A NOVEL STATOR DOUBLY FED DOUBLY SALIENT PERMANENT MAGNET BRUSHLESS MACHINE

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<u>Purpose</u>

Recently, the doubly salient permanent magnet (DSPM) machine has been attractive because of its high power density and high efficiency, but still suffering from limited constant-power speed range and high PM material cost [1],[2]. To solve these problems, the stator doubly fed doubly salient (SDFDS) machine topology has been proposed [3], which replaces the PM material by a dc field winding to facilitate flux weakening operation and on-line efficiency optimization. However, this topology inevitably needs high field winding MMF to realize the desired flux weakening, hence degrading its electric loading and power density. In this paper, a novel SDFDS-PM brushless machine topology is proposed, which not only reduces both PM material and field winding MMF significantly, but also offers the distinct advantage of wide constant-power operation range (namely, 4 times the base speed) which is essential for electric vehicle application.

<u>Proposed topology</u>

As shown in Fig. 1, the proposed machine consists of two types of stator windings – polyphase armature winding and dc field winding. The polyphase armature winding operates like that for a DSPM machine, whereas the field winding not only works as an electromagnet but also as a tool for flux weakening and/or flux optimization. The novelty of this topology is to purposely add an extra flux path in parallel with each PM pole. If the field winding MMF reinforces the PM MMF, this extra flux path will assist the effect of flux strengthening. On the other hand, if the field winding MMF opposes the PM MMF, this extra flux path will favor the PM flux leakage, hence amplifying the effect of flux weakening. The principle of operation is illustrated in Fig. 2.

<u>Results</u>

Based on equivalent magnetic circuit approach, the air-gap fluxes in the presence of zero, positive and negative field current can be respectively represented as:

$$\Phi_{g0}=\frac{F_{PM}R_S}{R_SR_g+R_{PM}R_g+R_SR_{PM}},\quad \Phi_{g+}=\frac{F_{dc+}(R_S+R_{PM})+F_{PM}R_S}{R_SR_g+R_{PM}R_g+R_SR_{PM}},\quad \Phi_{g-}=\frac{-F_{dc-}(R_S+R_{PM})+F_{PM}R_S}{R_SR_g+R_{PM}R_g+R_SR_{PM}}$$

When $R_S=R_{PM}/3$, $\Phi_{g+}/\Phi_{g0}=2$ and $\Phi_{g-}/\Phi_{g0}=1/2$, it yields $F_{dc+}=F_{PM}/4$ and $F_{dc-}=F_{PM}/8$. It illustrates that a quadruple change in air-gap flux only desires a small change in field winding MMF (one-fourth of PM MMF during flux strengthening, and one-eighth during flux weakening), which can be confirmed by finite element analysis as shown in Figs. 3 and 4. Moreover, the corresponding flux linkages against the rotor position are shown in Fig. 5. Finally, the torque-current characteristic of the proposed machine is shown in Fig. 6. *Detailed simulation and experimental results will be included in the full paper.*

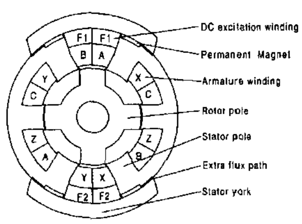

Fig. 1. Proposed machine topology.

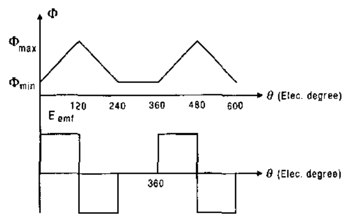

Fig. 2. Principle of operation.

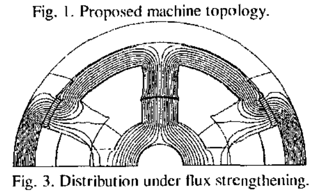

Fig. 3. Distribution under flux strengthening.

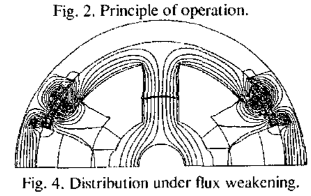

Fig. 4. Distribution under flux weakening.

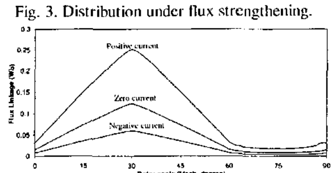

Fig. 5. Flux linkages at various field currents.

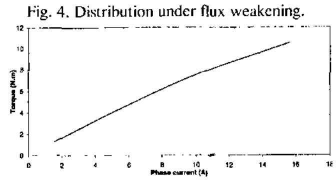

Fig. 6. Developed torque versus phase current.

<u>References</u>

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