PLC Soft Starter For Induction Motors

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Abstract:

Soft starters of I.M. have been extensively investigated and widely used in industry in the past few years. They offer many advantages over direct on line (DOL) starting, Y-Δ starting, autotransformer starting, or other methods.Soft starters are part of a group of motor control techniques classified as starter voltage control techniques.

The device circuit of any previous work about Softstarter consists of six thyristors connected in back to back. In spite of using a modified switching strategy for the I.M. soft starter to enhance its speed control and starting capabilities, still the main disadvantages lies in harmonic contents of the current waveforms.[1],[6].

To avoid harmonic problem this paper presents a new control technique using PLC by inserting an auto-transformer in the line to the motor, reducing or increasing the voltage at the motor terminals depend on selected taps according to a SW program in the PLC .

This Softstarter has the capability to feel load changes during motor operation, and it changes the driving voltage to a suitable minimum level improved motor efficiency and energy saving are achieved by applying this technique.Moreover PLC gives wide capability to control more than one motor in the same or different time for starting or stopping.

I. Introduction:

Motor under no-load, or which are lightly loaded for most of their operating time, uses more energy than necessary, softstarting is an energy –saving function, and using this the motor voltage can be adapted to the actual load. In this way the power factor and efficiency are improved and power consumption becomes lower.

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Softstarting is the solution for mechanical and electrical problems when starting and stopping motors.[2] Conventional A.C. induction machines have starting currents around 6 to 7 times normal full load when started direct on line or about 3 times on star- delta starting.[3]
Softstarting unit is recommended to reduce starting current as well as to adjust starting torque . Thus eliminating mechanical shocks which result an increased wear maintenance and production down.
Softstarting unit starts with reduced voltage. The voltage rises gradually until it reaches its rated value. Thus reduces torque surges which can be harmful both to the motor and to the mechanism being driven, and also reduces starting current.
Many induction motor starting methods have been developed over the years among the Y-Δ starters, autotransformers, and others.
The most recent starting technique for I.M is the Soft starter, which consists of six thyristors connected in back pairs. A control circuit senses the supply voltage and triggers the thyristors based on a switching strategy to start and run the motor.
A switching strategy is proposed to generate a low voltage, low frequency starting conditions thus keeping V/F almost constant, but still the main disadvantages lies in the harmonic contents of current waveforms.
The aim of each different starting method is to minimize the voltage drop at the motor terminal, the power distribution, utility bus, or provide a softstarting of drive equipment while still providing adequate accelerating torque to the driven equipment.[4],[5],[7].
The PLC , like a computer , employs a microprocessor chip to do the processing and memory chips to store the program. It is smaller , fast acting and more reliable than hardwired relays . Drum switches , timers , counters , are all obtained using software programs.

II. General principles :

The following is a short description of the most common starting methods for motors:

II.1. Direct on line start: (D.O.L)

This is absolutely the most common starting method on the market mainly it employs a contactor and a thermal overload relay , a very cheap starting equipment. the disadvantages of this method is that it gives highest possible starting current , which is approx. 7 times rated motor current. The value depends on the type and size of the motor .During direct on line start the starting torque is also, higher than necessary for most applications. The torque is the same as the force and unnecessary high force gives unnecessary high stresses on coupling and driven application.

II.2. Star-delta start

This is also a relatively cheap solution for starting this type of motors, and reduces the starting current and torque. The received starting current is 33% of the starting current during direct on line start and the starting torque reduces to 33% of the torque available at D.O.L start. This starting method works when the application is nearly unloaded during start. Otherwise, the motor will not have torque enough to accelerate to rated speed, before switching to the delta-position. If the switch-over to the delta-position takes place before reaching nominal speed, there will be high current and torque peaks. These peaks can have the same values as during direct on line start or even higher. The problem is the low starting torque received in the star connection (33%). This is very often too low for many applications. for example when starting up pumps and fans. The load torque is low in the beginning of the start, but the torque for this applications increases with the square of the speed and the motor is not able to accelerate more than approx. 80-85% of nominal speed, with transmission peaks as a result. Applications which need more than 33% torque during start are not possible to be started with this method.

