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Design of Prototype Model of Sensor less BLDC Motor in Comparison with PMDC Motor for Solar Water Pumping System

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ABSTRACT: At rural areas where the possibility of electricity transmission is less or irregularity in electrical supply the need of water supply can be fulfilled in a best way with the use of Renewable energy source i.e. solar radiation. By observing the performance of PMDC motor we are designing the Brushless DC Motor with much more compact design and much better performance. The main challenge is to design a motor with less cogging torque and less harmonics The additional feature to design the motor which can work in BLDC as well as PMSM controller. The motor is designed use of NdFeB permanent magnet which will increase the motor cost but also increase the reliability of the motor with a long run time. The skewing of magnet is ignored to reduce the cogging torque but to reduce it to some extent the rotor surface is bifurcated which also help in maintaining the air gap flux density curve more flat. To improve the back-emf waveform shape the motor is designed with distributed wounded stator with integral value of slots per pole per phase which is compatible with an existing sensor less EC Drive. To reduce the harmonics and maintaining the overhang length to get reduced copper loss and reduced temperature the slots per pole per phase is selected as 2.

KEYWORDS: Renewable energy, skewing of magnet, cogging torque, harmonics.

I. INTRODUCTION

To restrict CO_2 emission and to giving easy solution for water pumping in remote area. This involve introduction of solar supply in combination with pump and to optimize the system performance with proper design of complete system. PMDC is replaced with Sensor less BLDC with MPPT and get maximum output at lower irradiation also. The electrical steel used is of higher grade to reduce no load loss and NdFeB magnet are introduced to design the motor with higher service factor so that in future enhancement there is a possibility to improve the power rating with proper selection of drive. The electrical steel grade is taken similar but SmCo is been replaced with NdFeB.The PMDC motor with 15 slot armature 2 pole segmented magnet of SmCo grade Sm2Co17 26H. Br = 10.6 kG, Hc = 784 kA/m. The motor working temperature when loaded at 0.3 hp is 78˚.C Due to lower power rating of motor the magnet eddy current is to be reduced therefore the magnets was been segmented.

II. LITERATURE SURVEY

To save the fuel consumption by saving electricity leads to use of renewable energy source. Solar water pumping system was the best example of it but the system efficiency was not as good as with grid power. Therefore, to improve the wire to water efficiency of solar pumping system the system was designed in optimized manner. To reduce the cost with better performance. This thesis involves proper system design and Brushless DC motor as a replacement of Permanent magnet DC motor for better performance and better life span. The motor is to be designed with smaller size resulting in increased temperature. Odd Stator Slot Numbers in Brushless DC Machines—An Aid to Cogging Torque Reduction. David G. Dorrell, University of Technology Sydney, Sydney NSW 2007, Australia, Motor Design Ltd, Ellesmere, Shropshire SY12 0EG, U.K. Brushless permanent-magnet dc machines often use an integral number of slots per pole (e.g., 3slots/pole) with fully pitched coils in order to obtain a good trapezoidal back-electromotive-force(emf) waveform. However, this can lead to high cogging torque and load torque ripple. A simple solution is to add one additional slot so that the reluctance slotting that causes the ripple is removed, but the winding pattern is closely retained. This paper illustrates that simple design modification, where one additional slot is used so that the machine does not have an integral number of slots per pole. In this paper, the arrangement is analyzed using simple winding analysis and a finite-element analysis which gives more preciseness to calculations. It is found that there is a substantial reduction in cogging and load torque oscillation, thus proving the principle. However, the stator windings are slightly

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unbalanced and this can lead to vibration. This is also investigated and the resulting unbalanced magnetic pull under load is found to be present but of a low magnitude.

III. METHODOLOGY

3.1 Permanent Magnet design

Material Grade: NdFeB – N35-M

Back emf max: $= \frac{Vdc}{\sqrt{2}}$

$= \frac{36}{\sqrt{2}}$

$= 25.45\ VAC$

Maximum Speed: 1750 rpm

Torque required:

