POWER MANAGEMENT, CONDITIONING AND CONSERVATION IN OIL FIELD APPLICATIONS

Rhey W. Hedges, Mellin Industries, Inc.
Jerry Drew, Xencom Communications, Inc.

Energy Economizer Technology (**EET**) introduces a new approach to motor control. 50 granted USA and International patents say it provides power management that is truly different from familiar old-technology motor-control processes.

The vital role AC electric motors play in profit return on investment is universal. They are the "motive resource" that turn the wheels of productivity in every industry; the Petroleum Industry's dependency on motors is a prime example.

When pump motors stop, profit stops and "downtime" costs begin. This condition spans the globe. It is as true in developing countries as it is in Texas. Every country depends on electric motors for internal operations and growth by export dollars.

As is true with other resources, motors that are managed are the most productive.

Unmanaged motors start with avoidable electro-mechanical stress and full voltage is applied during light loads where a lesser current would reduce energy waste, life-shortening heat damage and increase production "uptime."

A large percentage of "downtime" cost could be avoided by supervisors who turn power off to protect motors and conserve energy by making manual adjustments.

Manual control for hundreds of millions of motors by "human" supervisors is not feasible. Most AC motors waste some energy as life-shortening heat and rely on thermal devices or fuses for protection. Even though such means prevent single-event catastrophic failures, some motor damage inevitably occurs with each over-current fault; especially with mechanical locked-rotor events.

Controlling power is an improvement over direct-on-line operation. But familiar voltage ramp "soft" starters, even new ones upgraded with the latest microprocessors, are limited by the "design approach" that earned the name: *Motor Controller*. The old familiar approaches ***literally*** control power to the motor.

Prior technology relies on measurements compared to arbitrary software or hardware references the designer believes will control motor performance under conditions that are "anticipated". The motor becomes a "design-controlled" item.

Energy Economizer Technology relies on *natural properties of standard induction motors* as the controlling elements of a "power management system" that:

(1) commands start acceleration, (2) adjusts run torque in proportion to work demand and (3) includes diagnostics that protectively respond to electro-mechanical faults.

The EET approach empowers THE MOTOR to command current in response to conditions and work of a moment without comparison to programmable, arbitrary references; "designer anticipation" of such conditions <u>is not</u> a performance factor.

A novel communications and power control system are united by the EET process.

Review of Motor Properties

The EET "process" is examined in light of standard induction motor properties that induce changes that are, in effect, a form of natural modulation that communicates dynamic changes in motor workload, speed, efficiency in every current alternation.

Illustrations convey the nature of current flow with various motor workloads when stator voltage is manually adjusted with a variable voltage transformer (e.g., a Variac) to precisely meet rotor torque requirements and maintain motor efficiency.

Figure one conveys the dual-component nature of stator current that sums to a total power line magnitude. Note that a motor's inductance is fixed by design and a change in the rotor's mechanical Workload acts as if it were a variable resistor in parallel with this fixed inductance.

Recall it is a natural property for an Induction Motor to develop torque only when rotor speed is less than synchronous and, further, torque is produced in proportion to this rotor speed decrease ... which is commonly referred to as "slip."

When load-induced changes in slip occur near synchronous speed, natural properties cause the rotor's mechanical workload to simulate action that would occur in a transformer with a variable resistive load in its secondary.

Expanding this view, the stator may be viewed as a "primary" the rotor as a secondary and workload changes appear as a variable resistance. Changes in workload demand appear as changes in this "equivalent resistance" and, in turn, it proportionally changes the rate of stator current increase in each alternation.

Refer to Figure 2 and the enlarged view of Initial Stator Inrush Current during the first few hundred microseconds at the beginning of each power source cycle; this sample period is designated for descriptive purposes as: "Isic Time."

During Isic Time, the dominant variable which determines the rate of stator current increase is the rotor-speed-induced Counter Electro-Motive Force (CEMF).

It is the slip-induced change in CEMF with work demand that simulates characteristics of a "load-proportional resistor" when a motor runs in that narrow range of near-synchronous speeds where highest operating efficiency is achieved.

Thus, the "dominant variable" of Isic Time is the resistive Component, since a motor's inductive reactance does not change appreciably when work changes.

Natural properties of the induction process by which motors convert electrical energy to mechanical energy cause Isic parameters to vary in proportion to load-of-a-moment near synchronous speed, and otherwise convey rotor dynamic status down to zero speed (a locked-rotor condition).