II.3. Soft start

A soft start has a completely different characteristic than the other starting methods. The softstarter is using the fact that when the motor voltage is low, also the starting current and starting torque are low at the beginning of thee starting process the voltage to the motor is so low that it only enables to adjust the play between the gear wheels or stretching driven belts or chains etc. In other words, eliminating unnecessary jerks during the start. Gradually, the voltage and the torque increases so that the machinery starts to accelerate. One of the benefits with this starting method is the possibility to adjust the torque to the application requirement , whether it is loaded or not. In principal the fully starting torque is available, but with a differences that the starting procedure is much more merciful for the driven machinery, with lower maintenance cost as a result.

With the softstarters is also possible to make a soft stop this is an advantage when stopping pumps and conveyor belts, where a direct stop gives problems. The soft stop function increases the stopping time, compared with the direct stop, by feeding the motor with the lower and lower voltage, making the motor weaker and weaker until it stops completly. This function is working best when there is a braking load torque on the motor shaft.

III. System description:

The proposed hardware system uses a drive circuit which consists of PLC with its Software and an auto-transformer.The PLC controls the connection points of auto-transformer then the proper voltage is applied to the motor Fig.(1,2).

The proposed switching strategy presented next is adapted to use a modified technique that can operate with hardware and software to produce different starting capabilities.

IV. Switching strategy:

Research in this area is focused on variable hardware scheme or variable timing scheme , to get start voltage as : constant voltage , linear-ramp , dual-ramp, S-ramp or Square-ramp applied to the motor .

IV.1. Hardware scheme connections:

In this case the software timing will be equal and symmetrical .But the distribution of the connection points along the auto-transformer will be a function suitable for starting voltage required .The constant starting voltage is obtained by a very easy direct connection, no need for the hardware mentioned above. In the case of linear ramp, the connection points would be distributed at equal distances along the auto-transformer. Dual ramp would be the result of two portion each has equal distribution points along the auto-transformer differs than the other one. To achieve S-ramp the connection points have a between distances proportional to [Sin (x)] where x changes from [$-\pi/2$ to $+\pi/2$].

In the square ramp , the distribution of the connection points proportional to the square of reference distances to the corresponding voltage .All different hardware connections are shown in Fig.(3).

IV.2. Software scheme:

The distribution of the connection points is equal and symmetrically along the auto-transformer where the timing software for connection of corresponding point differs from point to another in order to give suitable voltage form for required for starting.

Again with a constant driving voltage there is no need for this scheme.

For linear-ramp, equal duration successive intervals are arranged to realize this case. Dual- ramp depends upon 2 different timing periods. The timing software connections for S-ramp begins with long period intervals, and would be smallest at points n/2 and then becomes more larger every connection step after that of n/2 as in reverse directions to the beginning. Square-ramp timing connection begins with large periods ,and then intervals become smaller and smaller proportional to the square value of [1 to 0.1] in steps of 0.1 Fig.(4).

V. Simulation results:

For the switching process, the machine speed is assumed not to change at the instant of switching.The soft starter will be by-passed during continuous operation, by using a by-pass electronic contactors in parallel with the soft starter. The soft starter is then only active during the start and stop of the motor. A built in signal relay can be used for controlling the by-pass contactor. The by-bass contactor will be closed during continuous run and all current will pass through the contactor. The soft starter can still be active, but will not conduct any current as long as the by-pass electronic contactor is closed.

Fig.5. shows different shapes of starting voltages which includ , linear-ramp(VOLL), dual-ramp(VOLD), S-ramp(VOLS) , Square-ramp(VOLSQ), and also on line start (VOLC) against starting speed.

The comparison would be held for Starting of Currents(CURRC,CURRL,CURRD,CURRS,CURRSQ)(Fig.6),

Torques(TQC,TQL,TQD,TQS,TQSQ) (Fig.7) ,

Accelerations (ACCC,ACCL,ACCD,ACCS,ACCSQ) (Fig.8), versus starting speed corresponding to 5 cases for different control starting voltages.

During a direct on line start (DOL), the motor gives a high starting torque with a result that the motor accelerates and reaches nominal speed too quickly. This starting method (DOL) also gives maximum possible starting current about 7 times nominal rated motor current .

Softstarters reduce the voltage during the start with a result that the motor current and torque are reduced. During the start sequence, soft starter increase the voltage, so that, the motor will be strong enough to accelerate the load to the nominal speed, without any torque or current peaks Fig.(6) , and Fig.(7).Fig.(8) shows a good acceleration in the case for softstarter of different starting voltages.

Fig.(9) shows starting speeds versus time for 5 cases of different starting voltages .It is to mention here that the motor reaches its nominal speed very quickly in the cases of direct on line (D.O.L.) . Dual-ramp (TMD) , Linear-ramp (TML) , S-ramp (TMS) ,and later Square ramp (TMSQ) , starting voltages.

