Electromagnetic field disk generator for wind turbines

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Abstract. In this paper, we study, the distribution of magnetic field in two rotary generator with permanent magnets, where the main element is the axial generator stator fields to produce wind energy. Finding the field E^{\pm}, H^{\pm} requires the solution curve tasks for equations of electrodynamics. The obtained expressions of the field E^{\pm}, H^{\pm} name strict solution» to the problem of electrodynamics (diffraction). Rigorous solutions of diffraction problems, as a rule fail to obtain a closed form. For some geometrically simple cases they are expressed in the form of differential series. A typical example is the following problems of diffraction of a wave on the cylinder. [Zhamalov A.Z., Kunelbayev M.M., Issaev S.A., Tugelbayeva G.T. Electromagnetic field disk generator for wind turbines. Life Sci J 2014;11(9s):369-373] (ISSN:1097-8135). http://www.lifesciencesite.com. 78

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Introduction

In this article the electromagnetic field distribution in two rotor generator with permanent magnets is studied, where the basic element is an axial generator stator fields to produce wind energy. The aim of the analytical model is to develop a machine which will simplify timely design and full support of electromechanical energy receiving system model.

Methods

Electromagnetic field calculation is very important because it is necessary to calculate a rotation torque constant of electromotive force as well. To receive a magnet field solution by analytical method for a disc generator permanent magnets, in references there were the radial flow machines [1,2], straightline [3,4] and axial flow configuration[5,6,7]. However, axial machine flow solutions it is used the solutions for magnets width and stator ring finding.

Axial machines form a disc generator with support magnets which produce an axial flow disc stator which contains phase ventilation. This basic design has many variations which include adjoining [11], tow-sidedness [12], toroidicity [13,14] and many magnets [15].

Magnets are put in the disc generator oppositely. These magnets are made so that the north pole in one rotor has a contact with the south pole in another pole. That leads an axial magnet field so that a stator clamp needs N-N for front magnets. To analyze a magnet field in an axial machine there are basic calculations used in reference [6]. To analyze a magnet field in an axial machine there are basic calculations used in reference [6]. However analytical model which is presented in references [6] presupposes an iron stator presence and field strength on the stator and rotor boundary. Therefore, equations developed in reference [6] have been changed by superposition, that is to say fields are found by addition. As a result magnets on each side of the rotor act individually.



Figure 1. Construction of dual-rotor axial PM generator (looking inward radially)



Figure 2. Construction of dual-rotor axial PM generator: rotor (left) and stator (right)

The main part

When a concrete diffraction task is set geometric and electrodynamic characteristics of V body are defined and falling wave E^0 , H^0 . The outside environment is vacuum.

It is demanded to find a solution of Maxswel's equations E,H so that $E = E^+, H = H^+ e V u E = E^0 + E^-$

 $H = H^0 + H^-$ out of V. But the known conditions should be followed on the boundary of S and V. Our task is to study fields directly near such

surfaces $\mathcal{E}, \mathcal{\mu} \cap \sigma$ and fields' parameters, possibly meets with a step going through them. The easiest way is to consider this step as an ideal, in other words

to consider \mathcal{E} , $\mu \sqcup \sigma$ as discontinuous functions to a border. It would be possible to accept that a boundary is not sharp and there is very thin intermediate layer inside of which properties of environment change slowly, but an attempt to study these kind of layers within macroscopic electrodynamics would be gradual.

It very difficult to use Makswel's equations within border points.

The tangential vectors E,H and normal vectors B,D means that an equation $E_{\overline{x}}^{0} + E_{\overline{x}}^{+} = E_{\overline{y}}^{+}, H_{\overline{x}}^{0} + H_{\overline{y}}^{-} = H_{\overline{x}}^{+}, D_{y}^{0} + D_{y}^{-} = D_{y}^{+}, B_{y}^{0} + B_{y}^{-} = B_{y}$ is complete.

I case when a V body is an ideal conductor border conditions are as following:

$E_{\tau}^{0} + E_{\tau}^{-} = 0, \ [\nu_{0}\mu^{0} + \mu^{-}] = \eta, \ D_{\nu}^{0} + D_{\nu}^{-} = \xi, \ B_{\nu}^{0} + B_{\nu}^{-} = 0$ (x).

Outside field E, H should meet requirements for outer electrodynamics task solutions [17].

Thus, to find a field E^{\pm} , H^{\pm} needs curve solving for electrodynamics equations.

The received field expressions E^{\pm} , H^{\pm} are called "a rigorous solution" of electrodynamics' task (diffraction).

As a rule, rigorous solutions of diffractions are very difficult to find within a closed form.

For some simple geometric cases they are expressed by differential series.

A typical example is a task below which consider a cylinder wave diffraction.

So, as an diffraction object we take a perpetual round cylinder (Picture 1).