Summarizing, alternation current during Isic Time assumes particular characteristics when a motor operates at highest efficiency that change proportionally when the stator is over - or under - powered. Likewise, a locked rotor produces an Isic Time rate of rise and amplitude that is unique to that state compared to any other.

Stator Current Demodulation Process

Adjusting motor torque to match workload demand can be done manually with a Variac or automatically by a power management system that uses the Energy Economizer Technology process to enable the motor to control current to itself.

Figures 3 and 4 illustrate how the load-speed-efficiency related current changes that occur during Isic Time are electro-magnetically extracted from the power line and processed via a pulse-width modulator into a corresponding DC voltage.

Figure Five illustrates the elegant simplicity of the EET process. Load-demand, speed and efficiency parameters are communicated to the Control Signal Loop by natural rotor-slip-induced variations in each line current alternation; a power control information stream **from the motor** of 120 bits/second at 60 Hz.

In "system" form, the motor, workload and power source are arranged in a closed loop where line current changes are directly used to maintain optimum efficiency and power factor down to zero load PLUS command protection when extreme over current results from electrical faults or a mechanical locked-rotor event.

Control loops are closed by adjusting the Motor Rating Control for minimum power line current. Natural properties yield minimum stator current when rotor torque exactly matches work demand; recall that stator current naturally increases when an AC induction motor is "over" or "under" powered. Minimum current establishes load/speed/efficiency properties ***for that particular motor*** as the "system power control reference"; this puts the motor in charge.

In other words, a one-time adjustment empowers motor properties to command the beginning and end of gentle acceleration (soft start) and proportionally increase torque when the resistive (working) current increases, or vice versa ... PLUS simultaneously sets an "excess slip" reference for sudden-load torque increase response and/or to command protection with locked-rotor events.

The EET motor-communications process uses familiar properties of induction motor physics to implement a very unfamiliar system approach:

> ... ***motor-commanded*** power control technology instead of ***technology-commanded*** motor power control ...

The motor uses EET to literally control current to itself in proportion to work demand if all is well, or turn the current off with severe over current fault events.

Briefly reviewed, the Current Demodulator is the novel means by which a motor communicates signals to a protective "electronic supervisor" that implements a common-sense energy-saving concept: if a motor doesn't get more electrical power than needed for its mechanical work, less is wasted as life-shortening heat.

The Practice of EET

Load/speed/efficiency-related signals from each phase are used to implement a "motor-power management system" with industrial three phase motors. Gentle (start) acceleration, work-load-proportional run current control and locked-rotor protection are conceptually the same as described for single phase motors.

When controlled by a motor, the EET process becomes a "power manager"...

Figure Six shows retrofit installation of EET controls with three phase motors is uncomplicated and includes a partial listing of variable load-demand applications where unmanaged motor power typically wastes electrical energy at light loads.

Industrial products for standard induction motors are manufactured with a custom-designed Application Specific Integrated Circuit (EET-IC) as the electronic heart of the EET communication process; refer to www.webti.com/mellin.html for more information.

Petroleum Industry Power Management

Downtime can be avoided and some energy saved by adjusting motor electric power in response to real world field conditions. While it is possible, twenty four hour per day **manual** supervision of each electric motor-driven system is not economically feasible.

However, protective "electronic supervision" that does not de-rate horsepower or lower pump capacity by motor speed reduction is both possible and cost effective.

As explained above, induction motor properties have a natural capacity to command an electronic system which provides gentle acceleration to full speed, adjusts run torque in proportion to work demand thereafter and turns the power off when a fault occurs.

In addition to EET protection controlled by the motor, ITS Power Manager's "standard" electronic features* simulate twenty four hour *manual* supervision.

*Gentle (soft-start) Acceleration; Power Line Fault Detection...***including load-side phase loss;**
Locked-Rotor Power Off; Auto-restart when AC Power stabilizes after input Line Fault Events.

Three phase motor operating efficiency sags when load falls to 40-50% of rating and ***substantially*** decreases as demand falls below 15-25% of maximum rated load. Motor efficiency, power factor are optimized when torque is matched to work demand.

Energy saving occurs when unused current is prevented at light loads; a motor's ***self-*** reduction of unneeded magnetizing current maintains efficiency without appreciable change in RPM (and corresponding decrease in flow volume or pressure). Torque reduction, not "speed", is the load-controlled EET variable that conserves energy.