Fig.(10) illustrates the interval of the starting time for each speed , showing large jump of speed in the case of direct on line starting voltages for short interval time (TSC) , but in the other cases slow speed jumping , (TSD,TSL,TSS,TSQ).

A motor running at full speed without load does not need full voltage to keep on running. Softstarter feels when load changes and reduces the voltage to a suitable minimum level .By doing this, the current will be really low when the motor is unloaded , the power factor and efficiency will be improved ,Fig.(11).,Fig(12).

Also, during the stop sequence soft stop is the solution. Soft stop reduces the voltage during stop inverse to soft starting and the motor becomes slower and slower.

VI. Conclusion:

The paper presents a modified switching strategy for the induction motor (soft starter) to enhance starting capabilities. It is based on using PLC for switching strategy on starting and stopping intervals, for control the driving voltages during starting or stopping.

The suggested technique allows the motor to operate under a controlled starting voltage , thus smooth starting via improve current , torque and acceleration behavior.

Moreover it feels load changes and , changes the driving voltage to a minimum suitable level , improving motor efficiency.

Abbreviation:

(1) The first letter/letters will be for the corresponding parameter

VOL-- Voltages
CURR-- Currents
TQ-- Torques
ACC-- Acceleration
TM -- Total Starting Time
TS-- Starting Time Interval / Starting Speed Step

(2) The last letter/letters will be for the each case of starting driven voltages:

--C Constant driven voltage
--L Linear- ramp driven voltage
--D Dual - ramp driven voltage
--S S-ramp driven voltage
--SQ Square- ramp driven voltage

(3) Example : ACCS= starting ACCeleration corresponding to starting S-ramp driven voltage

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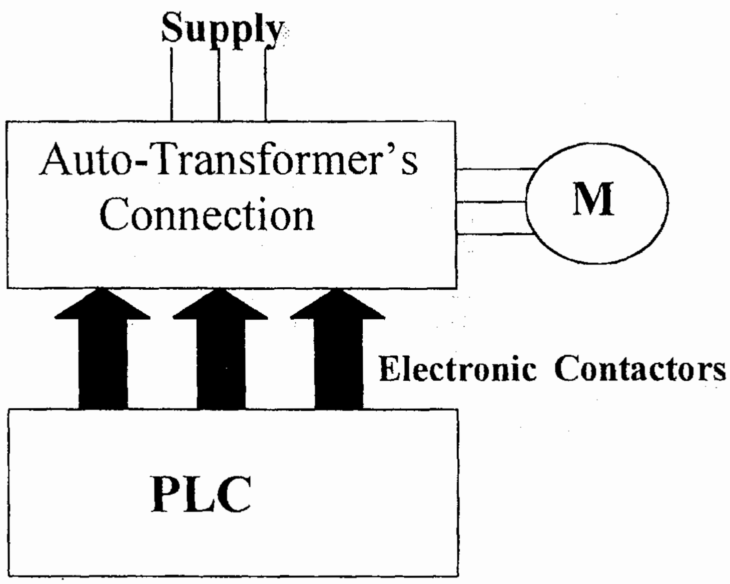

