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MODELING OF WIND POWER PRODUCING IN CASPIAN SEA CONDITIONS

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Abstract- A modeling of power producing characteristics for some specified regions of the Caspian Sea is carried out on the basis of long term observations and measurement of average wind speed and gusts as well as sea excitement. With the help of models developed, regions of the sea which are most suitable for wind power production are estimated. Main results of prospective wind farm location mapping are presented. All results obtained are based on the analysis of long-term monitoring and measurements of wind parameters for various regions of the Caspian Sea offshore zone and Global Meteorological Model parameters. The results of a feasibility study for using wind turbines of leading global manufacturers are presented.

Keywords: Wind Power Producing, Wind Potential, Wind Speed, Modeling, Assessment.

I. INTRODUCTION

For the last 20 years the rate of increase of renewable sources installed capacity have superseded the increase in traditional sources. In Power Energy programs of a number of leading European countries such as Germany, England, Spain, it is aimed to produce 50% of total energy from renewable sources. A factor stimulating of this tendency is the global limitation of primary energy carriers, increased demands for environment preservation, and also planned gradual reduction of nuclear power plants at some countries. According to the forecasts [1, 2] the growth of production of rather readily available oil and gas will be less than growth in demand by 2015.

Though the alternative power sources become much more significant in power balance, they will not cover the difference between supply and demand. Besides, the load to the environment will increase further. According to the global forecasts [1, 2, 3] even if it would be possible to keep an existing share of fossil fuels in power balance and to compensate for the increased consumption, growth of CO_2 emissions can lead to serious threat for the environment. To support the CO_2 concentration in the atmosphere at demanded level is becoming more and more difficult. The importance of wind turbines is increasing due to these reasons.

By 2015 the total wind farms installed capacity in offshore zones in Europe will be about 37 GW [3]. By 2020 an installed capacity of 70 GW is expected. In particular, a 30 GW increase is expected for Great Britain during the period from 2015 to 2020. In Figure 1 [3] the wind potential for offshore power production for some leading countries of Europe is presented.

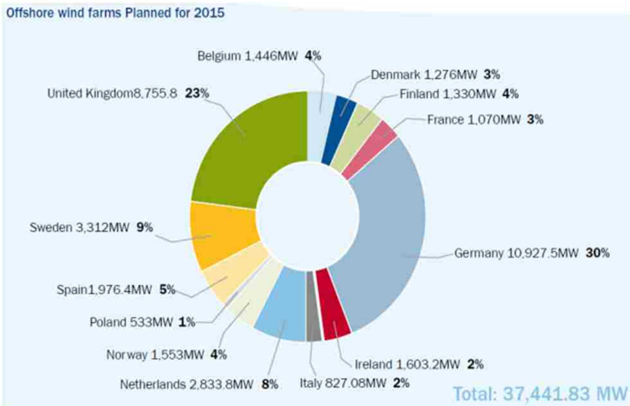


Figure 1. The wind potential for offshore power production for some leading countries of Europe

The region of the Caspian Sea offshore zone is characterized by fast development of oil and gas extraction fields and accompanying developments in infrastructure. Operating and development of offshore oil fields naturally need power supply.

Gas-turbine stations are generally used to cover the need for power offshore. The cost of power per ton oil/gas produced will have a steady tendency to grow, in connection with not only the universal prices for gas, but also a gradual decrease in production level on these fields. The wind farms will contribute to greenhouse gases emissions reduction and to climate change [4].

The aspects of wind potential estimation for different regions of the Caspian Sea and power producing modeling development for interesting regions by means of modern wind turbines are investigated.

II. MODELING OF CHARACTERISTICS OF WIND SPEEDS ACCORDING TO REAL MEASUREMENT DATA

The frequency of wind speeds and their orientation can be estimated for the purpose of definition of a technical resource of wind power production in an offshore zone. This information allows us to estimate the power generated by wind turbines during a certain period of time (usually in calculations annual development is accepted) and in turn, can enable us to make an assessment of economy of projects. A probabilistic assessment of wind power potential for offshore zones of the Caspian Sea is known [5] using a Weibull distribution with two parameters. Here for the first time the research results of wind as energy carrier characteristics were given. The expected total energy production over a year was defined given parameters such as efficiency in sea conditions, semi-annual wind speed, and its probability distribution.

