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Bulky Flywheel with a Smaller Flywheel and a Controlled Motor

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Abstract*: Wide variations in load torque are experienced by process equipment with more demanding duty cycles. Torsional oscillations are a drawback of these, which frequently require a large flywheel for torque equalization. As a result, mechanical power transmission components become worn out, which eventually leads to equipment failure and extended, frequent downtime, which costs money. This article suggests a more straightforward and suitable substitute. Low moment of inertia and properly monitored VVVf drives provide a far superior option for significantly enhancing system behavior.*

The VVVf control-system enables power input management to the main electric drive which results in nearly identical demand torque output. The torque matching can be enhanced by employing a smaller flywheel. The presented study calculates the minimum requirement for flywheel moment of inertia to reduce the supply torque gap relative to the required torque characteristics. The energy calculations focus on the net transactions between all the components. The flywheel must absorb and release the same quantity of energy through one complete torque variation cycle.

Keywords*: VVVf-drives, flywheels, process machines, and demand torque characteristics*

I. Introduction

A flywheel acts as a device which stores the energy of motion. The device maintains energy when supply surpasses demand but provides the stored energy when demand exceeds supply. Flywheels function to decrease velocity variations that occur because of torque variations. Multiple pieces of machinery including internal combustion engines and piston compressors and punch presses and rock crushers depend on flywheels to stabilize their angular velocity. Figure 1 represents the schematic diagrams of the arbitrary process unit P along with the typical mechanical power transmission system that reduces speed and amplifies torque. In the provided image D2 functions simultaneously as a flywheel and power gearbox pulley. The driving pulley called D1 gets power from the induction motor M while process machine P utilizes linkages and cams and sometimes these components together with gears. This type of process unit requires its demand torque to change throughout time. An analysis using process resistance together with inertia resistance along with cycle duration enables the determination of an arbitrary demand torque for any process machine.

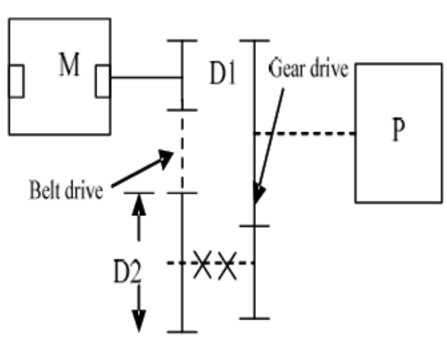

Fig 1: Diagrams of a Three-phase Induction Motor, Mechanical Power Transmission, and an Arbitrary Process Unit

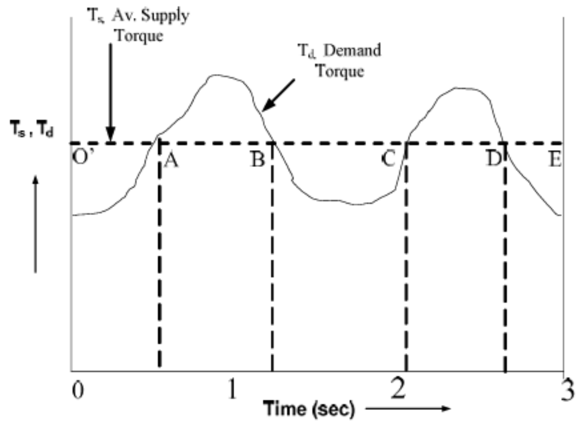

Fig 2: Features of Arbitrary Demand Torque

The proposed partial mechanical design specifications enable a description of the system operation. The continuous operation leads to periodic changes which match the rate of rotation in the process unit. The graphic in Figure 2 shows an arbitrary demand torque characteristic for such a process machine where Ts represents electromagnetic torque average and Td stands for demand torque. The chosen input shaft crank speed for the process machine is 30 rpm. The complete operational cycle requires a duration of 3000 ms which the input link of the process machine completes in one rotation. The depicted image shows how demand torque behaves at different time intervals. The motor cannot deal with these conditions.

The flywheel undergoes deceleration because the load torque exceeds the average electromagnetic motor torque in the AB and CD intervals. The flywheel experiences acceleration during the time spans OA, BC, DE when the load torque remains below electromagnetic torque average. The researchers have chosen the constant volt per hertz concept as their control technique selection for operating three-phase induction motors (Figure 3). The method uses two phases of equipment to develop dynamic three-phase induction machine models. The electromagnetic torque from this approach yields results which do not match the characteristics of the target torque characteristics [9]. A properly chosen small flywheel with an appropriate moment of inertia serves as the connection between the drive and process machine to match the precise characteristics of the demand torque.