$= \frac{Power}{2\pi N}$

$= \frac{224*60}{2\pi*3300}$

=0.648 Nm

$T = KD^2L$

$K = 6000$

$L = \frac{0.64}{6000 * (0.042)^2}$

$L = 60.46$ mm

$L_{considered} = 62$ mm

Number of pole = 4

Number of stator slots = 12

$\emptyset_r = B_r * A_m$

$= \theta_{radian} * r * l$

$\theta_{degree} = 87$

Therefore, $\theta_{radian} = 0.0174533 * 87 = 1.51844$

$r = 18.25$ mm ; $l = 62$ mm

$= 0.01825 * 1.51844 * 0.062$

$A_m = 0.001718114\ m^2$

$B_r = 1.17$ T

$\emptyset_r = 1.17 * 0.001718114$

$= 0.00201019$ wb

$P_{mo} = \frac{\mu_0 * \mu_{rec} * A_m}{l_m}$

$P_{mo} = \frac{4\pi * 10^{-7} * 1.04347 * 0.00178114}{0.003}$

$= 7.781 * 10^{-7}$

$A_g = [\theta_{radian} * (0.042 - 0.00125) + 2 * g] * (l + 2 * g)$

$A_g = [1.51844 * (0.042 - 0.00125) + 2 * 0.0025] * (0.06 + 2 * 0.0025)$

$A_g = 0.0043469\ m^2$

$A_g = \frac{[1.51844 * 0.042 * 0.062]}{2}$

$A_g = 0.001977\ m^2$

$C_\emptyset = \frac{A_m}{A_g}$

$C_\emptyset = \frac{0.001718114}{0.001977}$

$= 0.86905$

$B_g = \frac{C_\emptyset}{\{1 + P_m * P_{ss} * P_g\}} * B_r$

$B_g = \frac{0.86905}{\{1 + 1.1 * 0.5 * 0.7\}} * 1.2$

$B_g = 0.538\,T$

$B_m = \frac{1 + P_{r1} * R_g}{\{1 + P_m * P_{ss} * P_g\}} * B_r$

$B_m = \frac{1 + 0.85 * (-0.95)}{\{1 + 1.1 * 0.5 * 0.7\}} * 1.2$

$B_m = 0.166\,T$

$-H_m = \frac{B_r - B_m}{\mu_0 * \mu_{rec}}$

$-H_m = \frac{1.2 - 0.166}{4\pi * 10^{-7} 1.04347}$

$-H_m = 788952\ A/m$

$PC = \mu_{rec} * \frac{1 + P_{r1} * R_g}{P_{mo} * R_g}$

$PC = 1.04347 * \frac{1 + 0.85 * (-0.95)}{(0.98 * 0.95)}$

$PC = 0.215$

$g^{`} = K_c * g$

$g^{`} = 0.92 * 0.00125$

$g^{`} = 0.00115$

$\frac{B_m}{B_r} = \frac{PC}{PC + \mu_{rec}}$

$B_m = \frac{0.215}{0.215 + 1.04347} * 1.17$

$B_m = 0.1998\,T$

$E_b = 2 * \mathrm{N} * B_g * \mathrm{l} * \mathrm{r} * \omega$

$E_b = 2 * 32 * 0.538 * 0.062 * \frac{0.042}{2} * \frac{2\pi * 3300}{60}$

$E_b = 15.48\ \mathrm{V/phase}$

$E_b(\mathrm{l} - \mathrm{l}) = \sqrt{3}\mathrm{V/phase}$

$E_b(\mathrm{l} - \mathrm{l}) = 1.732 * 15.48$

$E_b(\mathrm{l} - \mathrm{l}) = 26.81\ \mathrm{V}$

$\emptyset = \frac{E_b}{4.44 * f * N}$

$\emptyset = \frac{15.48}{4.44 * 110 * 32}$

$\emptyset = 9.09 * 10^{-4}\mathrm{wb}$

3.2 STATOR LAMINATION DESIGN.

Number of stator slot = 12

Shape of slot = Tapper

Outer Diameter of stator = 92mm

Inner Diameter of stator = 42mm

Core Back = 0.00852 m

$Area\ of\ Core\ Back = h_y * K_i * \mathrm{l}$

$K_i = 0.96 - By\ manufacturer$

$Area\ of\ Core\ Back = 0.00852 * 0.96 * 0.062$

$Area\ of\ Core\ Back = 0.00050592\ m^2$

$Flux\ density\ in\ core\ back = \frac{\emptyset}{2 * Area\ of\ Core\ Back}$

$Flux\ density\ in\ core\ back = \frac{9.09 * 10^{-4}}{2 * 0.00050592}$

$Flux\ density\ in\ core\ back = 0.898$ T

Tooth width = 0.00472 m

$Area\ of\ tooth = b_t * K_i * \mathrm{l}$

$Area\ of\ tooth = 0.00472 * 0.96 * 0.062$
$Area\ of\ tooth = 0.000279744\ m^2$
$Area\ of\ teeth\ per\ phase = Area\ of\ tooth * Number\ of\ tooth\ per\ pole$
$Area\ of\ teeth\ per\ phase = 0.000279744 * \frac{12}{4}$
$Area\ of\ teeth\ per\ phase = 0.000839232\ m^2$
$Flux\ density\ in\ teeth = \frac{\emptyset}{Area\ of\ teeth\ per\ phase}$

