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Written-Pole Motor – A Mini Review

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Abstract: Electrical motors are used as drives in most of the industries. There is a progress in electrical motor technology in terms of design, new materials and performance characteristics based on the applications. The written pole motor is yet another alternative for certain specific applications. In this paper, an attempt is made to review the principle of operation, constructional features, operating characteristics, applications of written pole motor along with cost. The written pole motors permit flexible load available on an electric utility. It easily accelerates back to synchronism without excessive inrush current after a short power interruption even at rated load. These motors assure quality power and ride through from utility sags and surges. The motors also avoid harmonics of higher order. The discussion presented here also includes the protection to the utility consumer from reclosure and other operation for reliable utility operation. The paper highlights the potential application areas at present and future trends.

Keywords: Efficiency and Interruption; Ferrite; Re-magnetize; Ride through; Torque; Written-pole motor.

1. INTRODUCTION

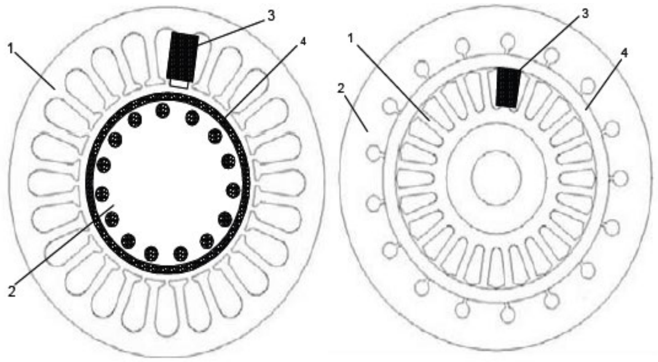
The current practice to change the speed of an electric motor is by changing the winding connection pattern. The variable speed can be obtained by changing the winding connection that depends upon the number of poles. This involves bulky winding arrangement and also having limited number of options. There is a need to get wide range option possibilities for number of poles. In written pole motor the poles are created (written) by design. Thus, it is a constant frequency variable speed machine. The smooth starting characteristics of written pole motor is a merit and demonstrated by developing three phase written pole motor by Precise Power Corporation, Florida, USA [1].

Written pole motors are used to extend assured quality power and ride through from power sags, swell and interrupt for remotely placed weather radars and different aviation loads. The construction of written pole motors consist an external rotor to take care of rated load in the case of a rated voltage interruption for period up to 15 seconds by continuously repeated magnetization of the ferrite layer when rotor speed reduces. Once the full voltage is resumed, the motor takes low current to reaccelerate the rotor [2]. The high inertia rotor is used and provides long run-up time to reach synchronous speed. This behavior will reduce the run-up torque when sudden load on the motor is applied. The manufacturer claims that “squared”-type loads can be easily connected to this type of motor. Squared loads include many agriculture and pumping applications, such as irrigation loads and agriculture implements. Since the motor can ride through short power discontinuity and reenergize with smoother run-up torque, water hammer can be minimized in pumping system applications [3].

2. CONSTRUCTION FEATURES OF THE WRITTEN-POLE MOTOR

The motor frame is constructed of ductile iron or aluminium castings to have maximum durability. The stator stack is laminated with laminations constructed using low loss electrical steel having oxide coating. The windings are constructed using suitable copper wire which gives reliability over long period with suitable windings having surge resistance. The windings design procedure of written-pole motors is similar to that of a conventional induction or synchronous motors besides functionality. On application of voltage the current flowing in windings produce magnetic field rotating at synchronous speed. The use of excitation winding is placed around an exciter pole placed at one or two locations of the stator is the special feature of written-pole motor. There is a magnetic coupling between the excitation winding and the adjacent stator windings to obtain energy for operation and eliminates the need of external energy source [4].

The induction, hysteresis and permanent magnet principle is used to construct the rotor. The basic platform consists of a conventional steel shaft. This is inserted into laminations stack of a rotor cage having high resistance. The quality of the laminations used in the construction of the rotor is same as that of the stator laminations using good grade steel material. The



(a) (b)

Figure 1. Construction of a written-pole machine: (a) with inner rotor (b) with outer rotor.
1. Stator, 2. Rotor, 3. Stator exciter pole, 4. Rotor ferromagnetic layer. Curtsy Precise Power Corporation, Palmetto, FL, U.S.A

machine can be found in two arrangements one with inner rotor and another with outer rotor as shown in Figure 1.

