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Variable Speed Induction Motor Operation From a 20-kHz Power Bus

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VARIABLE SPEED INDUCTION MOTOR OPERATION FROM A 20-kHz POWER BUS

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L-4618

ABSTRACT

Induction motors have long been recognized for their simple rugged construction. To date, however, their application to variable speed or servo drives has been hampered by limitations on their control. Induction motor drives have tended to be complex and to display troublesome low speed characteristics due in part to nonsinusoidal driving voltages.

A new technique has been developed which involves direct synthesis of sinusoidal driving voltages from a high frequency power bus and independent control of frequency and voltages. Separation of frequency and voltage allows independent control of rotor and stator flux, full four quadrant operation, and instantaneous torque control.

Recent test results, current status of the technology, and proposed aerospace applications will be discussed.

INTRODUCTION

This paper will discuss previous and ongoing work at NASA Lewis Research Center in the general area of aerospace electromechanical actuators (EMA's).

It has been recognized for some time that electromechanical actuators have many potential advantages over hydraulic actuators. Certain technical limitations, however, have prevented their adaptation in large (multihorsepower) applications.

Among the generally accepted advantages of EMA's are reduced maintenance, adaptability to built-in-testing (BITE), improved reliability, and greatly improved efficiency (typically 10:1 or more) (Fig. 1)[1]. The time is ripe for application of EMA's, as customers are recognizing their great advantage in reducing the life cycle cost of ownership.

PRESENT APPROACH TO EMA'S

Brushless dc motors

Historically, aerospace EMA's have used "brushless dc" motors. These are in reality permanent magnet synchronous ac motors requiring electronic inversion and control circuitry. There have been several technical limitations to the general application of brushless dc motors, which become overwhelming in large aerospace actuators.

One problem inherent in permanent field excitation concerns failure modes and their accommodation. In the case of a shorted stator winding or its associated drive circuitry, the motor becomes an uncontrollable load upon the rest of the system. While it has been proposed to accommodate single event failures with mechanical differentials, explosive clutches, etc., failure accommodation for multiple failures has become very difficult [2]. The permanent magnets are generally located in the rotor to minimize rotor loss. They are inherently fragile, however, and have a definite temperature limitation due to the Curie point transition of the permanent magnets.

While these first two limitations concern brushless dc motors in general, another problem has limited their application in large, multiple-horsepower, aerospace actuators. Typically, these motors have been driven from hard switched sources having turn off losses which are proportional to frequency. Additionally, voltage regulation is generally accomplished by pulse width (squarewave) modulation. Such waveforms cause increased motor losses due to their rich harmonic content (Fig. 2). In addition, the filtering required will be physically large due to the low machine frequency involved. When harmonic content and filter requirements are reduced by increasing switching rates, circuit complexities and losses rapidly increase. The effect of these limitations is such that the drive circuitry for large brushless dc motors is typically many times the size of the motor itself.

Switched Reluctance Motors

More recently high saliency, switched reluctance motors have been advocated for actuators (Fig. 3). One advantage realized is the avoidance of mechanical lock up under stator fault conditions. Another often cited advantage is that only half as many electronic switches are required. Since these switches, however, must carry twice the current as the motor power increases, doubling switch current becomes a devil's bargain when dealing with I^2 phenomena, such as leakage reactance energy. Low speed operation of switched reluctance machines becomes increasingly rough as the operating speed reduces toward that of a stepper motor. In spite of these limitations, switched reluctance machines are becoming popular in lower power applications, particularly in the United Kingdom [3]. However, their suitability for high power servo applications remains to be demonstrated.

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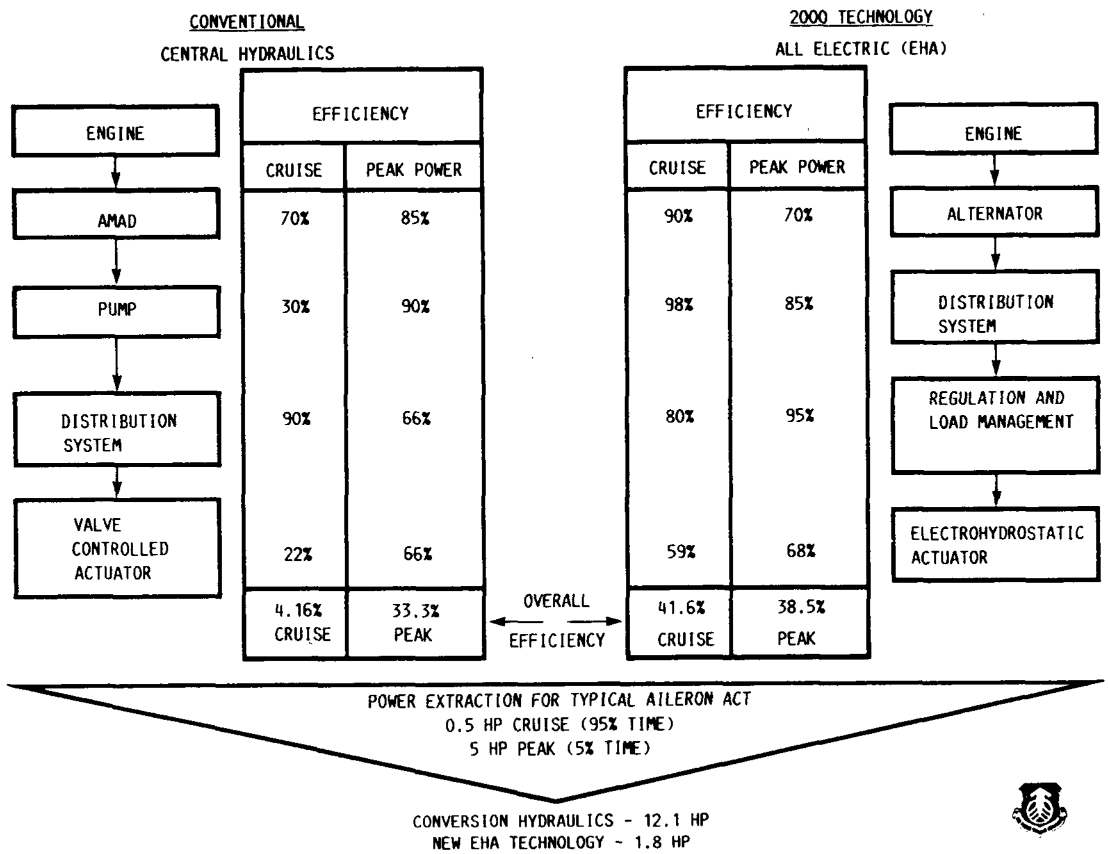