$$Flux\ density\ in\ teeth = \frac{9.09 * 10^{-4}}{0.000839232}$$

$Flux\ density\ in\ teeth = 1.083\ T$
*Note – Flux density are been calculated at No – Load
$Slot\ Area = 169.8\ mm^2$
$Turns\ per\ phase = 32$
$Number\ of\ parallel\ path = 11$
$Double\ layer\ distributed\ winding$
$Gauge = 0.75\ mm$
$Overall\ diameter = 0.81\ mm$
$Area\ of\ overall\ diameter = \frac{\pi}{4} * D^2$
$Area\ of\ overall\ diameter = \frac{\pi}{4} * 0.81^2$
$Area\ of\ overall\ diameter = 0.5150\ mm^2$
$Number\ of\ conductor\ per\ slot = 8 * 11 * 2 = 176$
$Area\ of\ conductors = 176 * 0.5150 = 90.64\ mm^2$
$Fill\ factor = \frac{90.64}{169.8} * 100\ \% = 53.38\ \%$
Cogging torque = Tmax – Tmin
=0.120 - 0.042 = 0.078 Nm.

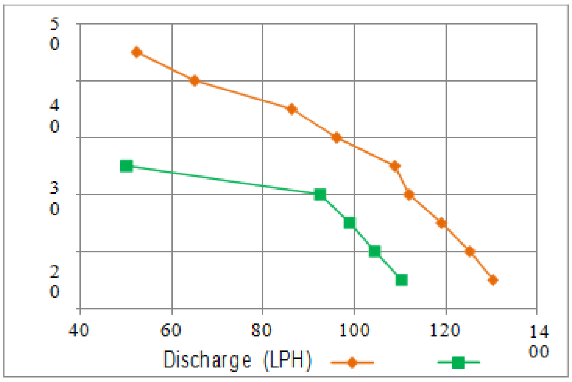
IV. EXPERIMENTAL RESULTS

250 Wp				
Head	LPH	LPM	Power	Efficiency
5	1303	26.1	91.9	19.3
10	1251	25.6	112.6	30.3
15	1189	24.9	110.7	43.9
20	1118	24.0	136.4	44.7
25	1087	22.9	164.8	44.9
30	959	21.5	173.9	45.1

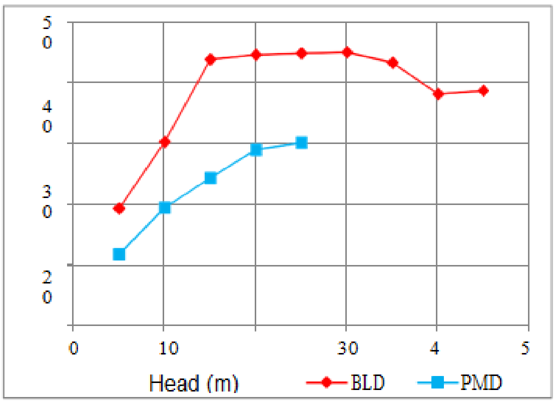
Table. No.2 Performance of BLDC with 250 Wp @ Solar radiation 1000 W/m2 with Temp 25 °C

250 Wp				
Head	LPH	LPM	Power	Efficiency
5	1102	19.9	128.0	11.7
10	1043	19.6	146.1	19.5
15	988	19.3	165.9	24.3
20	923	15.3	173.5	29.0
25	499	8.5	112.7	30.2

Table. No.3 Performance of PMDC with 250 Wp @ Solar radiation 1000 W/m2 with Temp 25 °C



Graph 3 Head vs. Discharge at250Wp



Graph 4 Efficiency vs. Head at250Wp

V. CONCLUSION

Brushless DC Motors give more wire to water efficiency as compared to Permanent magnet DC motor. With 300Wp BLDC motor the wire to water efficiency was 41.3% but in the case of PMDC motor it was 35.3%. It passes the criteria declared by MNRE for micro motors with 300 Wp panel for10,15 and 30m head ; giving almost double of the requirements of MNRE. As well as discharge was 1160LPH for BLDC-M and for PMDC-M is 440LPH.Similarly,the performance with 250Wp, 225Wp, 200Wp, 150Wp photovoltaic panel was much better with BLDC-M as compared to PMDC-M. Since the system is designed to better utilization of solar power due to higher cost of PV cells BLDC-M should be preferred. Motor has passed the criteria and found to stand in super premium efficiency (IE4) motor with efficiency of 84.6% at rated load. The initial investment will result in lifelong better performance.