The essence of this method is identification of parameters of the model describing power production in the form of integrated dependence on function of distribution of wind speed and technical parameters of wind farms.

The power producing from a wind turbine is defined as:

$$P_m(V) = 0.5\rho A C_p(\lambda, \beta) V^3 \quad (1)$$

where,

P: the air density;

A: rotors blade-swap area;

V: wind speed;

C_p (λ, β): power factor which is a function of λ and β;

λ: relative speed ;

β: the angle of the rotor blades.

The following system of equations is used to obtain an analytical description of function of wind speed distribution corresponding to orders of the initial moments:

$$M[V^m] = \sum_{i=1}^{n} V_i^m \cdot P_i \quad , \quad m = 1, 2, \ldots \quad (2)$$

where, $M[V^m]$ is the mathematical expectation of m order initial moment for wind speed, V_i is the measured wind speed value, P_i is the probability of speed occurrence in i time moments;

In Figure 2, the fragments of wind speed variations curves for 2 regions of Caspian Sea are presented. To take into account the random nature of wind speeds the Weibull density distribution function is used, in the following two-parameter representation:

$$f(V) = b\, a^{-b}\, V^{b-1}\, e^{-\left(\frac{V}{a}\right)^b} \quad (3)$$

where a and b are the coefficients of the density distribution function. The problem reduces to determining the values of these coefficients, which can be one of the methods [6, 7, 8]. After determining the parameters of the wind distribution function, the capacity of the power generation is determined [5]. Also the parameter $C_p(V)$ was defined as the wind power utilization efficiency.

Experimental estimates of average values (mathematical expectation of mV, dispersion of D_v), and also the probabilities distribution density of wind speeds for studied areas were defined on the basis of measurement data. Values mV, D_v, and also wind speed distribution density are given in Figures 3 and 4. Characteristics of density of probability, and also function of distribution of speeds of a wind are provided respectively on the Figures 3 and 4.