Fig.(1) Block diagram for Soft-Starter hardware

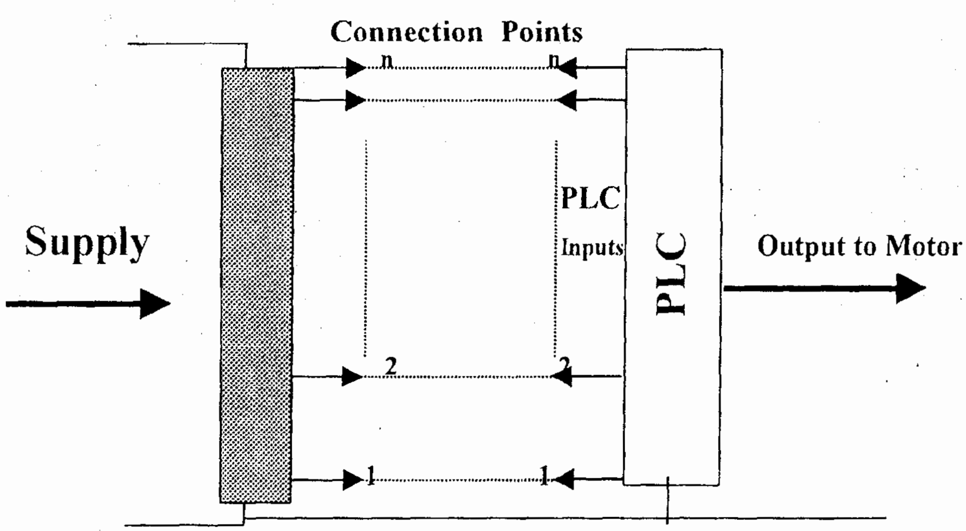

Fig.(2)
Connection for Auto-Transformer's point and PLC

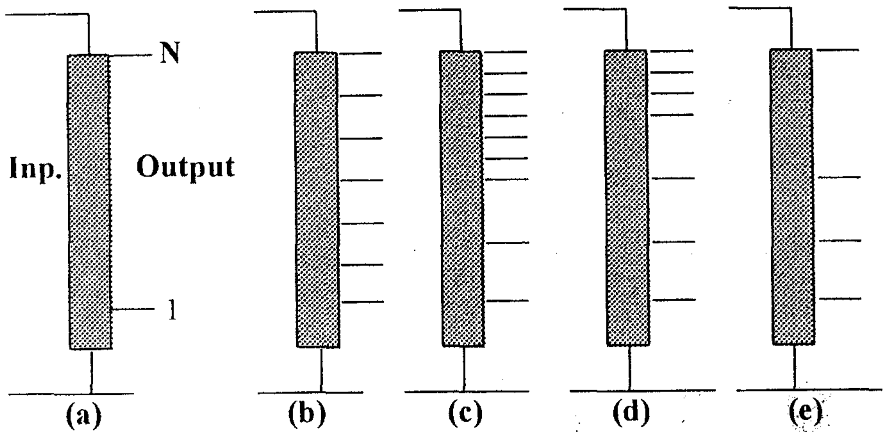

Fig.(3)

Hardwired Block connection for different driven voltages cases

(a) Constant Voltage (b) Single Ramp Voltage (c) Dual Ramp Voltage
(d) S-Ramp Voltage (e) Square Ramp voltage

