy. We could allegoristically say that the “wall” contributed to the power electronics package by automotive/traction has only a strong upper truss representing the high power portion of this application sector with little or no significant substance as one progresses to low power ratings.

VIII. THE ROOF - UTILITY APPLICATIONS

To complete the “package”, we need a cover or roof. This portion is contributed essentially by the needs of the utility industry where “the sky is the limit” in terms of power needs. When economics dictate, remarkable progress has been made in the application of thyristor type technology to multi-megawatt applications including large motor drives. However, because of the turn-off limitations of thyristors, these applications require massive amounts of filtering and/or power factor correction which, in turn, invite system resonances and control problems. The application of turn-off type switches would readily remove or minimize these problems but have encountered only spotty acceptance. The recent emergence of turn-off type GTOs such as MTOs and IGCTs may open the door to the promised land. Until

that time we might view this area of the technology as being well explored theoretically but fundamentally lacking when comes to applications. Hence, we the “major beams” have been laid for the roofing of the power electronics package but not the “roofing”.

IX. CONCLUSION - THE PRESENT DAY PACKAGE

After this quick tour of power electronics/drive technology, we might logically ask “How does this hypothetical Power Electronics Package look like at this moment?” The author’s view of its condition is shown in Fig. 2. Obviously it does not yet make a pretty package. After roughly a forty year effort we have at least formed the outline of the package. Reinforcing the walls, finishing the high power roof and laying the low power foundation may take forty more. At least we can dream of the day when we can step back and truly admire our handiwork. However, today it is still only “work in progress”.

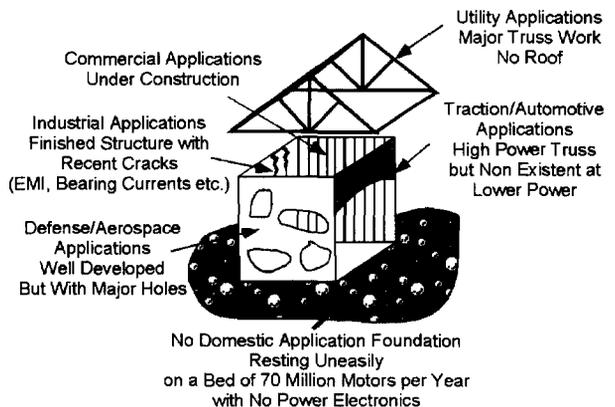


Fig. 2 Today’s Power Electronics/Drives Package

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