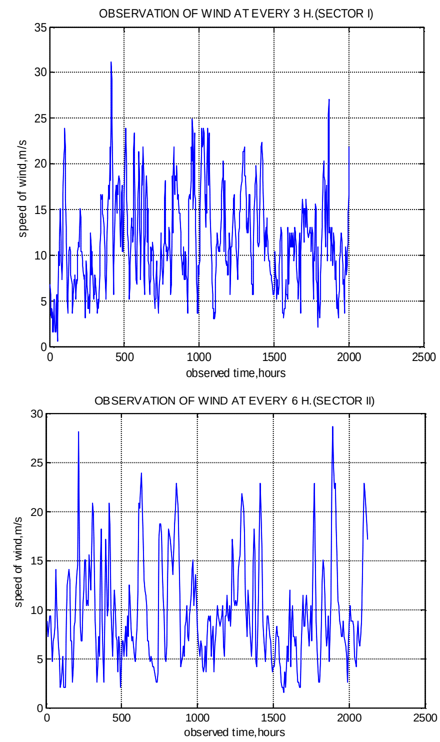


Figure 2. Wind speed variations curves in regions 1 & 2 of Caspian Sea

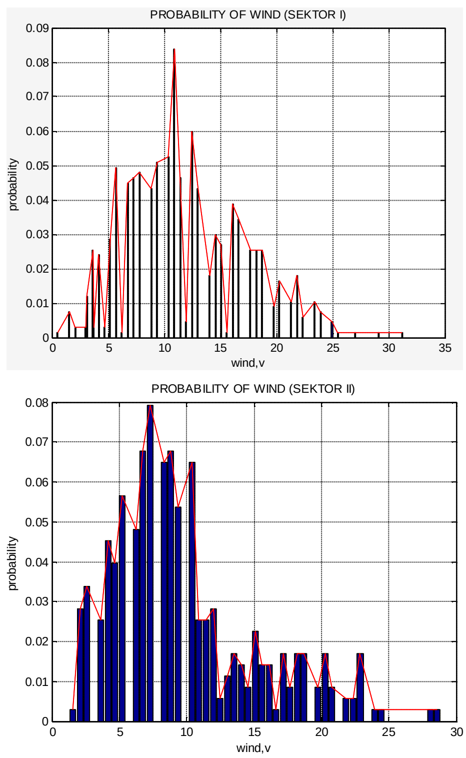


Figure 3. Histograms of distribution of wind speed density in regions 1 & 2

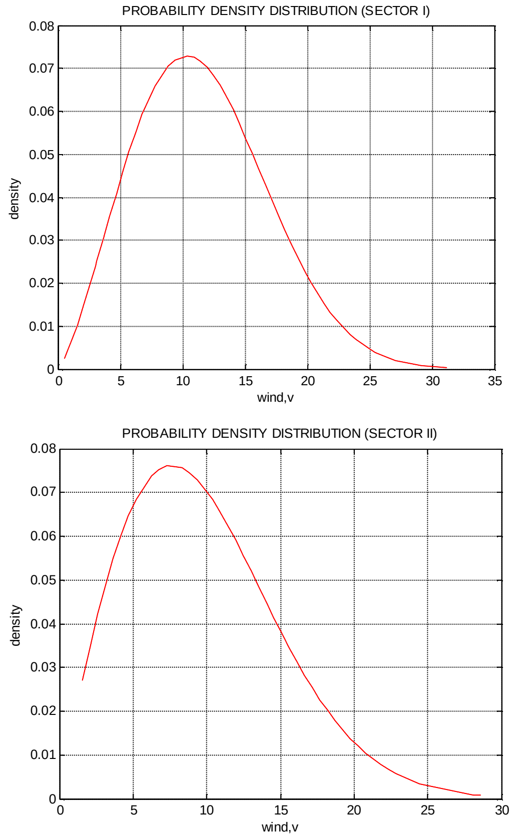


Figure 4. The functions of the probability of Weibull distribution density of wind speeds for regions 1 & 2

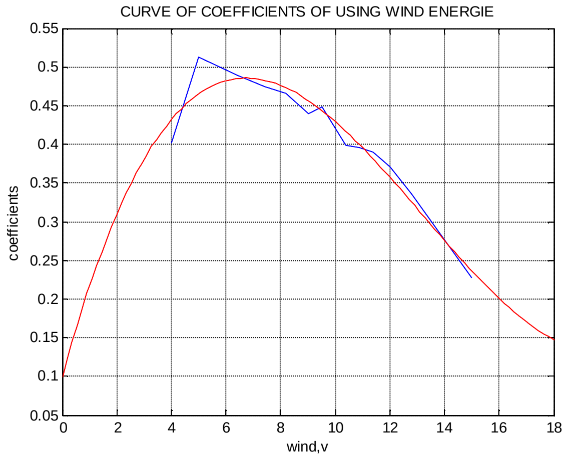
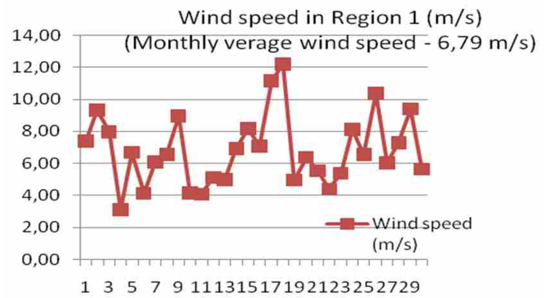
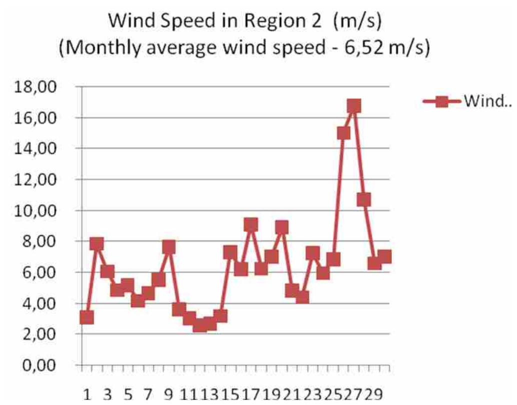