When commanded by a motor, an EET-based "Electronic Supervisor" maintains system operating efficiency with reduced loads. Although fewer watts are wasted during light work cycles, full horsepower remains available for sudden response to load demand... since the motor always runs at its magnetic pole determined, near-synchronous speed.

Power management that lowers operating cost, extends pumping system lifetime and improves operating efficiency does not necessarily involve control of motor speed.

Regarding Variable Speed Drives. Because watts decrease when flow "volume" is reduced, speed-reduced flow is often (and understandably) misinterpreted as an "efficiency" improvement. The confusion disappears upon closer examination.

When pump flow volume decreases, watts reduction can occur even if motor operating efficiency has decreased. After all, lowering the volume of fluid flow by speed reduction literally **decreases** the mechanical work the motor is being called upon to deliver.

Lowering RPM offers does not magically improve a motor's operating "efficiency".

On the contrary, speed reduction by an electronic variable speed drive is frequently accompanied by a decrease in motor "efficiency", an increased percent of watts wasted inside the motor … and an attendant decrease in the useful life of the motor.

Lower watts consumed is NOT synonymous with a higher "efficiency"; it naturally takes fewer watts to do less work. When pump RPM is decreased, lower work-watts may actually conceal an efficiency decrease (pump or motor). Whether accomplished electrically or mechanically, controlling pump RPM does not convey the benefits and efficiency improvement that are offered by motor-commanded "power management."

Key profitability issues of oil field operations are directly and positively addressed by AC motor-current management: "downtime"; "site maintenance"; "capital investment."

Lower man/machine productivity realized by operating AC motors direct-on-line is no longer supportable as a reasonable economic "tradeoff". Solid state control and motor communications technology have progressed to the point where it now costs more ***not to*** manage the "motive (motor) resource" that turns the wheels of oil field machinery.

"Unmanaged" power generates avoidable costs far beyond the pennies/kilowatt it adds to the price paid for energy that is needed to efficiently drive a pumping system.

It is doubly expensive to continuously buy unproductive kilowatts then **pay *again*** for the inevitable damage(1) to equipment caused by unproductive power line current:

- life-shortening heat ... dissipated in distribution wiring and the motors
- frequent motor burnout ... increases "downtime", "maintenance" costs
- equipment replacement ... higher cost of capital to maintain operations

(1) motors and machinery suffer electro-mechanical shock when "hard started" and accelerated wear from unneeded torque produced by excess power line current

It is universally accepted that profit is gained by managing business "resources" and that "resource management" by technology-based machines is cost effective.

Computers that "**consume**" rather than "**save**" energy - ...***pay for themselves***. Their management contribution pays <u>initial and unending</u> costs: (1) hardware, (2) software and (3) the endless chain of human operators we hire and train (and train) to use them.

Unlike computers, there is only **one EET investment** (hardware), **NO** software and **NO** operators to train (all motors know their status and what they need at every moment).

Like computers, EET controls pay for themselves by "resource management".

Additionally, motor-commanded (EET) power managers maintain higher efficiency with light-load cycles; this avoids wasted-watt heat damage ...***plus saves some energy***.

Oil field evaluation of EET-based motor power managers in representative environments with various types of pumping systems will identify the particular applications and operations which offer the fastest return on capital (hardware) investment.

Upon completion of the EET Field Monitoring project, pertinent performance data will be assessed and a summary report made available to interested parties upon request.