The centre portion of rotor makes use of high grade lamination having high resistance cage made up of carbon steel bars along with end rings. The high slip and high power factor during starting can be obtained by suitable cross sectional area and resistivity of the rotor cage.

The active surface of the rotor is coated with a magnetic material layer. The material composition is highly anisotropic SrO·n Fe2 O3 and the thickness is ranging from 15 to 30 mm with oriented direction based on the size and capacity of the machine. The ferrite material used in the rotor appears similar to the magnetic material found in conventional permanent magnet synchronous motors to achieve and maintain its magnetization throughout the normal range of operation. While the machine is in operation, the exciter pole will magnetizes magnetic layer in the required pattern [5]. A little literature is available and reveals that there is an effort to present the construction, working principle and functional parameters of three phase written-pole motors and the analysis is quite complex. To address the electromagnetic phenomena, the use of finite element related software will help in modeling the machines to analyze for finer aspects [6, 7].

3. STARTING CHARACTERISTICS

Three modes of operations viz start; transition and run are possible with written-pole machine based on the speed of the machine. In starting mode, the motor starts accelerating to reach the rated speed and will develop large amount of hysteresis and induction torque. The hysteresis torque is the result of the magnetic field due to stator, which is strong to magnetize ferrite material placed on the rotor to produce useful torque. The properties of rotor cage determine the magnitude of starting current and induction torque produced in this mode.

In transition mode excitation winding begins to influence the magnetic geometry of the rotor. In this mode motor attains electrical synchronism allowing it to produce synchronous torque though it is not running at synchronous speed. The current in excitation winding changes with one complete positive and negative cycle. An alternating field is produced. This induces pair of north and south poles on the magnetic layer which is present on the rotor. The rotor accelerates developing maximum torque to synchronous speed is due to the phase relation between the poles induced and the rotating field of the stator.
These poles form proper combination of electrical and mechanical phase angles to develop the torque irrespective of the rotor speed or prior pattern of the pole. This results in getting the magnetic pole pattern developed by excitation winding rotating in electromagnetic synchronization with the field of the stator windings though it is not physically rotating in synchronism with stator field.

In case of mismatch of magnetic material polarity passing under the excitation winding and polarity of magnetic field set up by the excitation winding. The polarity of the magnet is changed in reverse direction to suit the field produced by the excitation winding. Large number of smaller poles with shorter spans is produced during low speeds. At higher speed smaller number of larger poles having larger spans is produced. This concept is similar to the continuous tape looping in a recording system.

The excitation winding is so designed to control the phase angle between the current used for excitation and the current flowing in the stator winding. This will set up the torque angle between the poles of the rotor and the rotating field produced by the stator. This phase angle helps to attain maximum torque available during the transition period or to provide leading power factor operation at the highest specified load. Written-pole motors switch over to run mode upon attaining its specified synchronous speed. The charging of excitation winding is turned off as it is not required in this mode of operation so that the motor continue to work as synchronous motor with permanent magnet arrangement [8]. The written-pole motors develop large synchronous torque below the synchronous speed as shown in Figure 2.

