A Wind Farm Balancing Analysis

Mircea Grigoriu [1], Marius Constantin Popescu[2], Luminita Georgeta Popescu[3], Doina Cornelia Dinu [1], Cristinel Popescu[3]

[1]University POLITEHNICA Bucharest, 313 Spl. Independetei, Bucharest, ROMANIA
[2] Universty of Craiova, Craiova, ROMANIA
[3]University Constantin Brancus, Targu Jiu, ROMANIA

mircea.grigoriu@gmail.com, popescu.marius.c@gmail.com, luminita@utgjiu.ro, doinadinucornelia@yahoo.com, cristi67pop@yahoo.com http://www.hydrop.pub.ro

Abstract: Presently, the wind energy utilization devices approach is changed from individual isolated equipments, designated to a singular application, to compel wind farms connected to the electrical network. Supported by a favorable legal frame, they become competitive actors on the energy market, challenging traditional actors, like thermal or hydro power stations. The paper presents a computer modeling of such a farm, continuing with a study of balance of a turbine, by a MATLAB simulation of the resulting transfer functions.

Key-Words: Transfer functions, Simulation and modeling, Components balance.

1 Introduction

A wind turbine is a device that converts kinetic movement of a propeller blade in mechanical energy. If this mechanical energy is transformed into electricity we are dealing with a generator powered by wind / wind energy converter. But appropriation is time to "wind turbine". In wind power location we take into account the amount of wind in the area, land price, visual impact on surrounding structures and nearness of current distribution network. Production of electricity using wind energy is achieved by means of a synchronous generator (synchronous machine with magnet or with rotor) or asynchronous. The design of large pallets requires a speed of rotation of its axis very low (few tens of rounds per minute). If synchronous machine has a large number of poles where this will lead to realizing a large diameter generator (fig. 1).

Fig.1. Typical wind turbine with horizontal axis

Vertical axis turbines – the generator and more sophisticated components are placed in the bell tower, thus easing installation and maintenance. The main types are: Darrieus, Gorlov, Giromill and Savonius. Depending on the location of the turbines they can be categorized in offshore turbines and turbines placed in shore.

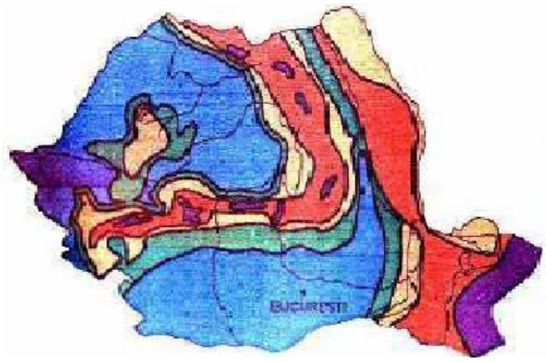

Fig.2. Romanian winds map (ICEMENERG 1992): violet- *high*, red- *moderate*, green- *low*, blue-*very low.*

2 Mathematical modeling of wind farms

2.1 Modeling of the aero generator.

It is considered a speed multiplier located between the blades and generator axis. In this configuration the generator will be a permanent magnet synchronous machine. Wind energy comes from the kinetic energy of air mass due to wind. If considered an air mass m moving with speed m, corresponding kinetic energy will be

$$E_c = \frac{1}{2} m v^2 . \qquad (1)$$

The applicable parameters equations are:
Power

$$P_c = \frac{1}{2} \rho S v^2 , \qquad (2)$$

Effective power

$$P_e = \frac{1}{2} C_p \rho \pi R^2 v^3 . \qquad (3)$$

$$C_p = 0{,}536 \sin(0{,}1836\lambda) - 0{,}004\lambda . \qquad (4)$$

Calculation of power factor. For a given wind speed, wind turbine has the speed Ω_{t1}, previous relations allow calculation of the coefficient of power as block diagram below

Modelling of Turbine-shaft gear assembly. The wind is transmitting to the turbine an aeraulic couple (Fig. 4), and flexibility of blades and the connecting shaft are detected by stiffness kt. If friction is neglected fluid inertia of blades can be considered Jt. Dynamic equations and elasticity equations are:

$$\Omega_{t1} = \frac{1}{J_t} \int (C_{aer} - C_a) dt , C_a = \frac{1}{J_t} \int (\Omega_{t1} - \Omega_{t2}) dt . \qquad (5)$$

Modeling multiplier. It uses the principle scheme illustrated in Fig. 4. Without neglecting mechanical losses and multiplier inertia are resulting relations:

$$C_{m0} = \frac{C_a}{G}, \qquad \Omega_{t1} = \frac{\Omega_{tm}}{G} . \qquad (6)$$

$$\Omega_{m1} = \frac{1}{J_m} \int (C_{m0} - C_m - f_m \Omega_{m1}) dt . \qquad (7)$$

Mechanical modeling of engine shaft and its inertia. As before, from the relations of elasticity and dynamic is resulting:

$$C_m = k_a \int (\Omega_{m1} - \Omega_{m2}) dt . \qquad (8)$$

$$\Omega_{m2} = \frac{1}{J_a} \int (C_m - C_{em} - f_a \Omega_{m2}) dt . \qquad (9)$$

Aero generator modeling mechanical parts. Last 5 equations translate into the following simulation scheme. Size which would be set is denoted by rotational speed of the turbine is noted with . Wind turbine torque rise Caer; to regulate speed , the torque can be considered as a random disturbance.