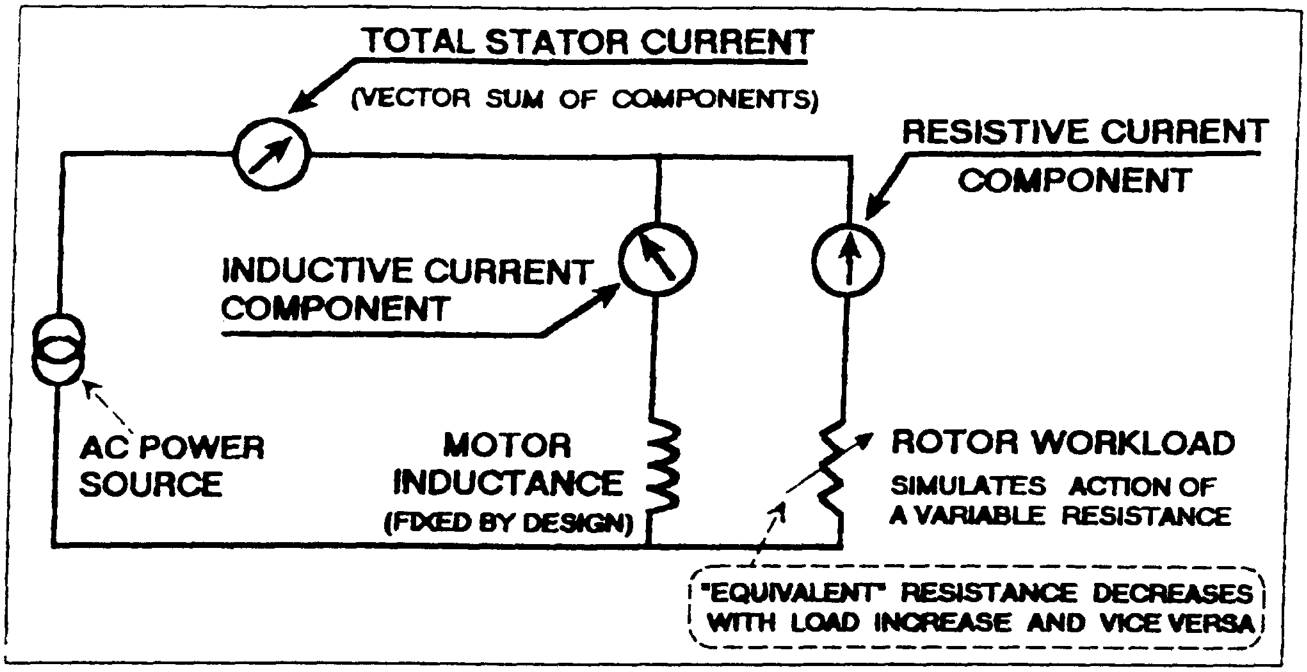


Figure 1 - Induction Motor Super - Simplified Equivalent Circuit

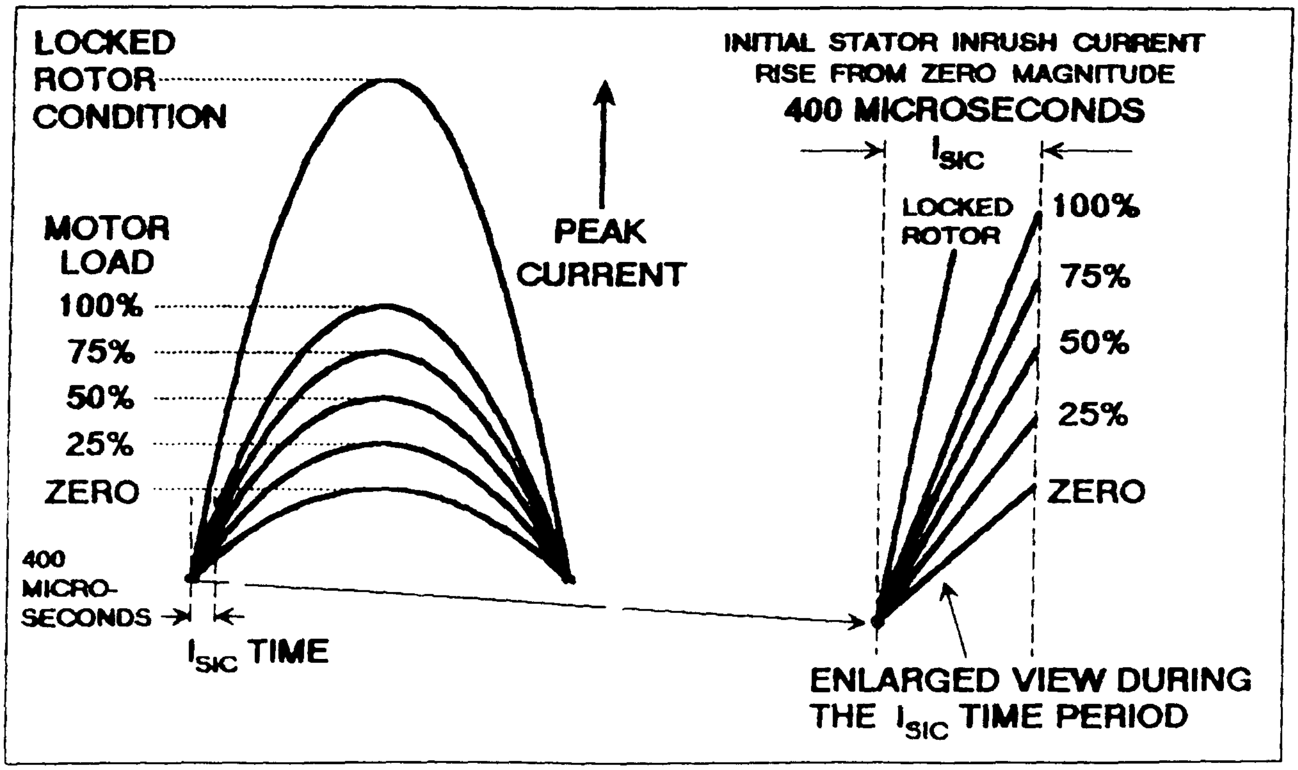


Figure 2 - Stator Current Alternations at Various Workloads

CONVERTING ROTOR SLIP TO A VOLTAGE PULSE

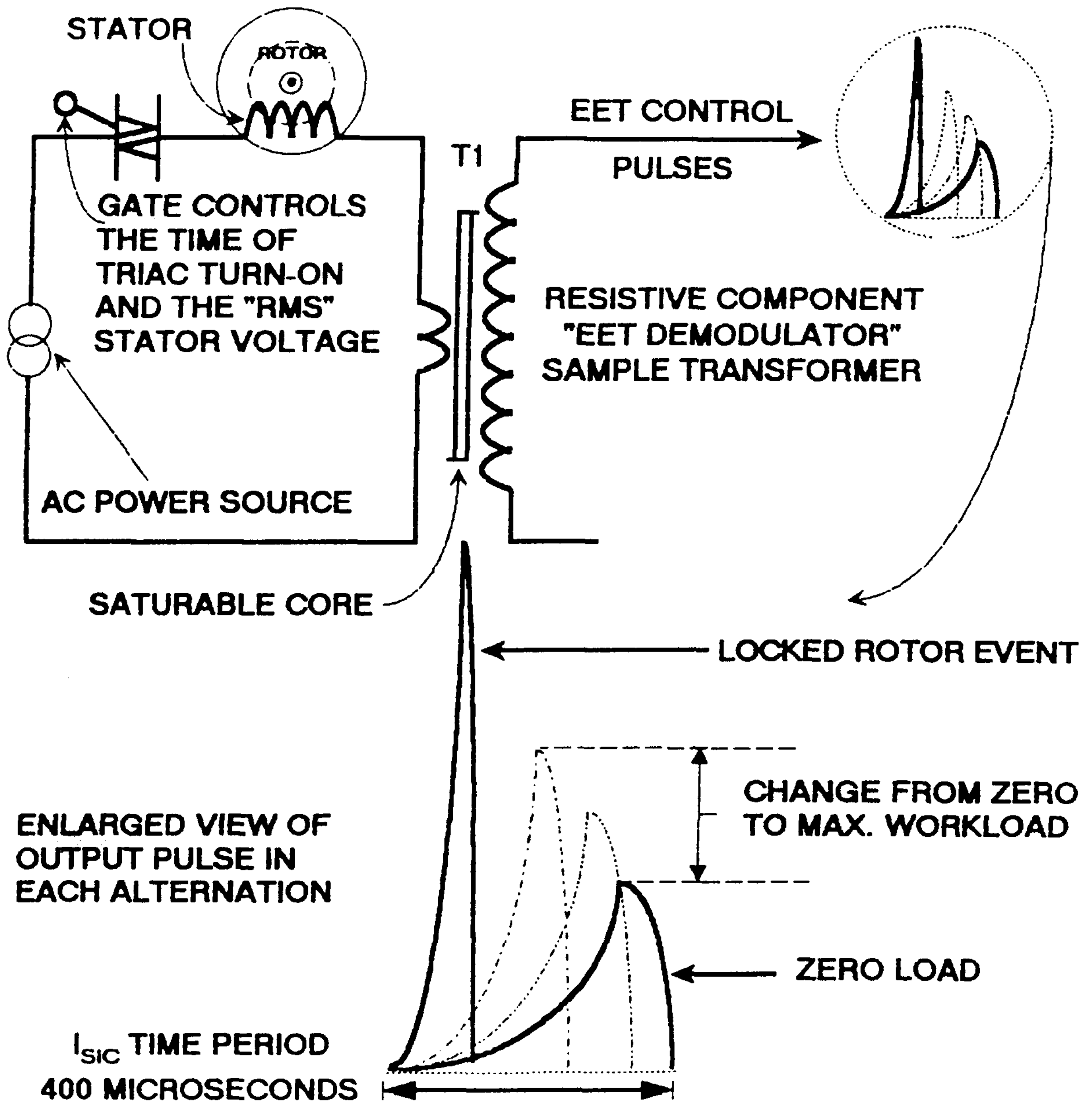


Figure 3 - "EET Control Pulse" Corresponds to the Characteristics of Initial Stator Inrush Current at the Beginning of Each Alternation of Current Flow... and is a Function of Rotor Slip With Full or Switched Partial Sine Wave Stator Voltage
(Energy Economizer Technology Process)

