APPLICATION OF SYNCHRONIZED ASYNCHRONOUS GENERATOR IN WIND POWER PLANT

A. I. Abdulkadirov, S. F. Quliyev

Azerbaijan State Oil Academy, Baku, Azerbaijan
tabdulkadirov@mcdermott.com
Phones: +99 450 553 00 14,
+99 450 358 20 05.

ABSTRACT

Interest to more extensive utilization of energy of renewable sources including power of wind grows increasingly. In spite of certain success in the field of creation of wind power plants, the working-out of alternative variants is being continued, especially electric part of these power plants. The task about application of synchronized asynchronous generator in wind power plant is considered and discussed in the paper. Such generator combines positive properties of both synchronous and asynchronous generator. The utilization order of these properties depends on work modes of wind power plant.

Keywords: Synchronized, Asynchronous Generator, Two-axis excitation, Wind Power Plant.

I. INTRODUCTION

Caspian Sea cost in Apsheron area of Azerbaijan Republic possesses important wind resources. Usage of these resources to achieve electric power is recognized advisable on the level of the State Program at present time. One of directions of this Program realization is researches in the transformation field of wind power into electric one by wind power plants (WPP). Both synchronous and asynchronous generators are used as generators in these plants. However, last time practically all European firms went into asynchronous generators, which meet requirements of WPP operation in the best way and are characterized with drastic and frequent changes of wind speed. There is noted their great stability, simplicity of lead-in parallel work and etc. [1]

However application of asynchronous generator in WPP has a number of defects main of which is reactive power drain from network system or generator must exite from the block of condensers. The last method is not to be used for WPP working for network system.

As it is known, most time of year WPP works at low speed of wind, accordingly at power output which is too mush less than installed capacity.

These modes are accompanied with essential change for the worse of energy datum of asynchronous generator. This fact was decisive at utilization of asynchronous generators with two windings on stator made by a number of firms. [1]

II. MAIN PART

In this paper there is suggested another method for solving of this problem – application of synchronized asynchronous generator in WPP [2]. The main advantage of this generator consists in its property to work both in synchronous and asynchronous mode. Special scheme of rotor winding feed by direct current at synchronous work gives additional properties to machine that distinguish it from usual synchronous machine [3].

The main of them – is possibility to adjust phases of magnetic field of stimulation in large bounds (±30 el.deg.) without change of stream amplitude. Researches carried out have shown that due to automatic regulation of excitation (ARE) of such machine oscillation can be damped at flaws not only of middle but also of higher power.

To achieve it in usual synchronous machine is not possible [3]. At the same time synchronized asynchronous generator has lack essence of which consists in the following.

It is known that asynchronous machine is made with smaller air-gap than synchronous machine has. Consequently, static overloading of synchronized asynchronous generator reduces. It should be noted that similar position takes a place in asynchronized synchronous generators.

Static overloading of synchronized asynchronous generator can be increased up to 150% by usage of all resources. This is less than it is necessary in wind power plant (200%). In principle, this problem can be eliminated. However, calculations made for concrete example gave not conforming results fro asynchronous mode (in the case of fourfold increase of gap):

- increasing of magnetizing current to 200%;
- increasing of stator current in nominal mode to 20%;
- decreasing of power factor in nominal mode from 0,907 to 0,760.

Certainly, practical usage of such machine as asynchronous machine is not reasonably. As regards synchronous mode, so, although wishful result is

achieved, however, such conversion of machine – is expensive undertaking.
However, the said above doesn't mean that synchronized asynchronous machine set on the base of standard machine doesn't find a use. An example for it can be use of such machine as drive motor in draw work [4].
Let's consider an advantage of utilization of this machine in wind power plant. In spite of less static overloading than usual synchronous generator has, the machine is able to work in synchronous mode at all speeds of wind. ARE is tuned to maximal decrement of oscillation and to provide stability. However, if ARE is not able to keep stability any more, then machine is to be switched into asynchronous mode. In contrast to usual synchronous machine there arise no negative effects.
Then, utilization of this machine in wind power plant gives following advantages :

1. Soft electric start of wind plant (at bounded start current);
2. Operation of generator at advance power factor (in the case of necessity with cosφ=1);
3. In comparison with synchronous generator of usual construction, more effective decrement of oscillation and more resulting stability.

Thus, the considered machine realizes positive properties both of synchronous and asynchronous machine.

In conclusion, let's consider possibility of synchronized asynchronous generator with regard to decrement of vibration.