The speed is expressed according to aeraulic torque and alternator torque.

$$\Omega_{t1}(s) = G_1(s) C_{aer}(s) - G_2(s) C_{em}(s) \qquad (10)$$

$$G_1(s) = \frac{c_0 + c_1 s + c_2 s^2 + c_3 s^3 + c_4 s^4}{d_0 + d_1 s + d_2 s^2 + d_3 s^3 + d_4 s^4 + d_5 s^5}$$

$$G_2(s) = \frac{c_0}{d_0 + d_1 s + d_2 s^2 + d_3 s^3 + d_4 s^4 + d_5 s^5} \qquad (11)$$

The terms of transfer coefficients of these functions are the following:

$$c_0 = k_a k_t ,$$
$$c_1 = G^2 f_m k_a + f_a (G^2 k_a + k_t) ,$$
$$c_2 = G^2 f_m f_a + G^2 k_a (J_a + J_m) + k_t J_a ,$$
$$c_3 = G_2 (f_m J_a + f_a J_m) , \quad c_4 = G^2 J_a J_m ,$$
$$d_0 = G^2 k_t k_a (f_a + f_m) . \qquad (12)$$

Aero generator simplified model. If a rigid transmission is considered then the equations of dynamic system of the aero generator, multiplier and the generator is simplified considerably.

Assuming a rigid transmission results $\Omega_t = \Omega_{t1} = \Omega_{t2}, \quad \Omega_m = \Omega_{m1} = \Omega_{m2}$. If the equations of dynamic system of the turbine and overall generator are written, then results:

$$\Omega_t(s) = G_{1s}(s) C_{aer}(s) - G_{2s}(s) C_{em}(s) = \frac{C_{aer} - G C_{em}}{[G^2 (J_m + J_a) + J_t] s + G^2 (f_a + f_m)} . \qquad (13)$$

2.2 Modeling static converters

A larger network can be regarded as frequency and voltage are required. To achieve an efficient transfer between wind energy and turbine speed must be adapted, what leads to getting out of a variable frequency generator. Adjusting speed of Helios power station is achieved by maintaining constant tension on the continuous bus and adjusting the power factor of the network. To obtain an electromagnetic torque and to insurance speed regulation of the aero generator, current loop reference voltage required by the pulse width modulation MLI1.

ISSN: 1790-5095

ISBN: 978-960-474-159-5

On the continuous bus, in addition to the electromagnetic torque is required a current I0. With the inverter, the modulator MLI2, and maintaining constant tension of the continuous bus is ensured the best transfer of power to the network.
The structure of the converter will contain: electric generator, a converter 2 for converting AC power to DC power fluctuated, a converter 3 to obtain AC power transfer network, an adaptive control block that takes account of wind speed, turbine speed and power transferred to the network, an optimal control block, a monitoring block of energy transferred in network, real time processing of data on wind speed, solar energy, the integration of micro power station into a single system.

3 The study of wind power stability

Turbine speed command. The alternator will be equipped with 2 pairs of poles and will likely be the following: =150 rad/s, rated power Pe=300kW which involves a nominal torque Cem=2000 Nm. The process of associating calculating power factor block control has a size which is the electromagnetic torque noted here with Cem and a disturbance of wind speed V. Size of the output controller is the blades speed. Equations of mechanical parts can be put in the form of two transmittance matrices G1(s) and G2(s) (Fig. 11). To obtain a high yield rate it may be fixed an optimal value of specific speed (with features of power coefficient Cp).

```
clear;ka=100000;kt=150000;c0=ka*kt;fa=2;
fm=2;
G=18;c1=(G^2)*fm*ka+fa*((G^2)*ka+kt);Ja=
0.6;
Jm=0.2;c2=(G^2)*fm*fa+(G^2)*ka*(Ja+Jm)+k
t*Ja;
c3=(G^2)*(fm*Ja+fa*Jm);
c4=(G^2)*Ja*Jm;d0=(G^2)*ka*kt*(fm+fa);Jt
=10;
d1=kt*((G^2)*fa*fm+ka*((G^2)*(Ja+Jm)+Jt)
);
d2=(G^2)*fm*(ka*Jt+kt*Ja)+fa*(kt*Jt+(G^2
)*…
(ka*Jt+kt*Jm));
d3=(G^2)*fa*fm*Jt+kt*Ja*Jt+(G^2)*(ka*Ja*
Jt+…
ka*Jm*Jt+kt*Ja*Jm);
d4=(G^2)*Jt*(fm*Ja+fa*Jm);
d5=(G^2)*Ja*Jm*Jt; e0=G*ka*kt;
numG1=[c0 c1 c2 c3 c4];
denG1=[d0 d1 d2 d3 d4 d5];
numG2=[e0]; denG2=[d0 d1 d2 d3 d4 d5];
z1=roots(numG1);r1=roots(denG1);r2=roots
(denG2)
G1=tf(numG1,denG1); G2=tf(numG2,denG2);
pzmap(G1);pause;pzmap(G2)
z1 =               r1 =            r2 =
-0.0043+0.0414i -0.2077           -0.2077
-0.0043-0.0414i -0.0000+0.0080i -
0.0000+0.0080i
-0.0000+0.0012i -0.0000-0.0080i -0.0000-
0.0080i
-0.0000-0.0012i -0.0000+0.0012i -
0.0000+0.0012i
-0.0000-0.0012i -0.0000           -
0.0012i
```

