Comparative analysis of stepper motors in open loop and closed loop used in nuclear engineering

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***Abstract*— There are many uncertainties concerning the dynamic system of a stepper motor, which shows a precision control methods increasingly lower. The purpose of the study is to highlight the phenomena observed when SM control is used both in the loop and the loop, including the accuracy of the increased speed of the stepper motors. Due to delays in the closed loop, feedback analysis is not accurate and the terms subsequent incremental depending on the position of the closed loop dynamics. This paper will conduct a comparative analysis of the effect of the closed loop and open loop for stepper motor with permanent magnets used in nuclear engineering. Nondestructive examination main equipment used in the ICN Pitesti consist in universal machines controlled by stepper motors. Applications stepper motors are restricted to situations that do not require high power (usual powers between fields microwatt and kilowatt).**

Keywords— step motor; closed-loop, open-loop; stepper motor

I. INTRODUCTION

In this paper is briefly discussed a comparison of open loop and closed loop control. Stepper motors are a growing category. With the help of improvements in the control systems based on microprocessor and help their development in power electronics, stepper motors are widely used for a variety of applications [1].

Stepper motors are used in low power applications characterized by rapid movements, precise, repeatable. These are used in nuclear engineering because of the presence of a wide range of frequency control, a precise positioning and high resolution and conversion ensures uniqueness number of pulses away and therefore can be used in open circuit (open loop without measuring and automatically adjusting angular position).

In the second part of the paper was presented the open loop controlled SM analysis with the analysis of the start / stop signal characteristics, the acceleration and deceleration capability and the acceleration and deceleration time capability. In the third part of this paper was presented a comparative analysis of SM control in open loop and closed loop with techniques for detection of alternative position. In the last part the closed loop SM analysis was presented.

II. THE ANALYSIS OF STEPPER MOTOR (SM) CONTROLED IN OPEN-LOOP

Early design of the system are concentrated of performance and the steady state of SM. The choice of SM and drive circuit is given mainly by the maximum permissible error (MPE) position and the maximum rate necessary step. The aim is to show that system performance can be maximized with costs minimized by proper selection of the control system and techniques for interference [2].

A system block diagram for a typical open-loop control is shown below. Digital phase control signals are generated by the microprocessor and amplified by the drive circuit before being amplified by the motor.

Whatever source, the designer needs to know what restrictions are imposed with regard to timing control signals of the drive parameters, and load motor. Some restrictions result from steady state performance. If the system has a high inertia, for example, the maximum rate can not be achieved instantly step, the step rate should be gradually increased to the maximum so the engine has enough time to accelerate [3].

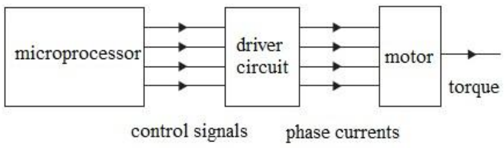

Fig. 1. Open-loop control with microprocessor

In an open-loop control system there is no negative reaction and therefore need the engine to correctly answer each change of excitation. If the excitation moves are made too fast, the engine is able to unfold the rotor to the required position and therefore there is a permanent error in the load position with the position expected by the regulator. Phase timing control signals for optimal performance open-loop parameters are appropriate when the load is constant in time [4]. However, in applications where the load fluctuating time must be chosen for the worst conditions, in which case the control scheme is not optimal for all other tasks.

A. The characteristic signal for start/stop

The simplest form of open-loop control is constant step rate, which is applied to the motor until the load reaches the desired position. Excitation sequence generator for producing phase control signals and control pulses is triggered by a step at a constant frequency clock. This clock can be activated by the signal START, causing the engine to operate at a speed equal to the clock frequency step and stopped by STOP signal, in which case the engine is off. Initially direction is sent to the excitation sequence generator, which then produces the phase control signals to start the motor in the appropriate direction. The position is loaded in a downcounter, which keeps a record of the steps you order, and the clock pulses are fueled generator phase sequence and the downcounter. Phase changes are made to the constant frequency, and the instantaneous position of the engine relative to the target registered in the downcounter. When the load reaches the target, downcounter zero passes and zero generates the clock signal STOP [5].

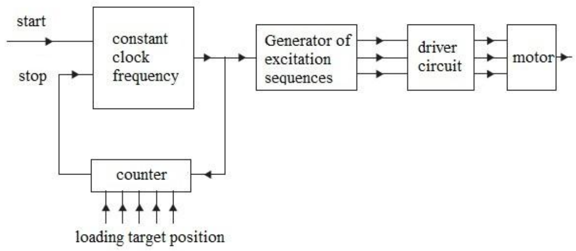

Fig. 2. The step rate constant open loop control

If constant clock frequency is too high, the engine is able to accelerate at the appropriate step, and the system is not working at the beginning of the shift or lose its steps. The maximum rate at which the engine can react step without losing steps is known as the "pull in installments". Similarly "stopping rate" is the maximum rate that can be switched the step and stopped abruptly without using the engine exceeding the target position[6].