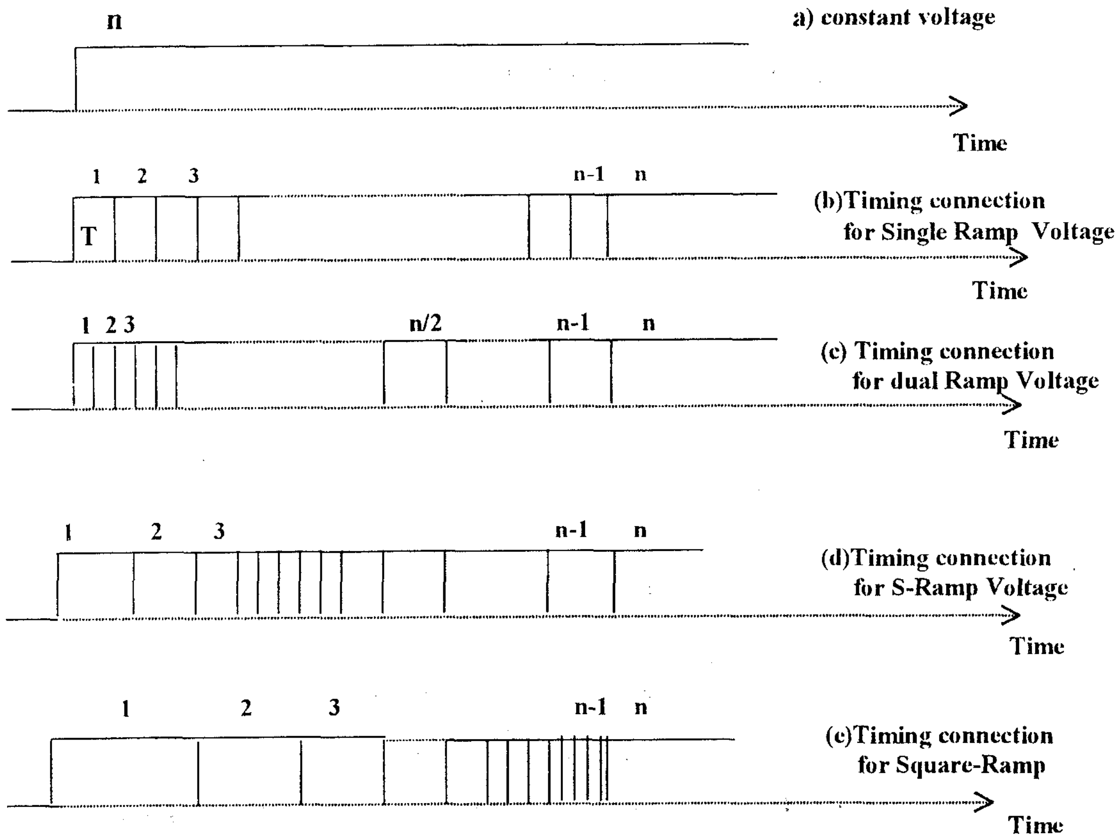

Fig.(4)