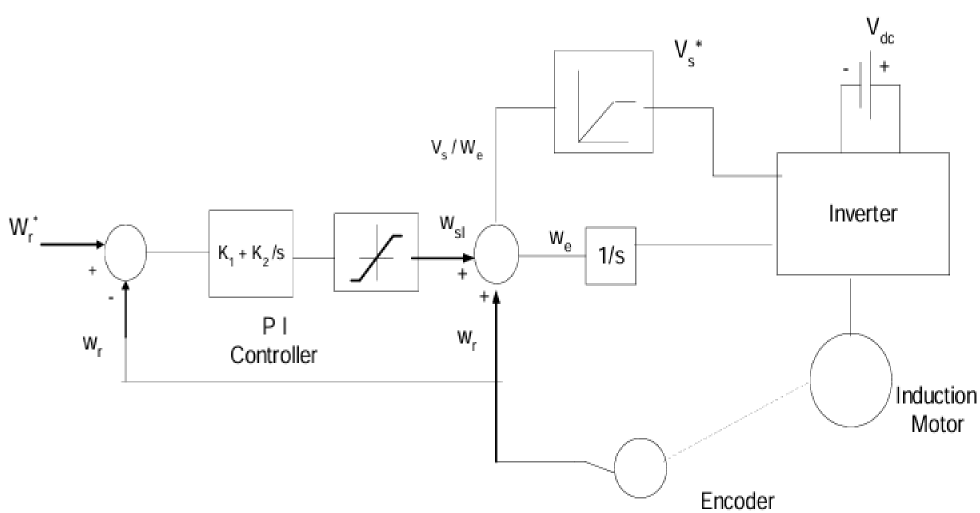

Fig 3: Closed Loop Induction Motor Drive with Volt/Hertz Control

This research investigates the method to determine which total rotating mass inertia is needed to achieve the minimum disagreement between generated and demand torques. One can determine flywheel energy fluctuations to complete this task. The flywheel operates by releasing kinetic energy to the system when the generated torque falls below the required demand torque and it uses the same kinetic energy to store energy when the generated torque exceeds the required demand torque.

II. Closed-Loop Induction Motor Drive with Constant Voltages

Changes in frequency and current cause the drive to accelerate, generating torque that matches the demand torque. At a slip speed where motor torque matches load torque, the drive speed finally stabilises. As a result, the drive produces electromagnetic torque that almost equals the process machine's demand torque when the load torque varies with time.