Figure. 3 Wave diffraction by a circular cylinder

The environment transitivity we may present as piecewise constant function of a radial coordinate $\boldsymbol{\varepsilon}(\boldsymbol{r}) = \boldsymbol{\varepsilon}, \mu(\boldsymbol{r}) = \boldsymbol{\mu}$ when r<R (inside the cylinder), $\boldsymbol{\varepsilon}(\boldsymbol{r}) = \boldsymbol{\varepsilon}_0, \mu(\boldsymbol{r}) = \boldsymbol{\mu}_0$ when r>R (outside the cylinder)[18]. Let a flat homogeneous wave fall on a cylinder perpendicularly to a Z axis and it is polarized parallel with respect to the latest $\boldsymbol{E}_0 = \boldsymbol{Z}_0 \boldsymbol{E}^{\boldsymbol{\nu}}$. Write: where $\sqrt{\mathcal{E}_0 \mu_0}$, $\sqrt{\mathcal{E}_0 m}$. If we express \mathbf{E}_m^0 in cylindrical coordinates we have $\mathbf{E}_m^{\mathbf{v}} = \mathbf{Z}_0 \mathbf{A} e^{-ik_0 r \cos x_3}$

Presenting $\mathbf{E}_{m}^{\mathbf{0}}$ as the following partition: $\mathbf{E}_{m}^{\mathbf{0}} = \mathbf{z}_{\mathbf{0}} \dot{A} \sum_{n=-\infty}^{+\infty} (-i)^{n} j_{n} (k_{\mathbf{0}} \mathbf{r}) e^{i n \alpha}, \quad r > R \qquad (2)$

As far as the field E^0 , H^0 is not changed within Z coordinate and a vector E^0 is parallel to a cylinder axis a diffracted field should have the same properties:

$$\nu/\nu_{\nu Z} = \nu \quad E^{\pm} = z_0 E^+,$$

That is to say this task is bideimensional. This implies spiral, meets the function

$$\mathbf{E}_{m}^{o}$$
, \mathbf{E}_{m}^{+} н \mathbf{E}_{m}^{-} ;
 $\nabla_{+}^{2} \dot{E}_{m} + k_{0}^{2} \dot{E}_{m} = \mathbf{0}$
(3)

where $k_0^2 = k_0^2 = \omega^2 \dot{\varepsilon} \mu$ when r<R and $k_0^2 = \omega^2 \varepsilon_0 \mu_0$ when r>R.

We express $\mathbf{E}_m^+ \mathbf{m} \mathbf{E}_m^-$ as linear combinations like RA. Choosing R we will regard that limited solutions for r=R fields and for r>R have a character of diverging waves. Thus we may write the following rows with unknown coefficients:

$$\mathbf{E}_{m}^{*} = Z_{\mathbf{s}} \mathbf{A} \sum_{n=-\infty}^{\infty} (-i)^{n} b_{n} j_{n}(kr) \varepsilon^{in\alpha} \quad r < R$$
(4)

and

 $\vec{E}_m = z_v \dot{A} \sum_{n=-\infty}^{\infty} (-l)^n c_n H_n^{(2)}(kr) e^{in\alpha} \quad r > R$ Further we will write down the same diffraction for a magnet field. (5)

According to the 2 Maxwell's equation

$$\mathbf{H}_{m}^{i} = \frac{i}{\omega\mu}\omega t \mathbf{E}_{m}^{i} = \frac{1}{\left(\omega\mu\right)\left(r_{0}\frac{\nu E_{m}}{\nu\alpha} - \alpha_{0}\frac{\nu E_{m}}{\nu\gamma}\right)}$$

when $\mathbf{E}_m = \mathbf{Z}_{\mathbf{O}} \mathbf{E}_m$

Close to that (2), (3), (4) μ (5) the following correspond:

$$\dot{H}_{m}^{+} = \frac{i\dot{A}}{\omega\dot{\mu}} \sum_{n \to -\infty}^{\infty} (-i)^{n} b_{n} \left[r_{0} \frac{\dot{i}_{n}}{z} j_{n} (\dot{k}z) - \alpha_{0} \dot{k} j_{n} (kr) \right] e^{in\alpha}$$

< R,

$$H_{m} = \frac{i4}{\omega \mu_{0}} \sum_{n \to -\infty}^{\infty} (-i)^{n} c_{n} \left[i v \frac{i_{n}}{\tau} H_{n}^{(2)}(k_{0}r) - \alpha_{0} k_{0} H_{n}^{(2)}(k_{0}r) \right] e^{i n \alpha}$$
⁽⁷⁾

and

(6)

$$\dot{H}_{m}^{+} = \frac{i\dot{\lambda}}{\omega\mu_{0}} \sum_{n \to -\infty}^{\infty} (-i)^{n} \left[r_{0} \frac{in}{r} j_{n}(k_{0}r) - \alpha_{0} k_{0} j_{n}(k_{0}r) \right] e^{in\alpha},$$

$$, r > R \qquad (8)$$
After all the presentations are written down

the solution of the task goes to coefficients b_n and C_n finding by demanded border requirements application [19]. Tangential vector E and H component continuity requirement take a form of

$$\mathbf{E}_m^{\mathbf{o}} + \mathbf{E}_m^{\mathbf{i}} = \mathbf{E}_m^{\mathbf{i}}$$