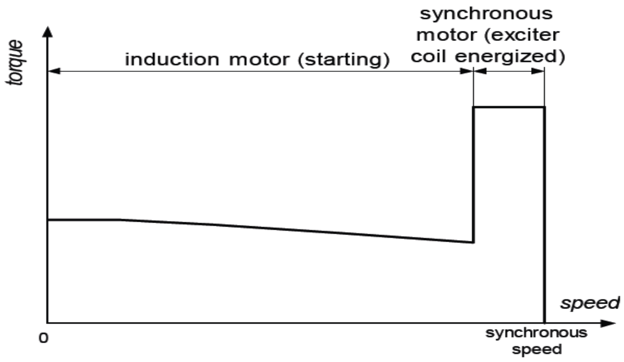


Figure 2.Torque vs. speed characteristic of a written-pole motor

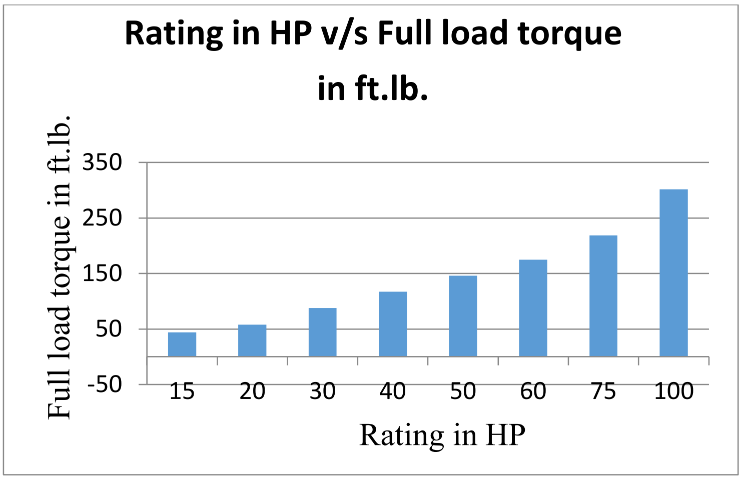


Figure 3. Specifications of 1-φ written-pole motor
Curtsy Precise Power Corporation, Palmetto, FL, U.S.A.

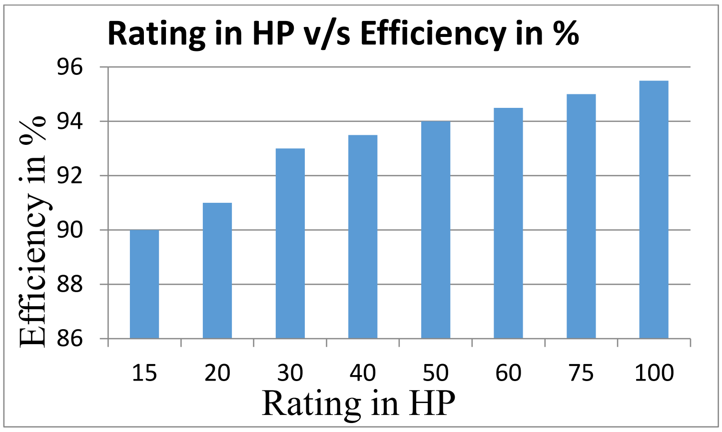


Figure 4. Rating in HP vs. efficiency in % for 4-pole, 240 Volt single-phase written-pole motor
Curtsy Precise Power Corporation, Palmetto, U.S.A.

4. SPECIFICATIONS AND PERFORMANCE

Precise Power Corporation, Palmetto, U.S.A. is in to the development and manufacture of single phase written-pole motors and can develop high starting torque per ampere. Single phase ratings of written-pole motors TEFC can be in the range of 15 to 100 HP. It can start with high inertia loads. The full load torque for different rating motors is shown in Figure 3.

It is learnt that the starting current of written-pole motor is 1/3 or less than that taken by same capacity induction motor. Single phase applications recommend the use of written-pole motors as the starting current is relatively low. Many utilities insist starting current restriction on large single phase motors, typically when the associated voltage drop is more than 3%. The efficiency of written-pole motors is relatively high. Figure 4 depicts efficiency in % for different rating motors.

These motors also yield many desirable characteristics such as starting line current of lower magnitude, operation at UPF and relatively higher power factor at the time of starting, which gives smooth start, low harmonic content and instantaneous restart after momentary power interruptions (MPIs). This eliminates flicker and line voltage sags. Hence, 1-φ written-pole motors are preferred for applications in villages having single phase reticulation systems [9].

A prototype written-pole motor exhibits exceptional operating efficiency with the reported value of efficiency of 94.2% at full load and 94.5% at 115% of full load. The motor efficiency is high and power factor is nearly unity when it operates at rated load and the temperature rise is within the limits. Because of increase in friction and windage the external rotor design suffers from decrement in efficiency of approximately 2% [10].