FIGURE 1. - CHART SHOWING ADVANTAGES OF ELECTROHYDROSTATIC ACTUATORS OVER CENTRAL HYDRAULICS (WPAEB STUDY).

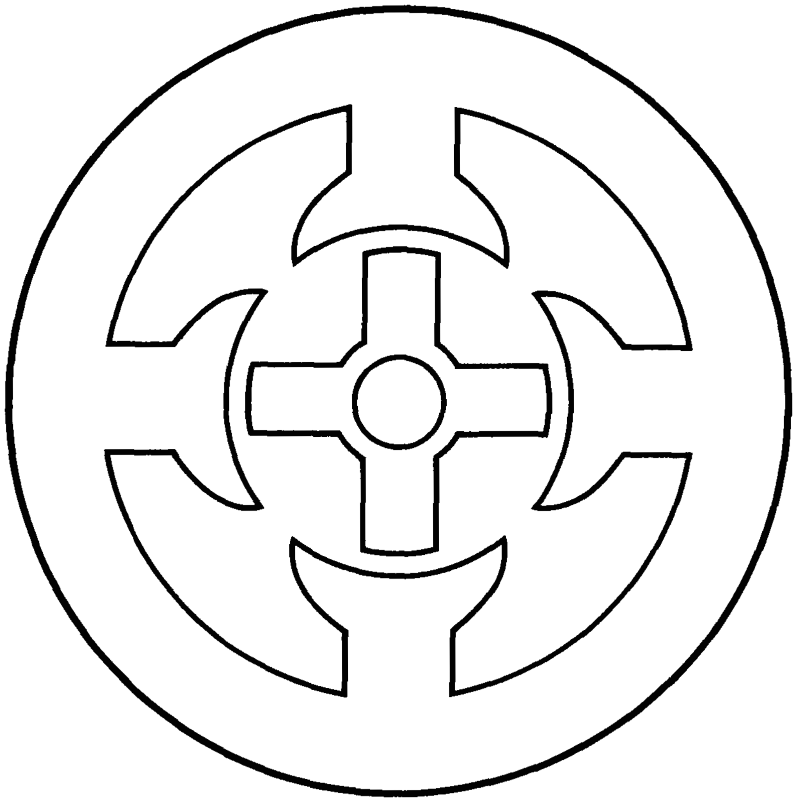

FIGURE 3. - GEOMETRY OF HIGH SALIENCY SWITCHED RELUCTANCE MOTOR.

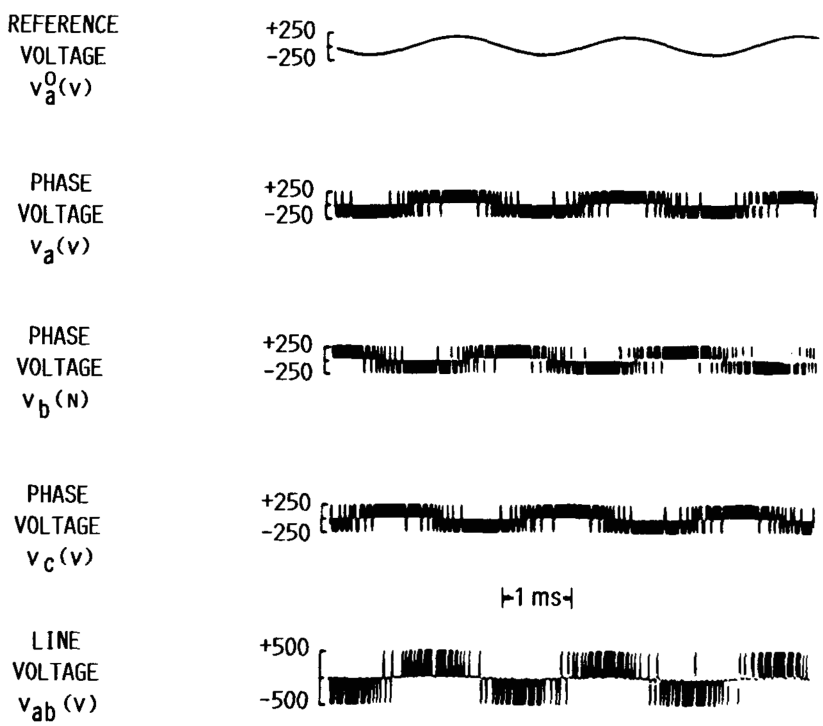

FIGURE 4. - SYNTHESIS OF A BALANCED SET OF VOLTAGES HAVING SINUSOIDAL. FUNDAMENTAL FREQUENCY IS 400 Hz WITH A MODULATION INDEX OF 0.9.

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