B. Acceleration/deceleration capability

Overall rate of starting a system with SM is much lower than the "pull-out" so that positioning can be substantially reduced by further accelerating the engine over several steps until the rate of "pull-out" is reached. When the position is reached step rate, this rate is gradually reduced to on / off, so the engine can be turned off when it reaches the end position. The graph rate step function of time, as the engine moves from the initial and target positions is commonly referred to as "velocity profile". It should be noted that the rate of deceleration can be significantly faster than speeding up because the load torque tends to delay the system and the motor is able to develop more torque deceleration than acceleration [7].

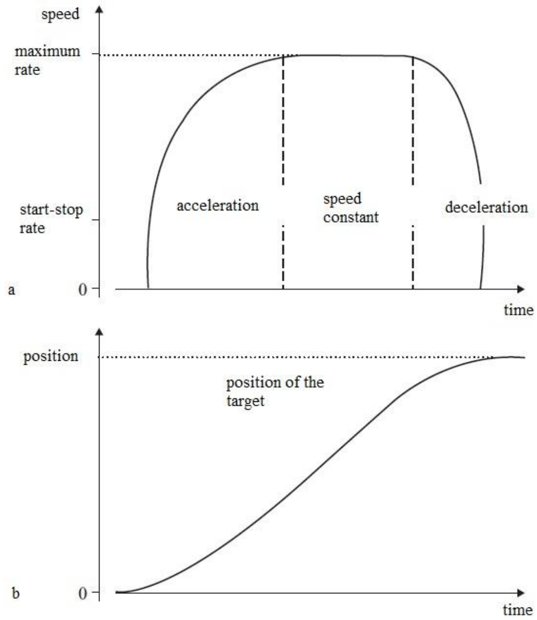

Fig. 3. Acceleration and deceleration target position

a. The speed profile

b. The appropriate response position / time

It has established the relationship between system parameters and the ability acceleration / deceleration. Majority of the sophisticated methods of open-loop control, allows the system to approach the "pull-rates", therefore, the dependence of the rate of engine torque step to be taken into account. This is done quite easily by using the engine characteristic torque / speed as the basic unit for analysis. Variations in load and friction torque speed can be considered [8].

With a chopper driver circuit, current control circuit will be ignored at the right time to ensure increased blood continuously. In these conditions below using the following circuit can be useful [9].

C. Increase the capability of acceleration / deceleration time

The rated current of a winding of the SM is measured as an increase in the allowable temperature where it is continuously excited. This occurs only when the engine is stationary; if the motor is in motion, the phases are in order and exit any winding is energized for only a fraction of the cycle. In this sense, the engine is rotating windings currents can be adjusted until it reaches nominal extra heat generated when the stage is set to be dissipated later when the phase is off. While the SM is magnetically saturated at a rated current higher currents can further improve the torque and the rise and fall time.

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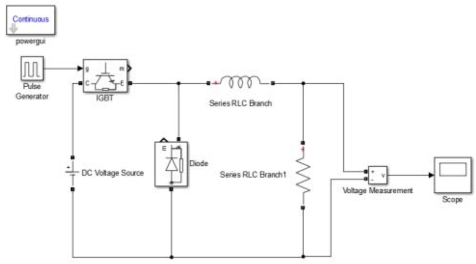

Fig. 4. Chopper circuit simulation in Matlab

The circuit operates by storing energy in the capacitor C, which can be quickly evacuate the phase windings when additional torque is required. During normal operation, the transistor is open. Values of both capacitor and resistor must be chosen carefully.

First capacitor size is dictated by the phase current. Large phase currents and long pulse times require higher values of capacitors. R Resistance limited in supply additional current to charge the capacitor when the transistor is open. If the capacitor is completely discharged, high resistance reduces the charging current due to the initial current is Vdc / R [10].

III. THE ANALYSIS OF SM CONTROLED IN CLOSED-LOOP

In the light of analyze the open loop control and the closed loop of the above, it should be taken into account and the relationship between them.

There can be no doubt that SM has achieved prominent current market position due to the simplicity with which it can be controlled in open loop. It is suitable for many applications using open loop control in exchange for control of closed loop which is quite expensive. However, the high cost of closed-loop systems is assigned to a lower developing markets. If the reliability of the two methods is compared control, closed-loop control starts to look very attractive because it eliminates many of the problems associated with open-loop control (magnetic Resonance, changes of load). It is ironic that an incremental optical encoder is expensive - often used by some designers to verify the open loop business systems. Election systems in closed loop or open loop does not present a major difference when engine torque is envisaged. With the open-loop control, the speed of operation is set by the phase control signal and the switching angle varies automatically until the engine torque corresponding to the load torque. However, the closed-loop system, the angle switching is determined by the controller, and the engine speed varies until it matches the load torque. This difference is significant when the engine is at maximum torque and any small increase in load causes the system open loop to hang, while the system closed-loop slows to a lower speed resulting in the system open loop is unstable, in exchange for the closed loop is stable.

