Research and design of wind power grid switch for low voltage crossing ability

Liu Zhang1,2, Shaohua Ma1, Cailian Gu2, Quanping Zou2
1Shenyang University of Technology, Shenyang, Liaoning, 110023, China
2Shenyang Institute of Engineering, Shenyang, Liaoning, 110036, China
*Corresponding author’s e-mail: zhang_liu2007@163.com

Abstract. This paper proposes a new type of wind power grid switch design, according to the requirements of the wind power generation system for grid switch technology, combined with the electromagnetism theory and empirical formula. The new interconnection switching used the characteristics of the high remanence of two-phase magnetic materials to solve the problem such as great power consumption, holding not across low voltage, in view of the traditional electromagnetic grid switch, and then set up new interconnection switching of the three-dimensional entity model, finally used the finite element simulation software, the change of the curve, such as the electromagnetic suction parameters and contact motion speed was obtained, the relationship between the structure parameters and interconnection switch operating characteristics of the contact was also obtained. Finally simulation experiment results show that the new grid switch in the case of no excitation current keeps off state, which can be well applied to wind power generation system, and can effectively improve the stability of large-scale distributed power grid operation, and has a certain theoretical significance and practical value.

1. Introduction
With China’s policy of promoting energy saving and emission reduction, energy-saving new materials to replace traditional high-energy material has become the future development trend of the electrical equipment design and manufacturing. As a distributed wind power generation system in the main control switch, the interconnection switch’s reliability will directly affect the stability of wind power generation system. This paper proposes a design scheme of wind power grid switch, according to the requirements of the wind power generation system for grid switch technology. The effects of different constituent elements on the magnetic properties of materials were studied. Combined with the electromagnetic theory and empirical formula, the material size and structure of the new grid-connected switch were calculated and determined. And then the new grid switch form is set up[1].

2. Wind power system requirements for parallel switch between low voltage across
When the wind power system fluctuates or is not during normal operation, the phenomenon of wind turbines and node voltage lower can be caused. At this point, if the wind turbine can keep a good connection status, or also can provide some additional to the wind power system reactive power and voltage of the system and branch through the voltage drop time, eventually return to normal, the system voltage is said that the wind turbines has a low voltage across functions. In GB19963-2011, the low voltage crossing requirements for grid-connected switches of wind power generation system are shown in table 1.
Table 1. Requirements for low voltage ride through.

| Voltage                        | Indicator                                      |
|-------------------------------|-----------------------------------------------|
| More than 40% of the rated voltage | Maintain reliable closed                       |
| 25% of the rated control voltage and the following | Release and breaking                           |
| Voltage drop to 20% rated voltage | More than 625 ms will remain closed           |
| Voltage drops to zero          | Keep on state more than 20 ms regardless of fault |

3. New interconnection switching parameter design and determined

According to the requirements of distributed wind power system for grid switch, the structure of the new grid switch is designed. What is preliminarily determined of the interconnection switch is the main part of the chart shown in figure 1, the shaded part for nano two-phase magnetic materials, reaction spring is also included in this switch, normally open contacts, normally closed contact, dynamic iron core, coil and other parts [2].

![Diagram of the new grid connected switch](image)

1- normally closed contact 2- normally open contacts 3- dynamic core 4- coil 5- reaction spring 6- static iron core

Figure 1. The electromagnetic structure diagram of the new grid connected switch

3.1 The determination of four parameters of contact

Contact from, contact distance, the early and final pressure of contact is the beginning of the switch contact four of the main parameters in the system. The new switch is designed to ensure that the switch is not breakdown, at the time of system appear abnormal overvoltage. To reduce the contact bounce, lighten the load capacity of electromagnetic system, the contact distance open is calculated, according to that the contact opening distance is related to the current passing through the main contact of the grid-connected switch. And then it is calculated the main contact from 5.5mm, auxiliary contacts from 4mm [3].

The purpose of designing the contact distance of the switch is to ensure that the switch can be closed well and reliably even when the switch contact is worn to a certain extent. According to the calculating formula of distance (1), it is concluded that the main contactor distance of 3mm, auxiliary contact distance of 3mm. In the formula, e for distance, the unit is m.

\[ e = 0.6\sqrt{I_n} \times 10^{-3} \]  

(1)

In addition, according to the empirical formula of contact pressure, what finally calculated is that the main contact pressure for a group of 35N, three sets of a total of 105N. Auxiliary contact pressure for a group of 12.8N, two sets of a total of 25.6N. The phenomenon of mechanical vibration will be produced in the process of closing of the switch. There are many factors, such as electric repulsion between the switch contacts, switch contact collision and switch between the collision of dynamic and static iron core, etc. Determine principle of the early contact pressure, is that the interconnection switches are not guaranted bounce off when just contact, and contact will not be melted. According to the empirical formula, the primary grid switch at the beginning of the main contact pressure is 65.7N, switch at the beginning of the auxiliary contact pressure is 9.6N.
3.2 the design of action core sizes and coil parameters