RESISTIVE COMPONENT (EET) CURRENT DEMODULATOR

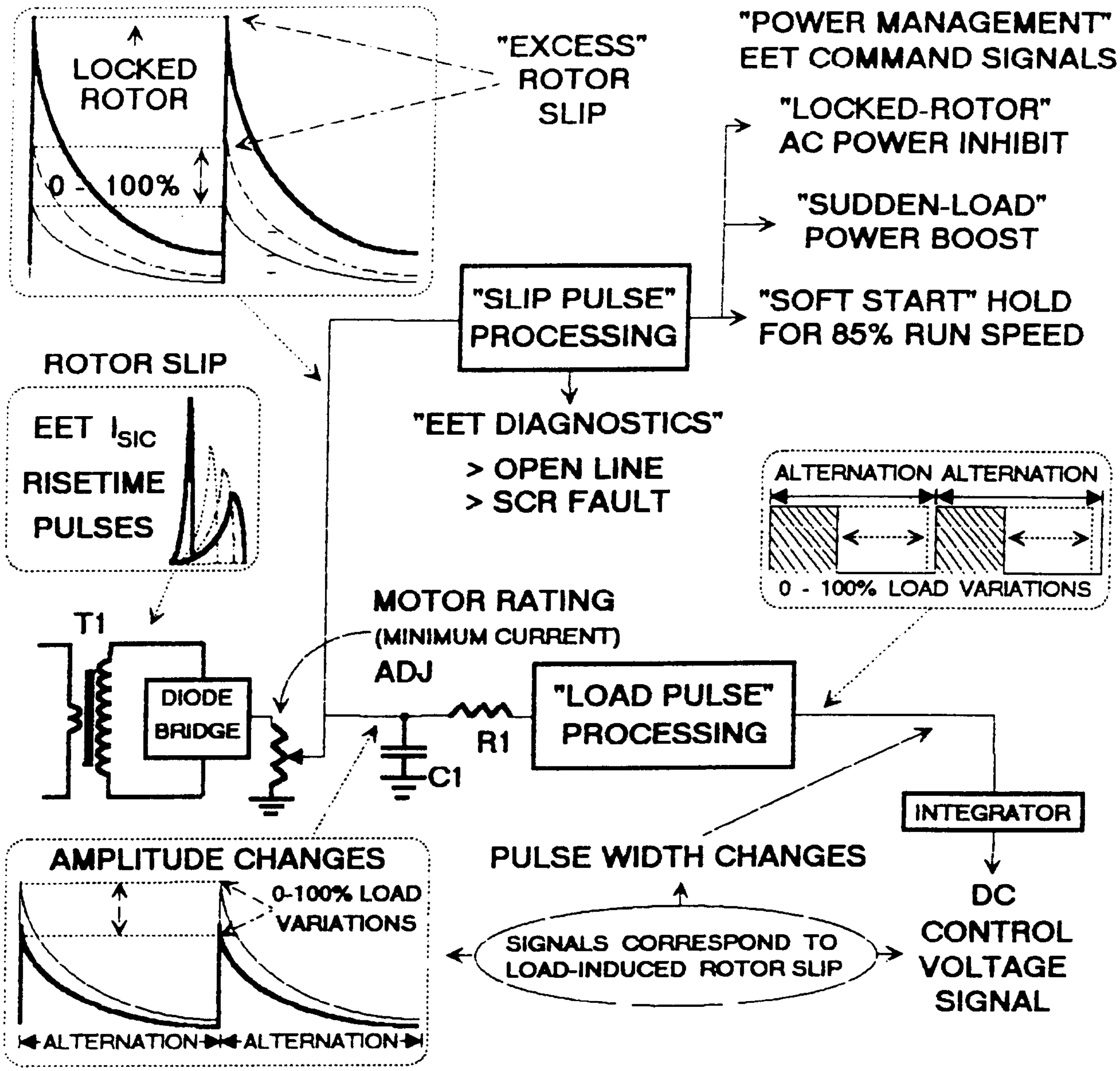


Figure 4 - Operation "Slip Pulse" Charges "C1" in One Isic Time Period (Microseconds). C1 Discharges VIA "R1" in One Alternation Period (Milliseconds). ISIC Amplitude Changes are Converted to Pulse Width Changes. DC Voltage" Changes are Proportional to Workload Changes. ISIC Pulses are Processed into Various "EET Command Signals".
Rotor Slip Pulses Command "Motor Power Management"
Soft Start-Fault Detection-Electronic Protection-Power Saving