For this reason, open loop systems are rarely used to operate in situations where the engine produces a maximum torque so that the engine is under-utilized. Closed loop control is the right choice SM is used in complex applications where use is more important than cost.

IV. COMPARATIVE ANALYSIS IN OPEN-LOOP AND CLOSED-LOOP

In an SM system with closed-loop rotor position is detected and fed to the control unit. Each order is issued only when the engine has satisfactorily responded to the previous command, and the result is that there is no possibility of losing synchronism engine. A closed loop control scheme is shown in the figure below. Initially, the system is stationary, to one or more of the excited phases. Counter is loaded into the target position, a START pulse signal is applied to the control unit gives a command to step the phase sequence generator. In these circumstances, there is a change of excitation and engine begins to accelerate at a pace dictated by the task parameters. As a first step in finalizing the position detector generates a pulse signal which is sent to both the numerator and the control unit. By controlling open loop there is no guarantee that the steps were executed due to counter the number of steps that were registered only sent to the engine. By controlling in closed loop, the counter records the actual position of the load.

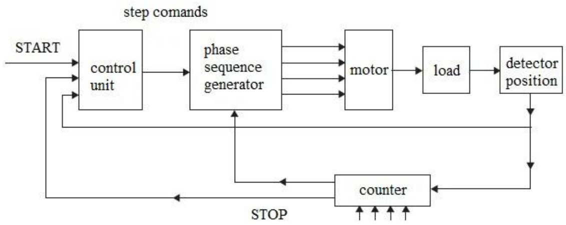

Fig. 5. Closed loop control of an SM

Therefore, a closed loop control to match the time of excitation by the load conditions. Optimal speed is achieved with a fast positioning of the load. For most users the most important feature is that the loading position is monitored directly so that even in the worst load conditions there is no possibility of loss of synchrony between orders of steps and position of the rotor.

Techniques for detection of the alternative position

Optical incremental encoder is conventionally used in the detection of the rotor position in a closed loop system can be expensive and has gained a reputation for poor reliability. It proposed a series of position sensors capacitive and inductive sensors built into the motor, but none had a commercial success.

A block diagram of a system for detecting the closed loop waveform is shown in Figure below. The currents are monitored by measuring the voltage drops on the resistors connected in series with the windings. A waveform analyzer processes signals from the pulse voltage and returns to the control position to the required position.

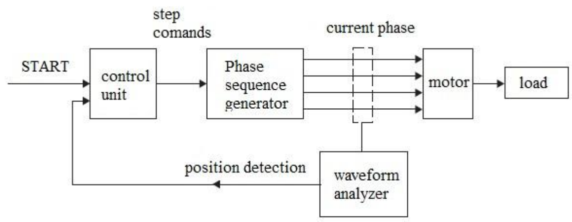

Fig. 6. Closed loop control by detecting the waveform

Detection system using voltage waveform impairments is unable to operate successfully at low speeds. In an attempt to overcome these limitations was introduced a new technique for detection of the waveform based on the phase inductance variation with rotor position. Inductance variation is present in all types of SM. The most convenient system used in which these effects is driver operated chopper type, where the current changes continuously within a well-defined. The figure below shows a waveform of the chopper's current typical behavior of a transistor switching control for the amount of phase excitation the motor moves by one step. In the first part, the inductance is high, so changes are made slowly.

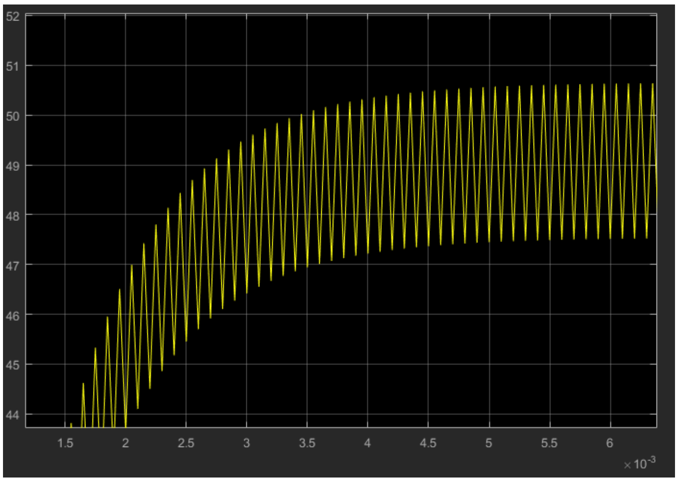

Fig. 7. Chopper operation simulation in Matlab

As the rotor moves towards completing the process, inductance winding down, allowing current changes fast and consecutively. The rotor position can be detected using synchronization circuits in examining chopper's behavior.

V. Conclusion

In this paper an open-loop controlled and closed loop control comparison was discussed. The role of this comparison has been made to show which type of control is more effective in SM applications with very good accuracy. This comparison has proven to be much more effective in closed loop control because the SM is used to obtain much better accuracy. The role in future research is to use a more precise control to avoid step losses in non-destructive measurements in the nuclear environment.

Acknowledgment

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