3.2.1 pole area of the core
According to the demand of miniaturization design, grid switch electromagnetic mechanism adopts electrical pure iron DT4 as dynamic core permeability material. DT4 as the permeability of materials known as is commonly used in engineering practice. Compared with other materials, DT4 permeability is higher, its maximum magnetic conductivity is higher than vacuum magnetic permeability of hundreds or thousands or even tens of thousands of times. DT4 coercive force in this range between 39.8 ~ 95.5A/m. According to DT4 materials and reaction curve calculated electromagnetic pole area, and the electromagnetic theory, the calculation is usually electrical and magnetic flux density of pure iron as 1.5T. Then it can estimate the armature switch in the open circuit state air gap flux density, usually values between the range of 0.25T - 0.25T. According to the formula of dynamic core area and the magnetic poles diameter can get pole out core area of 392 mm², pole diameter of 12.61mm. Considering the dynamic core in the process of actual assembly, some components, such as driving rod and the nut of occlusion may exist a certain size deviation between diameter, the design of switch poles should have a certain margin, 14mm.

3.2.2 the size of the magnetic material
The size of two phase composite magnetic materials should be properly selecting fill, in order to ensure the interconnection switch on and off, can rely on nano two-phase composite magnetic materials after the completion of the remanence of reliable, and ensure the remanence retention must be greater than the maximum reaction. If the material selection size is small, switch could occur and unreliable, contact vibration, etc, that will affect the reliability of the grid switch. If the selection is larger, it may cause impact on electromagnetic system and process dynamic core too big, and then cause the contact wear and tear, what will affect electric grid switch life. Afterwards, the safety factor of 1.5 times is calculated by nano two-phase magnetic materials, that produce electromagnetic force 211.41N. Under this premise, combined with the empirical formula and the demagnetization curve, nano two-phase composite magnetic material can be calculated for switch static core cross section area of magnetic materials for:

\[ S = \frac{B_1}{B_2} = \frac{B_1}{B_2} \]  

In the formula, respectively through the cross-sectional area of the magnetic core and static dynamic core flux, B1 and B2, respectively, said moving iron core and magnetic field intensity. Cross-sectional area of material static iron core is 464 mm² [4].

3.2.3 coil related parameters
The coil provides the magnetomotive force for the magnetic system of the grid-connected switch. When work air gap for δ₀, can use the switch working air-gap magnetic pressure drop(B₀δ₀)/μ₀ and non-working air gap, and \( \sum U_f \) magnet switch's total magnetic pressure drop, \( \sum U_{IN} \) combination of all three said magnetomotive force of wire coil. Assuming that grid switch adopts is duty for a long time, average temperature rise on the surface of the coil can be calculated by Newton formula. Using dc electromagnetic system, this paper obtained that the coil wire diameter was 0.27mm, through calculation. Coil number of turns N calculation formula is:

\[ N = \frac{4K_{th}hA}{\pi d^2} \]  

The number of turns of the coil of the designed electromagnetic mechanism N can be calculated to be 2400 turn, and the coil resistance R can be finally calculated to be 78 ohms.

4. interconnection switch electromagnetic mechanism of dynamic and static simulation analysis and parameter adjusting
The electromagnetic system is an important part of the electromagnetic switching apparatus, and the parameters of each part are the main factors affecting the overall performance of the switching
apparatus, and the degree of cooperation between the electromagnetic suction and system reaction in the electromagnetic mechanism will directly affect the reliability of the grid-connected switch in the working process. By analyzing the simulation results of dynamic and static characteristics of the grid-connected switch electromagnetic mechanism of the wind power generation system, it is not only possible to verify whether the remanence holding control scheme based on two nano-magnetic materials meets the feasibility requirements, but also very important in the design of the whole grid-connected switch. In this paper, Ansoft Maxwell finite element software was used to establish the simulation model of specific design, and the characteristics of the electromagnetic mechanism were analyzed in three stages, namely, pre-processing, processing and post-processing[5].

4.1 Static characteristic calculation and simulation analysis

According to the requirements of the grid switch design, the geometry model of electromagnetic agencies is set up as shown in figure 2.