EET ENERGY-SAVING "POWER MANAGEMENT" CONTROL LOOPS

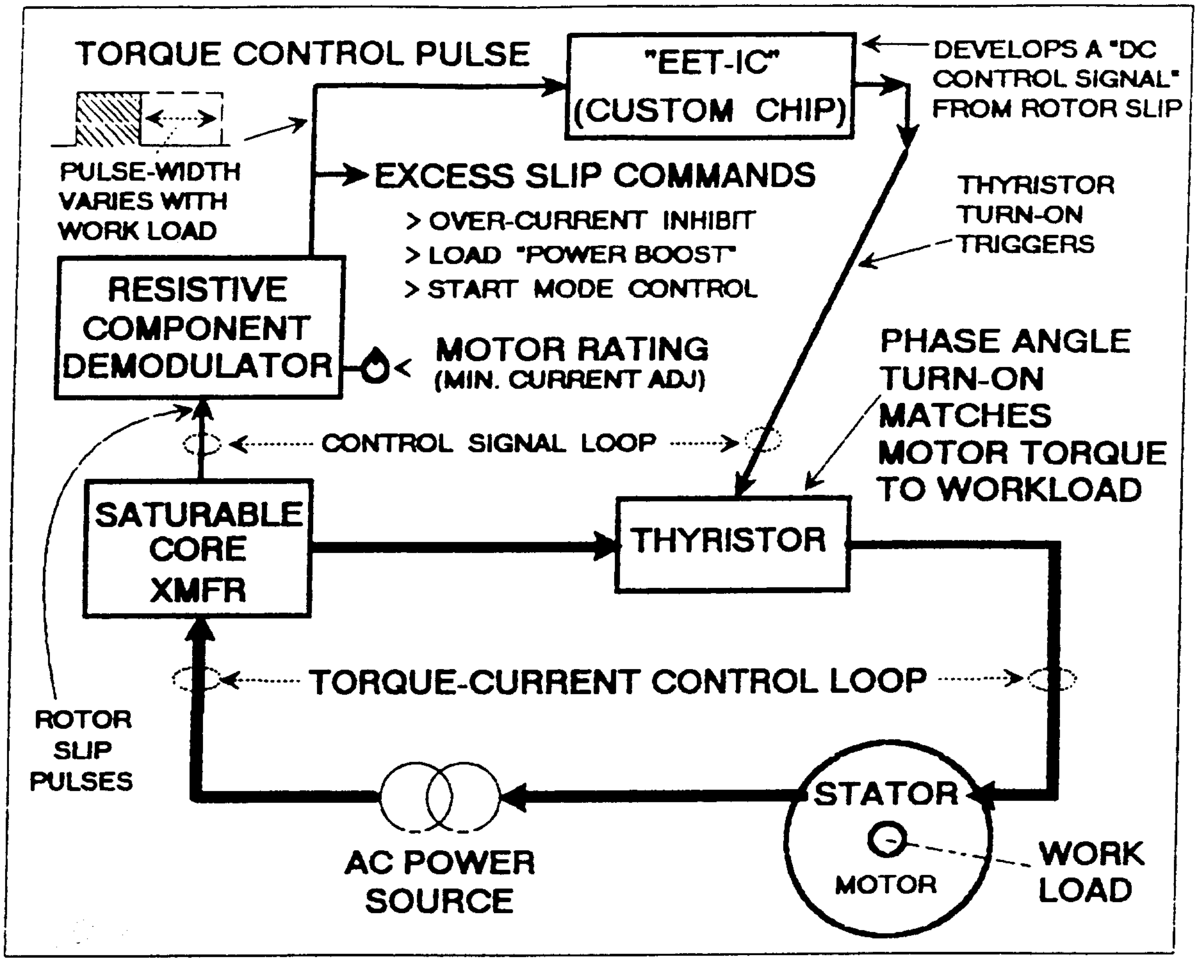
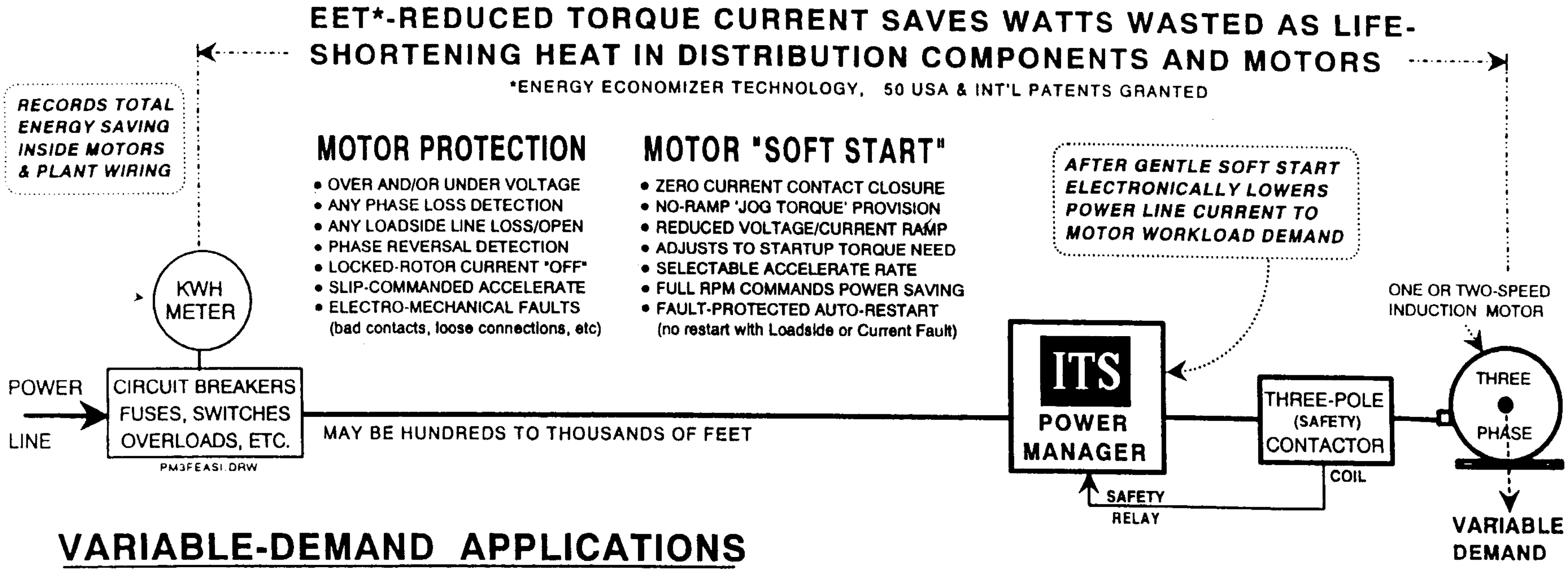


Figure 5



VARIABLE-DEMAND APPLICATIONS

METAL - WOODWORKING - PLASTIC MACHINES
grinders, polishers, shears, sanders, drill presses, Milling, lathes, punch pressess, saws, chippers, etc.

HEATING - VENTILATING & AIR CONDITIONING
cooling tower fans, "VAV" air handlers and exhaust fans, staging pumps and compressors', etc.

GENERAL CATEGORY INDUSTRIAL MACHINES
escalators, elevators, people movers, conveyors, mixers, centrifuges, mechanical and hydraulic presses, crushers, compactors, stampers, staging compressors, tumblers, sewing machines, food processing, textile machinery, etc.

DOLLAR-SAVING PAYBACK

- REDUCED PRODUCTION DOWNTIME
- REDUCED MACHINE WEAR & TEAR
- REDUCED SERVICE/PARTS COST
- EXTENDED EQUIPMENT LIFETIME
- SAVES ENERGY OTHERWISE WASTED

Figure 6