Change of wind speed is represented by:

$$u=u_0+u_m\sin\omega t \qquad (1)$$

where u_0 – average value, u_m – amplitude of pulsation of wind speed; ω - angular frequency of pulsations.
Torque moment of windwheel

$$M_B=\frac{\pi R^2\rho u^3}{2\Omega}\cdot\xi(z,\varphi) \qquad (2)$$

where R – radius of windwheel; ρ – mass density of air; φ – angle of fan installation; z=ΩR/u – specific speed of windwheel; ξ(z, φ)-wind powers, use factor puting (1) to (2) well get

$$M_B=\frac{\pi R^2\rho}{2\Omega}\cdot\xi(z,\varphi)\Big[(u_0^3+\frac{3}{2}u_0u_m^2)+(3_0^2u_m+\frac{3}{4}u_m^3)\sin\omega t-\frac{3}{2}u_0u_m^2\cos2\omega t-\frac{1}{4}u_m^3\sin3\omega t\ \Big] \qquad (3)$$

The analysis of the expression (3) shows that even with the high wind surge, the amplitude of the 2nd and 3rd harmonies is less than the amplitude of the 1st harmony. This will allow accepting (1st approximation)

$$M_B=M_0+\Delta M_B\sin\omega t \qquad (4)$$

where

$$\Delta M_B=\frac{\pi R^2\rho}{2\Omega}\cdot\xi(z,\varphi)3u_0u_m^2$$

Harmonic oscillation of torque on the shaft of synchronous generator causes oscillation of rotor angular (θ) and power oscillation(P), current (i) and other values connected with it. To research this task, we provide three-phase rotor winding feeding by special algorithm and direct current with two windings of excitation: one into direct axis , and other – into transverse one [4]. As result of it, we get cylindrical rotor synchronous machine with two axis excitation, electromagnetic torque is defined by :

$$M_e=(U/x)(e_{fd}\sin\theta+e_{fq}\cos\theta) \qquad (5)$$

Equation of rotor motion in deviations for unregulated machine ($U_{fd}=U_{fd0}$=const; $U_{fq}=U_{fq0}$=const) and with taking into consideration of harmonic character of change of torque (p=d/dt=jω) has following view :

$$(-\omega^2H+j\omega D+k_s)\Delta\dot\theta=\Delta\dot M_B \qquad (6)$$

where H – is inertial constant; D – factor of damper moment; k_s – factor of synchronized moment.
From the last expression amplitude of oscillation of rotor angular :

$$\Delta\theta_m=\frac{\Delta M_B}{\sqrt{(k_s-\omega^2H)^2+(\omega D)^2}} \qquad (7)$$

Without taking influence of free current of rotor circuits into consideration, it can be supposed that change of rotor angular occurs by static characteristics :

$$\Delta\theta_{mst}=\Delta M_B/k_{SO}$$

Having denoted $\sqrt{k_{SO}/H}=\omega_0$, where ω_o – frequency of free oscillation of generator with taking fly mass of windwheel into consideration, we get

$$\Delta\theta_m=\Delta\theta_{mSt}/\sqrt{\left[1-(\omega/\omega_0)^2\right]+(\omega D/k_{SO})^2} \qquad (8)$$

From the last expression it follows that at endless small value of frequency of forced oscillation $\Delta\theta_m=\Delta\theta_{mst}$, and at resonance frequency $\omega=\omega_o$ $\Delta\theta_m>>\Delta\theta_{mst}$.

To reduce this oscillation various methods including ARE of synchronous generator are used.
In usual machine ARE is not enough effective as brings to high oscillation of active power, and wishful decrement of oscillation of active power and current can not be achieved.

In the considered machine at regulation of excitation in both axis, equation (6) is to be written as follows :

$$\Delta\dot{\theta} = \frac{\Delta\dot{M}_B - \Delta\dot{M}_f}{-\omega^2 H + j\omega D + k_s} \qquad (9)$$

where

$$\Delta\dot{M}_f = \frac{U(x_a/x)(1 + j\omega T_{do})}{r_{fd}\sqrt{1+(\omega T_d^{'})^2}}(\Delta\dot{U}_{jd}\sin\theta_0 + \Delta\dot{U}_{fq}\cos\theta_0) \qquad (10)$$

- constituent of electromagnetic moment caused by regulation of excitation.

Δ U_{fd} and Δ U_{fq} – voltage on clutches of excitation winding formed by ARE in transient.
Oscillation of active power:

$$\Delta P_e = \Delta M_e = (U^2/x)\Delta\theta + \frac{U(x_a/x)(1 + j\omega T_{do})}{r_{fd}\sqrt{1+(\omega T_d^{'})^2}} \Delta U_{fd}\sin\theta_0 + \Delta U_{fq}\cos\theta_0) \qquad (11)$$

Oscillation of reactive power :

$$\Delta Q_e = \frac{U(x_a/x}{r_{fd}\sqrt{1+(\omega T_d^{'})^2}}(\Delta U_{fd}\cos\theta_0 - \Delta U_{fq}\sin\theta_0) \qquad (12)$$

ARE algorithm is forming in such way that to achieve full decrement of rotor oscillation (Δθ≈0). As $\cos\theta_0 > \sin\theta_0$, so necessary value of maximal tension of Δ U_{fq} is less than Δ U_{fd}. Therefore, to get simultaneous reducing of ΔP_e and ΔQ_e , it is enough to make regulation only on one axis, in this case – on transverse axis (Δ U_{fd}=0). As a result of it, one by one constituent remains in equations (11) and (12).

III. CONCLUSION

At the result of implemented researches there has been defined that utilization of synchronized asynchronous generator constructed on the base of asynchronous machine with phase rotor of standard type, in wind power plant allows to settle following tasks:

- soft electric start of wind plant (at bounded start current);
- operation of generator at advance factor of power or with cosφ=1;
- more effective decrement of oscillation and more resulting stability in comparisons with usual synchronous generator.

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