![Figure 2. Geometric model of electromagnetic mechanism of grid connected switch](image)

Figure 3 is the vector diagram of the magnetic induction intensity B electromagnetic mechanism, the vector in the direction of the arrows in figure represents the direction of the magnetic inductive intensity. Different color represents the size of the magnetic intensity of perceptual differences. What can be seen from the diagram is that most of the magnetic flux will pass by the dynamic core and core of the main magnetic circuit, only a small amount of air leakage.

| The switch of the air gap length (mm) | Switch electromagnetic suction (N) | The switch of the air gap length (mm) | Switch electromagnetic suction (N) |
|-------------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|
| 0.000                               | 199.460                           | 3.000                               | 48.806                            |
| 0.500                               | 132.505                           | 3.500                               | 42.355                            |
| 1.000                               | 80.698                            | 4.000                               | 39.527                            |
| 1.500                               | 66.864                            | 4.500                               | 35.699                            |
| 2.000                               | 59.453                            | 5.000                               | 32.084                            |
| 2.500                               | 53.580                            | 5.500                               | 29.420                            |

Electromagnetic suction values summarized in table 2. From the table, when the air gap is zero, the value of the electromagnetic suction maximum, 199.461N. The data trend shows that at the beginning, with the increase of air gap, the electromagnetic drop is very fast. When the air gap increases to 4mm, the holding force of the nanocomposite magnetic material decreases slowly, and its numerical value is relatively small compared with the reverse force of the reaction system of the electromagnetic mechanism.

4.2 Simulation and characteristic analysis of dynamic characteristics

4.2.1 The electromagnetic current, suction characteristic analysis

Two parallel switch electromagnetic mechanism of electromagnetic suction changes over time the relationship between contrast diagram are shown in figure 4.
Figure 4. The contrast diagram of electromagnetic suction
Figure 5. The matching diagram of suction and counterforce

Table 3 is the specific numerical table of electromagnetic force. According to the data in the table, the maximum electromagnetic force of the new grid-connected switch electromagnetic mechanism based on the nanometer two-phase magnetic material is 208.1N, and the remanence holding force is 195.804N.

Table 3. Specific numerical table of electromagnetic suction.

|                             | The minimum electromagnetic suction(N) | The biggest switch electromagnetic suction(N) | Switch the remanence retention(N) |
|-----------------------------|-----------------------------------------|-----------------------------------------------|----------------------------------|
| the traditional electromagnetic institutions | 0.000 | -500.300 | 0.000 |
| New type of electromagnetic institutions | -16.624 | -208.100 | -195.804 |

Figure 5 shows the matching diagram of the suction reaction of the new grid-connected switch. The output voltage of the distributed wind power generation system is often not a stable value due to the randomness of wind power. It can be seen from the figure that the reaction characteristic curve is located below the suction characteristic curve and close to each other, which can achieve a good cooperation between suction and reaction.

4.2.2 nano two-phase magnetic material cross section width affect and characteristics

In guarantee under the premise of other structure size remains the same, the section width of L of two-phase magnetic materials will be changed. The change quantity to 2 mm respectively, 1, 0, 1 mm mm (positive) in cross section width increase direction. In the finite element software under different conditions of the simulation model is established, the resulting data are imported into the Matlab matrix, were compared. With the increase of the width of the material section, a corresponding shorter closing time, average speed in the process of moving iron core movement, the remanence retention after the power is also bigger. Concrete numerical value as shown in table 4, according to data in the table every increase 1mm cross section width, and time will reduce 0.5ms, electromagnetic agency core breaking speed is compared with before changing section width slightly faster. On the whole were similar, but considering the cross-sectional area will increase the material usage, it is not conducive to product miniaturization. Therefore, the design should reduce material consumption as far as possible in 1.5 times meet under the premise of safety margin, in order to achieve the purpose of cost savings.

Table 4. The influence of the cross section width of the material on the closing characteristic.

| L change quantity(mm) | suction time(s) | Maximum speed(m. s⁻¹) | The average speed(m. s⁻¹) | Remanence retention(N) |
|-----------------------|-----------------|------------------------|---------------------------|-------------------------|
| 1                     | 21.0            | 1.370                  | 0.405                     | 173.6                   |
| 0                     | 21.5            | 1.360                  | 0.395                     | 185.5                   |
| -1                    | 22.0            | 1.333                  | 0.385                     | 195.9                   |
| -2                    | 22.5            | 1.310                  | 0.376                     | 214.6                   |
5. Conclusion
This paper calculates and designs the new grid material size and structure of the switch, using nanometer two-phase magnetic materials, combined with the electromagnetism theory and empirical formula. And finite element simulation software is used to analyze the dynamic and static characteristic of the new grid switch and its influencing factors. The simulation experimental results show that combined reaction absorption characteristics of switch to the points of interconnection switch closing time also conform to the technical requirements, and can rely on nanometer two-phase remanent magnetism of magnetic materials and reliable keep holding state. The energy-saving effect is more remarkable than traditional electromagnetic grid switch. It can be well applied to wind power generation system, can effectively improve the stability of large-scale distributed power grid operation, and has a certain theoretical significance and practical value.

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