Software timing diagram connection for different driven Voltages cases

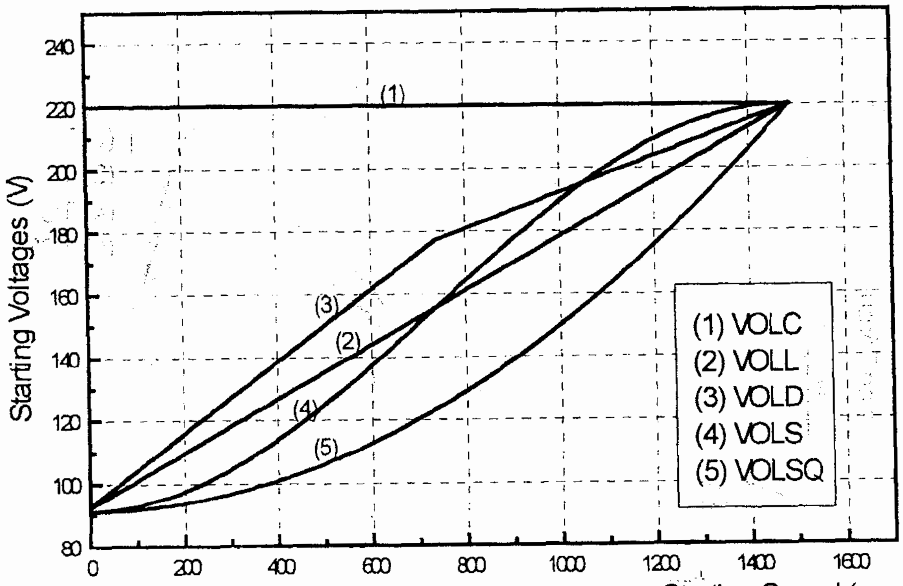

Fig.(5)Starting Voltages shape for Starting Speed

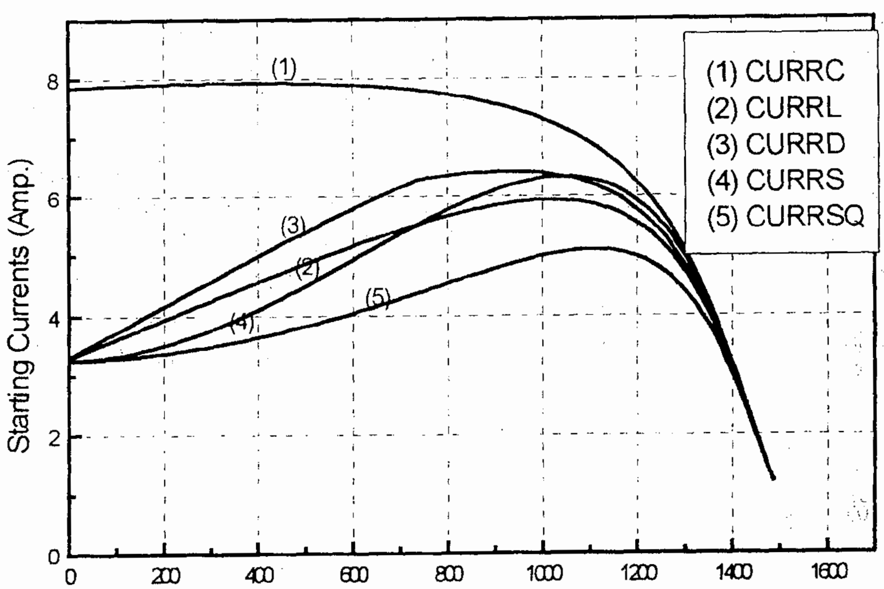

Fig.(6) Starting Currents corresponding to driven Starting Voltages

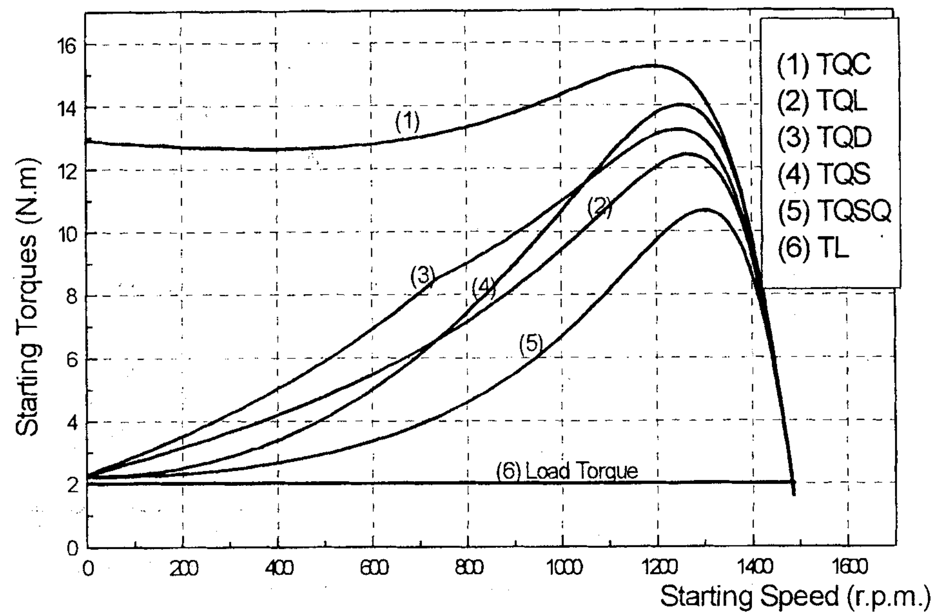

Fig.(7) Starting Torques corresponding to Starting driven Voltages

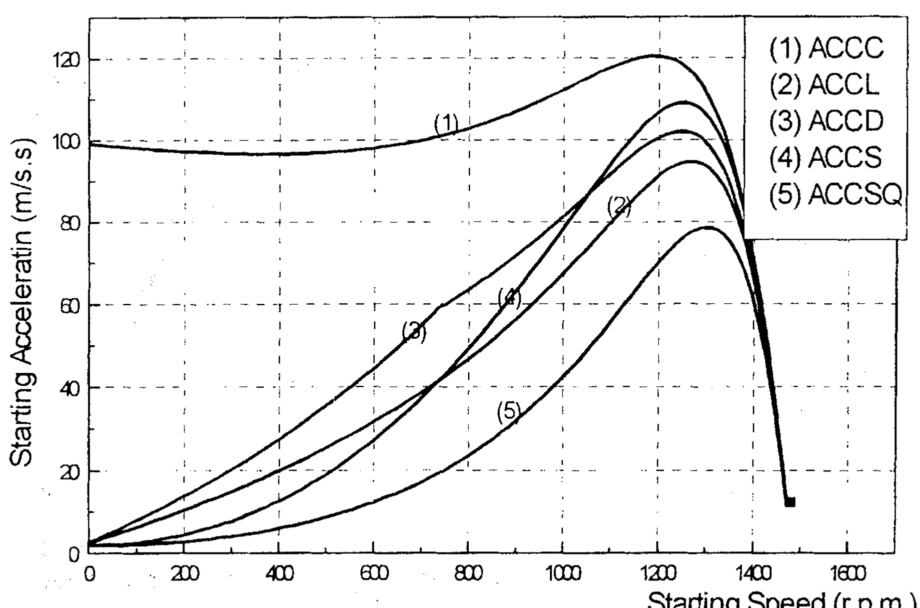

Fig.(8) Starting Acceleration corresponding to Starting driven Voltages

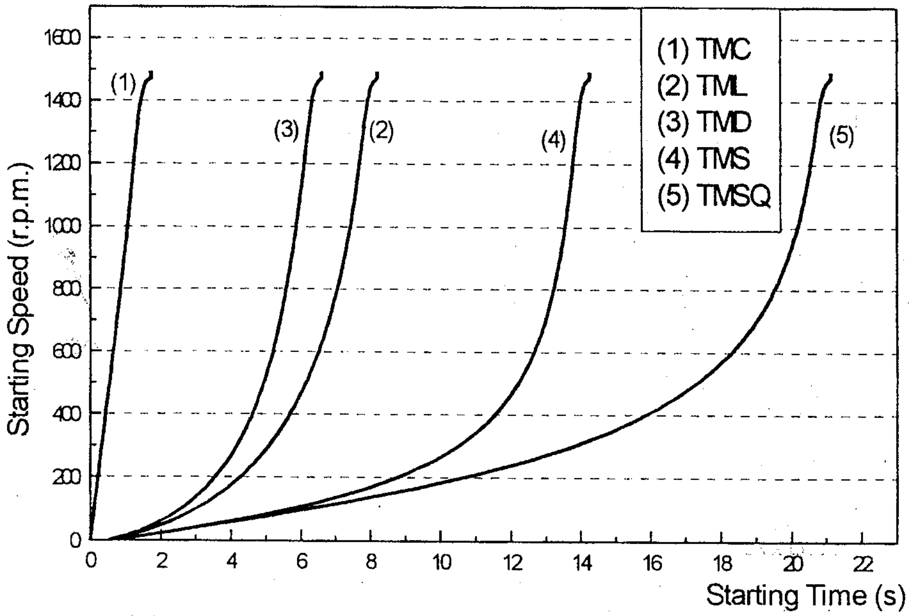

Fig.(9) Starting Speed corresponding to Starting driven Voltages

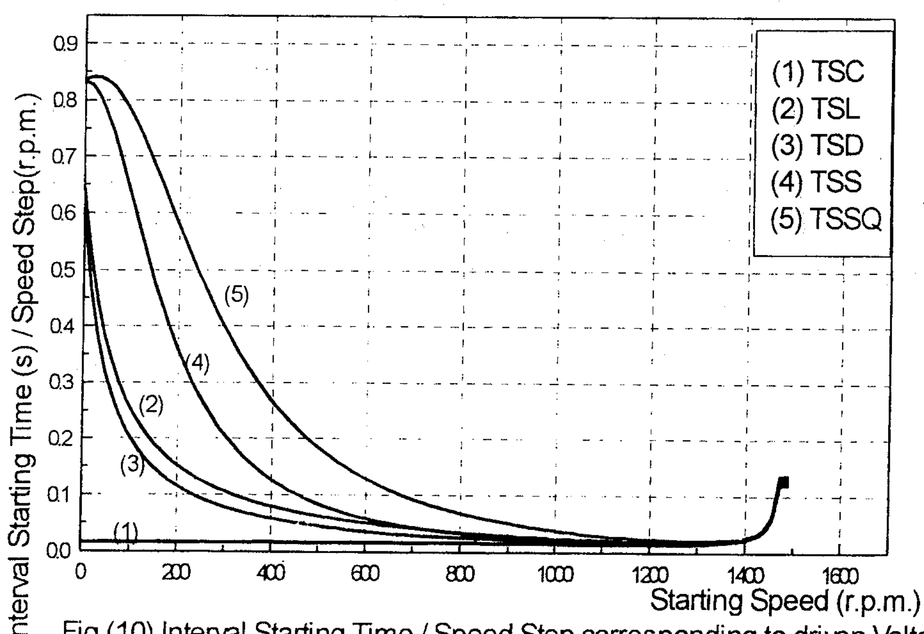