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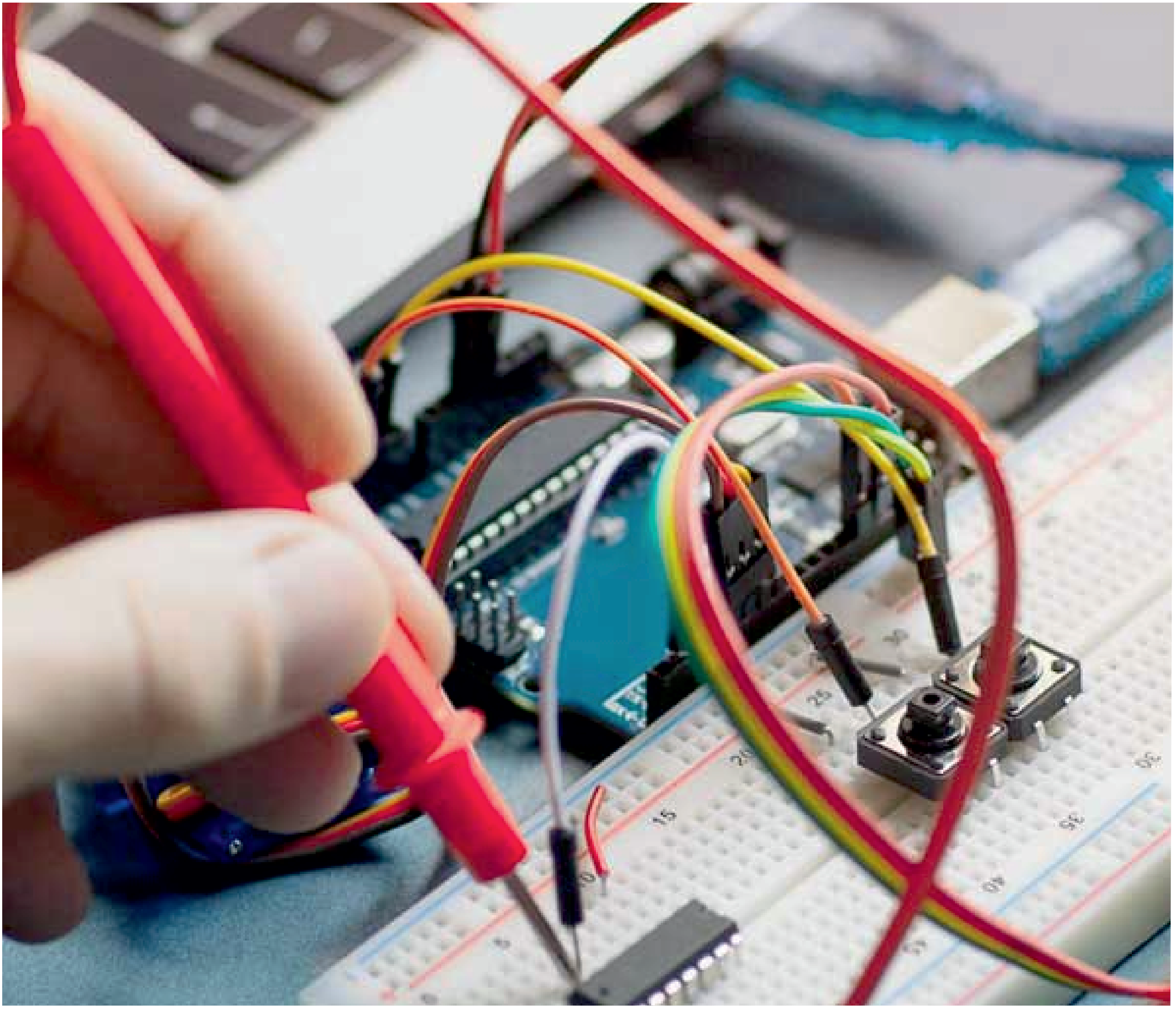

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