4 A swat analysis on the wind energy in Romania

Romania has good wind resources, mainly on the Black Sea coast and in mountainous areas. Available realistic potential (i.e. taking into account both resource and site restrictions) can be estimated at 2,000 MW producing over 4,000 GWh/year.
At the same time, within the national R&D programme, several favourable sites for wind farms were investigated and pre-feasibility studies were carried out (the Semenic Mountains, the Black Sea coast and off shore, the Sub-Carpathians areas).
Four experimental 300kW wind turbines were assembled on location in the Semenic Mountains. Two of the wind turbines never became operational because of lack of funding. The first set is still operational, but it has to be dismantled because it is in an advance stage of wear. The set belonging to Electrica S.A. has fallen into disrepair because of a broken blade.

Positive factors:

- The vertically integrated monopoly CONEL (power utility) has been unbundled, therefore decentralised generation is now legally and commercially possible.
- New energy laws have been passed and are now in force accounting for energy market liberalisation.
- The absorption of the EU *acquis* is an immediate policy goal for Romania. The promotion of renewables is a priority for the EU energy policy (see the Directive on renewables and the Green Paper towards a European Energy Strategy). Romania has to comply with this option.
- Other political commitments (e.g. the Kyoto Protocol, ratified by Romania, sets the target to reduce GHC emissions by 8% during the first commitment period), favour the development of renewables. Use of the Kyoto flexible financial mechanisms (joint implementation and emissions trading in particular) can also provide an additional financial input for the development of renewable sources, especially wind power.

ISSN: 1790-5095 ISBN: 978-960-474-159-5

- The Romanian power and heat regulatory agency (ANRE) has established rules to guarantee equal treatment of actors on the energy market. ANRE produced a clear regulatory framework for IPPs to operate according the regulated Third Part Access (rTPA) principles.
- The cross subsidies for electricity were removed. The tariffs, based on transparent methodologies, reflect the real electricity costs.
- The Romanian industrial sector has a proven capability to transfer and implement modern technologies for wind turbine components manufacture, i.e. towers, nacelles, gearboxes, generators.
- Good wind energy resources.
- Quite good own R&D experience. There are various centres in Romania where extensive research in the field of renewable energies, particularly wind energy, has been performed. Sound knowledge and professional skills are available from a group (albeit a rather small one) of qualified local experts.
- The development of remote rural areas where connection to the grid is not possible or is too costly calls for decentralized power generation solutions. Renewable provide such environment-friendly alternative solutions.
- Many companies that have considerable electricity bills and own sites with good wind potential are interested to become self-producers.

Information, awareness and human resources barriers

- Earlier demonstrative applications in the area of wind power using exclusively Romanian equipment and know-how undermined the credibility of the new technology as a result of their poor performance due to inadequate materials and maintenance.
- No convincing demo application using commercially available proven wind energy technology has been installed in Romania yet. Although there were attempts in the past to produce wind turbines for electricity generation, they were unreliable and inefficient.
- The population has no recent experience with wind energy. It is, therefore, necessary to overcome the lack of knowledge about the availability of alternative renewable energies, particularly wind, and to educate the population, at all levels, by providing tangible demonstration that such alternative technologies offer real solutions.

It is clear that, without addressing the above-mentioned barriers, it will be difficult to promote sustainable wind energy alternatives and open the market. In this context, ENERO is committed to contribute, according to its objectives and resources, to the wind energy development in Romania. Identifying the barriers is a first, necessary, step.

4. Conclusions

It is noted that the function has 5 poles and 4 zeros. A pole is real and 4 poles are complex conjugates with negative real parts (for the parameters considered), so the system is stable - in fact the limit of stability (a calculation can be done in MATLAB with roots (denG1) - see file eolian_1. m). Zeros are complex conjugate (the values considered), two of them having negative real part. The function has 5 poles, one real pole and 4 pole complex conjugates having zero real part (for the parameters considered), so the system is at the limit of stability.

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