Figure 5. Diagram of wind turbine utility factor depending of wind speed

In the Figure 5, the $C_p(V)$ characteristics performed on the base of provided calculations is presented. As a whole, the problem of the wind potential assessment is complex as other aspects than economic should be considered. It is important to take into consideration issues connected with use of the water area for navigation, oil/gas production, fishery, military purposes, environmental protection and so on. All these factors can be summarized in specific maps which would simplify the task of choosing a suitable site for wind farms installation. It is necessary to have data of wind speeds and directions at heights of 25 m, 50 m, 75 m and 100 m above sea level to be used at installation of the corresponding equipment. It is necessary to monitor the wind parameters in the chosen zones of all-year-round or, at least, semi-annually. Only in this way, it will be possible to optimize the choice and installation of wind turbines and other power equipment. Such monitoring demands also corresponding instrumentation.



(a)



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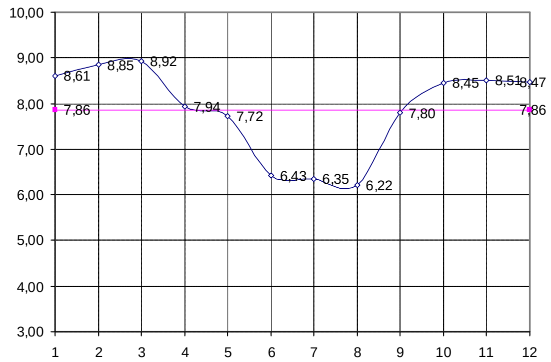


(c)

Figure 6 (a, b, c). Charts of average wind speeds for the chosen regions of an offshore zone of the Caspian Sea

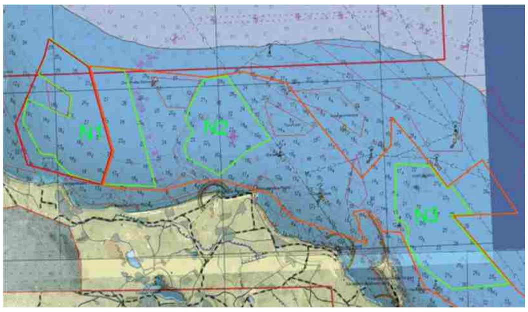
In Figure 6, the average wind speeds for two regions of an offshore zone of the Caspian Sea with coordinates are presented: Region 1 - Position Data: Lat.: 40.05 degree, Long.: 51.2 degree; Region 2 - Position Data: Lat.: 40.2 degree, Long.: 49.7 degree.

Semi-annual values of wind speeds for these regions are also provided. The wind speed was measured at height of 40 m above sea level. From Figure 6(c), it is clear that monthly average wind speed changes between 6.22-8.92 m/s, thus the period of strong winds is January-April and September-December; the period of light breezes is May-September.

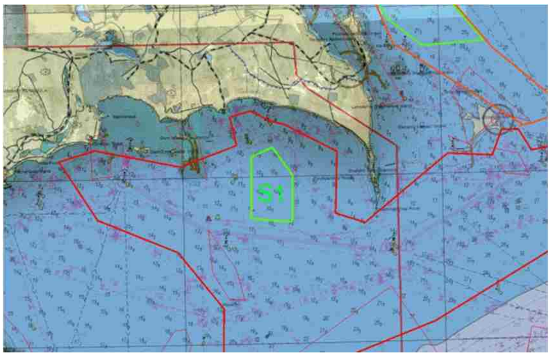
III. ASSESSMENT OF WIND POWER PRODUCING ACCORDING TO THE WORLD GLOBAL WEATHER MODEL

The purpose of this work was to identify and assess the wind energy technical potential in the chosen zones around The Apsheron Peninsula. First, the wind potential was preliminarily estimated based on information from the World databank of weather - the digital Numerical Weather Prediction Setup Global Model NCEP/NOAA. So, areas suitable for wind farm installations were defined for feasibility study. Factors such as carrying out necessary measurements, researches of parameters of soil, a choice of the corresponding equipment and constructive materials etc were considered.

The main results of data analysis (wind parameters) show that four prospective sites - three peninsulas at the northern coast of Apsheron - N_1, N_2 and N_3 (Figure 7) and one for the southern coast - S_1 are well suited.