(9)

 $\mathbf{H}_{m\alpha}^{\mathbf{o}} + \mathbf{H}_{m\alpha}^{\mathbf{i}} = \mathbf{H}_{m\alpha}^{\mathbf{i}} \mathbf{r} = \mathbf{R}$

Within term by term row (2),(4) and (5) comparison the first written requirement gives:

 $-b_n j_n (kk) + c_n H_n^{(\omega)} (k_0 R) = -\gamma_n (k_0 R)$ (10)

In the same way in accordance with diffractions (6) - (8) from the second condition we may find:

$$b_n \frac{\dot{k}}{\mu} \gamma_n (kR) - c_n \frac{k_0}{\mu_0} \mathbf{H}_n^{(2)} (k_0 R) = \frac{k_0}{\mu_0} J_0(k_0 R)$$
(11)

Now p_n and c_n are defined as a set of equation solution (10) and (11).

$$b_{n} = \frac{\left(J_{n}(k_{0}R)H_{n}^{(2)}(k_{0}R) - J_{n} \middle| (k_{0}R)H_{n}^{(2)}(k_{0}R)\right)}{\left(J_{n}(kR)H_{n}^{(2)}(k_{0}) - \frac{W_{0}}{W}J_{n} \middle| (kR)H_{n}^{(2)}(k_{0}R)\right)}$$
(22)

$$e_{n} = \frac{\left(-f_{n}\left(\dot{kR}\right)f_{n}\right|\left(k_{0}R\right) + \frac{W_{0}}{\dot{W}}f_{n}\right|\left(\dot{kR}\right)f_{n}(k_{0}R)\right)}{\left(f_{n}\left(\dot{kR}\right)H_{n}^{(2)}(k_{0}R) - \frac{W_{0}}{W}f_{n}\right|\left(\dot{kR}_{1}\right)H_{n}^{(2)}(k_{0}R_{1})\right)}, \qquad \dot{W} = \int_{\bar{k}}^{\bar{\mu}}$$

So, diffraction coefficients (4)-(7) and diffraction field are found.

Conclusion

Lets pass to a received results discussion having taken perfectly conducting cylinder. A given case we will regard as a limitary $\varepsilon \rightarrow -i\omega$. In far as $W \rightarrow 0$ at the same time limitary coefficients expressions $b_n \ u \ c_n$ are as following:

$$C_n = -\frac{J_n(k_o R)}{H_n^{(22)}} / k_o R$$
(13)

Expectedly, an inside field E^+ , H^+ does not exist now. Certainly boarder condition (9) for H_{α} on the perfectly conducting cylinder is not met[20].

It is changed by a corresponded boarder condition (x).

 $[r_0H_m^0 + H_m^-] = \bar{\eta}_m_{\Pi P H T = R}$ (14) It gives a possibility to find a superficial current density, that gives waves. On the basis of (14)

 $\dot{\eta}_m = \mathbf{Z}_0 \left(H_{m\alpha}^{i} + H_m^{i} \right) \quad r = R$

Wishing to find outside diffracted field, in a far zone lets use asymptotical Hankel's function:

$$H^{(2)}(k_0r) \approx \sqrt{\frac{2}{\pi k_0 r}} e^{-i\left[k_0r - \frac{\pi}{2}\left(n + \frac{1}{2}\right)\right]}$$

and $H^{(2)^{1}}_n(k_0r) \approx -iH^{(2)}_n(k_0r)$ (16)

Taking into account (13), (5) μ (7) for far field dissipation we receive the following series: $\vec{E_{m}} = -z_{\alpha}\dot{A} \int_{-\infty}^{\infty} e^{-i\left(k_{0}r - \frac{\pi}{4}\right)} \Sigma^{\infty} - \frac{\alpha_{n}(k_{0}R)}{\alpha_{n}(k_{0}R)} e^{in\alpha}$

$$E_{m} = -Z_{0}A_{\sqrt{\pi k_{0}r}}e^{-(\sqrt{k_{0}r}-4)}\sum_{n=-\infty}^{\infty}\frac{1}{H_{n}^{(2)}(k_{0}R)}e^{-(\sqrt{k_{0}r}-4)}$$

(17) And

$$H_{\overline{m}} = \alpha_{\bullet} \frac{A}{\omega_{\bullet}} \sqrt{\frac{2}{\pi k_{\bullet} r}} e^{-i(k_{\bullet}k_{-}\pi_{f_{\bullet}})} \sum_{n=-\infty}^{\infty} \frac{J_{n}(k_{\bullet}R)}{H_{n}^{(\alpha)}(k_{\bullet}R)} e^{in\alpha}$$
(18)

The solution \mathbf{E}_{m} , \mathbf{H}_{m} (17),(18) meets the requirement, which guarantees its uniqueness [21].

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