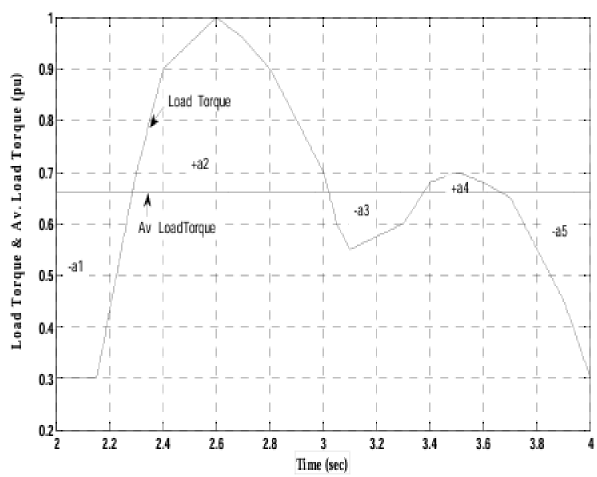

Fig 4: The demand torque feature of a certain machine

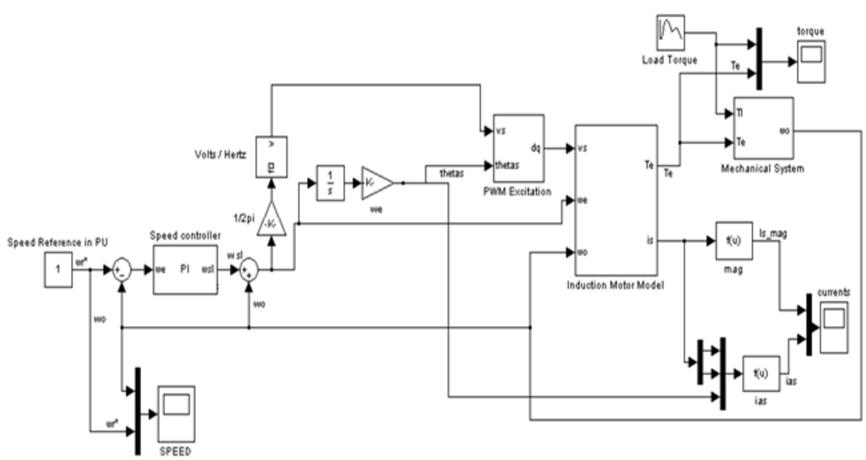

Fig 5: Complete induction motor model in MATLAB program with PWM excitation, mechanical system, and v/f control scheme.

III. Proposed Computational Procedure

The authors simulated a closed loop v/f-controlled induction motor drive using synchronous rotating reference frame with MATLAB Simulink [5] software [9] which includes basic and complex load torques (Figure 4). The Table 1 presents all the parameters used to examine the induction motor. Model results demonstrate that by adjusting the motor frequency an induction motor generates electromagnetic torque with similar quantity as the demand torque illustrated in Figure 7. The system speed declines when the load torque rises since supply torque becomes slightly smaller than the applied load torque.

After reaching its steady value the supply torque track proceeds identically in relation to load torque to sustain constant speed. As the load torque diminishes supply torque becomes higher than it while the speed of induction motors starts to increase. The simulation outputs demonstrate this phenomenon. The relationship between generated electromagnetic torque and speed under various load torques appears in Figure 7. Stator current patterns as well as their intensity variations for an induction motor can be observed on the upper section of Figure 8 when torque load changes.

The variation of induction motor stator current follows directly with torque changes that support torque requirements. The supplied three-phase AC voltages to the induction motor adjust per unit to sustain v/f stability while the load torque changes as Figure 9 shows. Different frequencies are applied according to the duration of each time period in order to create electromagnetic torque that matches demand torque while preventing excessive flywheel usage.

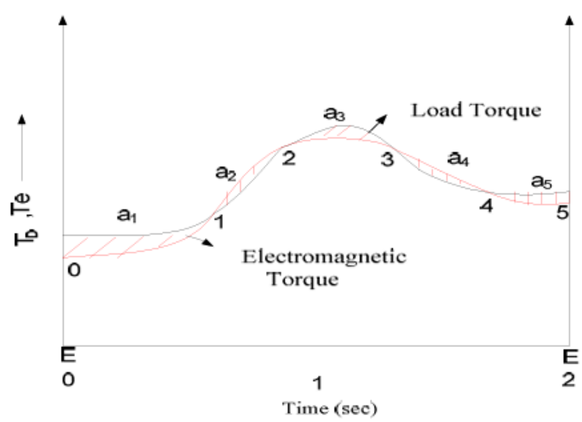

Fig 6: Demand torque versus electromagnetic torque

IV. Computational Procedure

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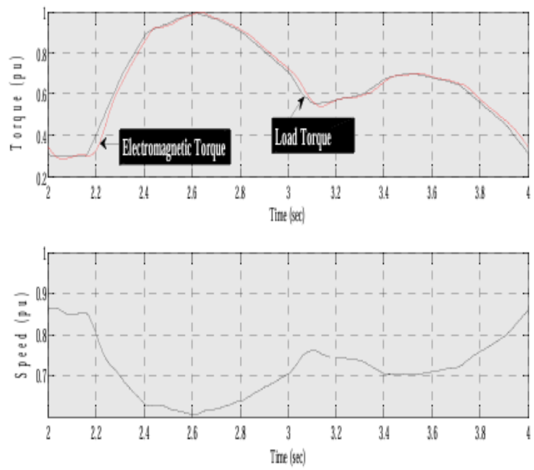