5. TARGET APPLICATION AREAS

The installation of electric motors virtually eliminates harmful emissions at the irrigation site, while typically reducing the user's energy costs by more than 60%. Certain rural applications require high output power motors capable of operating on single phase power supplies, e.g., oil fields, gas fields, sewage lift stations, crop irrigation, grain drying and handling, lake aeration and roller mills. Written-pole motors provide a feasible solution with both economic and environmental benefits. The starting demand of a written-pole single phase motor is generally about 25 to 30 percent of the starting demand of a similar capacity single or three phase induction motor, dramatically reducing electrical demand and objectionable voltage flicker on utility distribution systems. The written-pole motors can safely accelerate inertial loads of at least 10-20 times that of a conventional high efficiency squirrel cage induction motor. The written-pole motor can drive such loads without electronics in the power path. In case of a heavy sudden overload the written-pole motor increases the pull-in torque and resynchronizes easily. It is also capable of repeated starts in a short time without overheating, which gives better reliability, efficiency and ruggedness. The slow start up speed is beneficial in some applications such as water pumps. Since the slow speed can prevent water hammering that is prevalent in water pumping applications with fast ramp up speeds of conventional motors

6. ELECTRIC UTILITY PROTECTION FROM ELECTRONIC LOADS

The population growth of computers and other advanced electronic equipment made feasible for new demands on the electric utility network. The input impedance of these loads is often highly non-linear. This results into abnormally high harmonic currents and noise levels in the distribution system. Due to these and other problems, it is becoming more important not only to isolate critical loads from the electric utility supply variations but also to protect the distribution system components from these nonlinear loads. The chosen protective scheme must meet the customer needs in the most cost effective way. However, the proper choice of a power conditioning system can also serve to extend protection to the utility.

Two widely applied power conditioning devices are the battery powered solid-state inverter an uninterruptable power system (UPS) and the Motor-Generator (M-G) set both are capable of offering reasonable protection to critical loads. Unfortunately, battery chargers for the solid state UPS are themselves non-linear loads and hence do not provide much help for the high harmonic current problem on the utility side. When solar and wind energy sources produce power and the same is injected in to the grid but there are certain technical challenges such as avoiding variation in frequency and voltage levels, generation of harmonics and non-linear behavior. This will happen because of the intermittency observed with solar and wind due to change in intensity of light and wind velocity respectively. In certain occasions it requires islanding due to the aforesaid parameters deviating from the preset values during transmission and distribution [11].

The conventional M-G set completely isolate the utility system from the loads and offers better protection for the utility from these non-linear loads. However, the conventional MG set can supply only a short "ride-through" time about 0.1 to 0.3 seconds at load and within typical frequency limits. This is generally not enough to extend protection from power interruptions for most critical loads. Hence, as a consequence battery systems are usually used to achieve longer "ride-through" time. Further, for the conventional M-G set, it is difficult to start and may cause high surge current on the utility system after a very short power interruption.

The combined operation of written-pole motor generator unit will help for effective ride-through operation. The first commercially available motor is 42 HP, 3-φ motor drive which has high inertia rotor assembly to have effective "ride-through" for defined time when there is an interruption in the input supply. Here 28 kW, 35 kVA, three-phase written-pole M-G set maintains a constant frequency output even when the rotational speed is changing. A 15 seconds ride through can be obtained during power interruption by suitably designing MG set such that delivering full load, while speed changes from 3600 rpm to 3150 rpm [12].

It completely protects the utility distribution system from abusive loads and customers from line transients. Also provide enough time to the customers to start a stand by engine generator set for virtually 100% protection from long term interruptions caused by power distribution system failure. Application of this new M-G set not only provides the utility customer with highly cost effective and superior power protection but also offers the utility system the maximum protection from the customer's non-linear loads.

7. CONCLUSION

The review reveals that written-pole technology is progressing with many advantages over the existing drives. The written-pole motor has feasible construction features. The capability of motor operating in three modes namely start, transition and run will help the motor to accelerate to reach the rated speed with reasonable torque developed avoiding inrush current. The motor with existing specifications are performing reasonably. The use of written-pole motor also minimizes harmonics and do not affect the power quality. The motor is suited for driving non-linear loads which are presently with increasing trend. The review provides avenues to have insight about modeling, simulation and analysis pertaining to written-pole motors for further flexibility.

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