Fig.(10) Interval Starting Time / Speed Step corresponding to driven Voltages

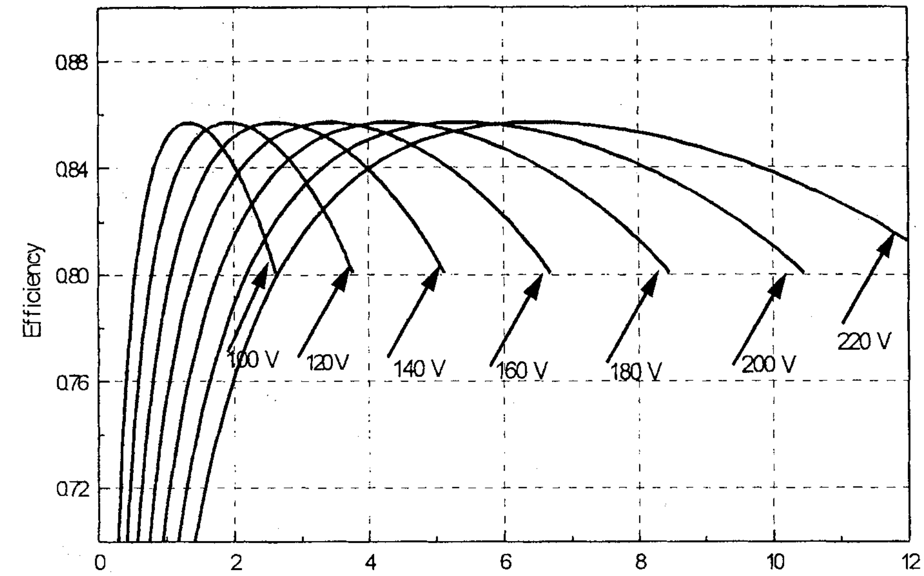

Fig.(11) Eff. corresponding to diff. Voltages

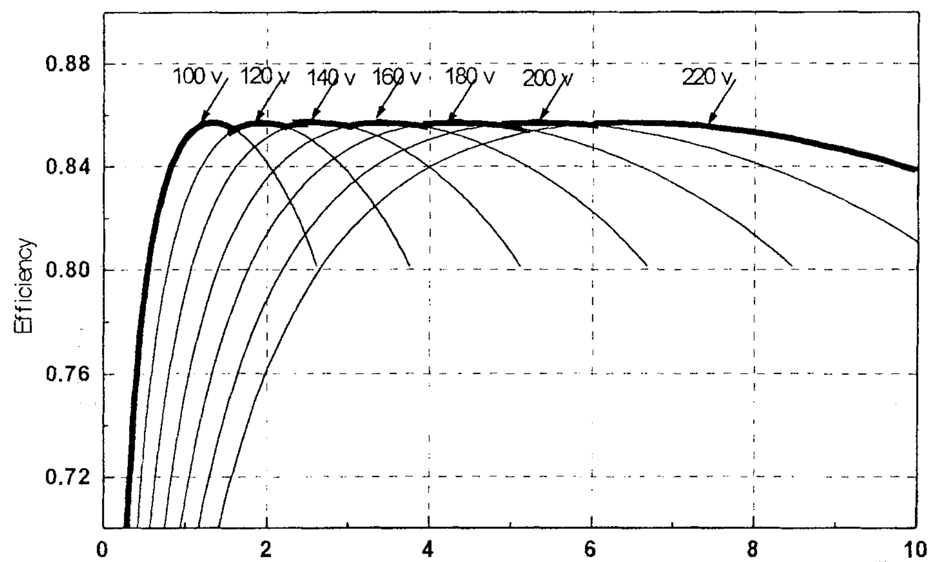

Fig.(12) Eff. versus Torque: (a) uncontrolled Voltages
(b) controlled Voltages

التحكم الرقمي للحصول على بدء ناعم لمحرك

د. عطية السباعي عزام

ينتج عن التغذية المباشرة من المنبع إلى المحرك في بداية الحركة زيادة في التيار تصل إلى سبعة أضعاف تيار الحمل الكامل وكان يتم إنقاص التيار على مرحلتين أو ثلاث مما ينتج عنه صدمات ميكانيكية مفاجئة على عمود المحرك والحمل وكذلك وسيلة الربط بين المحرك و الحمل على اختلاف أنواعها مما يؤثر على خطوط الإنتاج.
و البحث يقدم وسيلة التحكم الرقمي الذي به يمكن التحكم في تيار بدء المحرك بمعدل تغيير طفيف يؤدي إلى بدء ناعم بالقيمة المطلوبة وليس للتيار فقط بل أيضا للعزم، وبمعدل تغيير يناسب طبيعة كل حمل بحيث لا يؤدي إلى أية صدمات ميكانيكية أو كهربية.
ولقد تم بالبحث تجربة أربعة نظم مختلفة بالبدء الناعم كلها تعتمد على التحكم في شكل جهد البدء منها: *التغير الخطي – التغير الخطي المزدوج- ، نظام التغير S- نظام التغير التربيعي* – و أعطت نتائج مناسبة للبدء الناعم للمحركات.
كم أنه يمكن استخدام بادنى الحركة أثناء دوران المحرك بالسرعة المقننة له وعندما يكون الحمل أقل من الحمل الكامل بأن يتم تخفيض الجهد المسلط على المحرك كلما نقص عزم الحمل و هذا يعطى كفاءة عالية للمحرك ويحسن أداءه.