Fig 7: Induction motor speed and electromagnetic torque for load torque

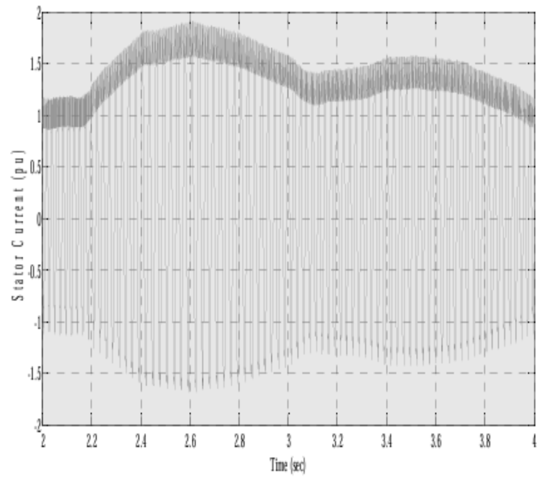

Fig 8: Induction motor stator current for load torque

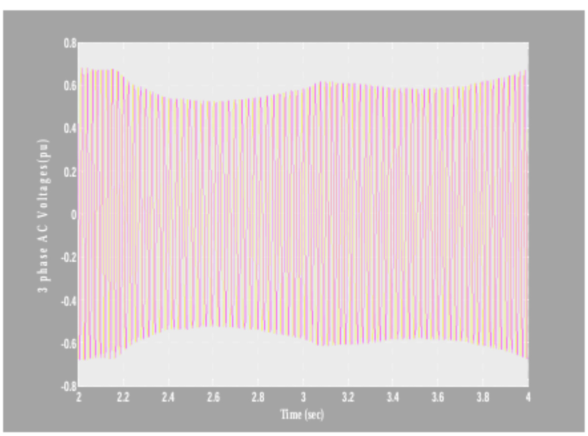

Fig 9: AC voltages in three phases for load torque

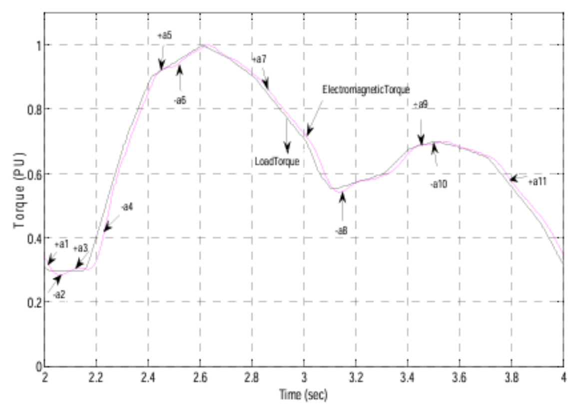

Fig 10: Calculating area using load torque against electromagnetic torque

The Figure 10 shows a detailed view of the demand torque along with the generated electromagnetic torque throughout time. The chart reveals that actual torque generation fails to match exact values of requested torque. An appropriate minimal flywheel moment of inertia needs to be added as compensation against the torque differences between the generated and demanded torques. The entire torque time cycle has been divided into different zones according to electromagnetic torque position shifts relative to demanded torque as depicted in Figure 10 for determining the suitable flywheel moment of inertia. Researchers evaluate the maximum kinetic energy variation of the flywheel by finding the measurement area of each defined zone in kgf-m.

V. Conclusion

It is feasible to use the VVVf technique to manage the input side of the main drive by using a constant f/v scheme, so eliminating the traditional huge flywheel from the process machine with wide changes in demand torque. The induction motor's generated supply torque characteristics and the process machine's demand torque characteristics are nearly identical. A small flywheel effect with a lower moment of inertia between the drive and process machine is necessary to generate a precise supply torque in relation to the demand torque. Because there are far fewer torsional vibrations and wear on the mechanical power transmission component, the drawbacks of a big flywheel are completely eliminated.

References

[1] Joseph Edward Shigley, Charles R. Mischke. Mechanical Engineering Design, 2nd edn, Tata McGraw Hill, Ed.

[2] Joseph Edward Shigley, John Joseph Vicker Jr., Theory of Machines & Mechanisms, 2nd edn, Mcgraw Hill international, 1995.

[3] D. James, Ven de Ven, "Fluidic Variable Inertia Flywheel", American Institute of Aeronautics and Astronautics, pp.1 -6

[4] Bimal K.. Bose, Modern Power Electronics and AC Drives,5th edn, Prentice Hall PTR, 2005.

[5] R. Krishnan Bharat, Electric Motor Drives, Modeling, Analysis and Control, PHI Learning pvt. Ltd. , 2008.

[6] Burak Ozpineci, Leon. M. Tolbert, "Simulink Implementation of Induction Machine Model- A Modular approach" IEEE Transaction on Industry Applications, page 728-734, 2003.

[7] Hussei. Sarhann, Rateb Issa, "Improving Mechanical Characteristics of Inverter Induction Motor Drive System, American Journal of applied Sciences 3, Vol..8, pp 1961-1966, 2006.