(a)



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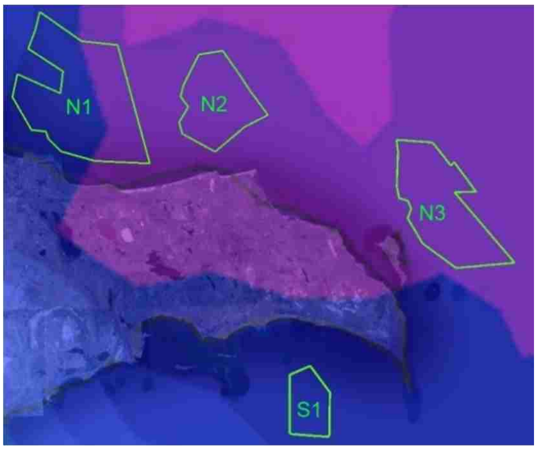

(c)

Figure 7 (a, b, c). Results of mapping of sites of an offshore zone of the Caspian Sea, for perspective wind farms placement

The allocated sites are characterized by:

• The wind potential in specified zones is sufficient for;

• The Sea depths on the specified sites don't exceed 35 m which is a limit for existing offshore wind farms;

• Within the allocated zones there are no sites of oil and gas exploration or production;

• There are no restrictions on other factors - there are no underwater communications, pipelines nor cables, and they are far away from shipping routes and other restrictions.

Table 1. Technical information of the scenarios

Turbine type	Vestas V112	Siemens 3.6-120	REPower M5
Turbine cap (MW)	3	3.6	5
No. of turbines	85	71	51
Wind Farm capacity (MW)	255	255.6	255
Gross production (MWh)	1,277,550	1,248,180	1,112,310
Turbine down time	4%	4%	4%
Wake losses	6%	5%	4%
Transmission losses	3%	3%	3%
Other losses	1.5%	1.5%	1.5%
Net production (MWh)	1,101,501	1,087,627	979,436
Net cap. Factor	0.49	0.49	0.41

Table 2. Economical information of the scenarios

Description	Siemens, k€	Vestas, k€
Turbines	383,400	382,500
Foundations		
"Soft"	154,989	168,137
"Hard"	151,792	157,494
"Hard with drilling"	170,263	177,997
Grid connection	133,720	133,720
Development cost	30,000	30,000
Decomissioning	81,725	81,725
Total		
"Soft"	782,934	796,082
"Hard"	779,737	785,439
"Hard with drilling"	798,208	805,942
Per MW		
"Soft"	3,074	3,125
"Hard"	3,061	3,084
"Hard with drilling"	3,134	3,164
Per position		
"Soft"	11,040	11,225
"Hard"	10,995	11,075
"Hard with drilling"	11,255	11,364
k€	Siemens 3.6-120	Vestas V112
Average annual O&M cost	20,395	20,358
€/kWh (Net)	0.019	0.018

Average value of wind potential for the chosen zones is estimated to be about 2,000 MW. It should be noted that the assessment was made in the conditions of known limitation of initial information, further detailed studying should consider additional factors, which can either limit, or expand borders of prospective zones available for use.

A preliminary feasibility study was made for the N_3 area (Figure 7). This area is about 104 sq.km and the technical and financial elements of this prospective wind farm were estimated. The total installed capacity for the given wind farm is estimated to 255 MW. Wind turbines from two suppliers (Vestas and Siemens) are considered.

Estimated cost of each scenario is about €800 million. Total annual electric power production by this wind farm is estimated to be about 1100 GWh per year. The O&M of wind farm is estimated to be about €18-19 per MW installed capacity. Detailed technical and economic indicators of the considered scenarios are presented in Tables 1 and 2.

These results are based on information from open sources. Following parameters should be considered in more detail for more exact assessment of economic indicators of the project:

• Wind parameters: specifying measurements data at chosen heights are necessary for calibration of calculation model.
• Parameters of soil of a seabed in the chosen area – for specification of technical parameters of the bases and foundations of the wind turbines;
• Additional specific information on restrictions of navigation, air traffic, boundary aspects for chosen area.
• Future oil and gas production in the zone.

The fragment of Grid contiguous to chosen site is presented on the Figure 9.

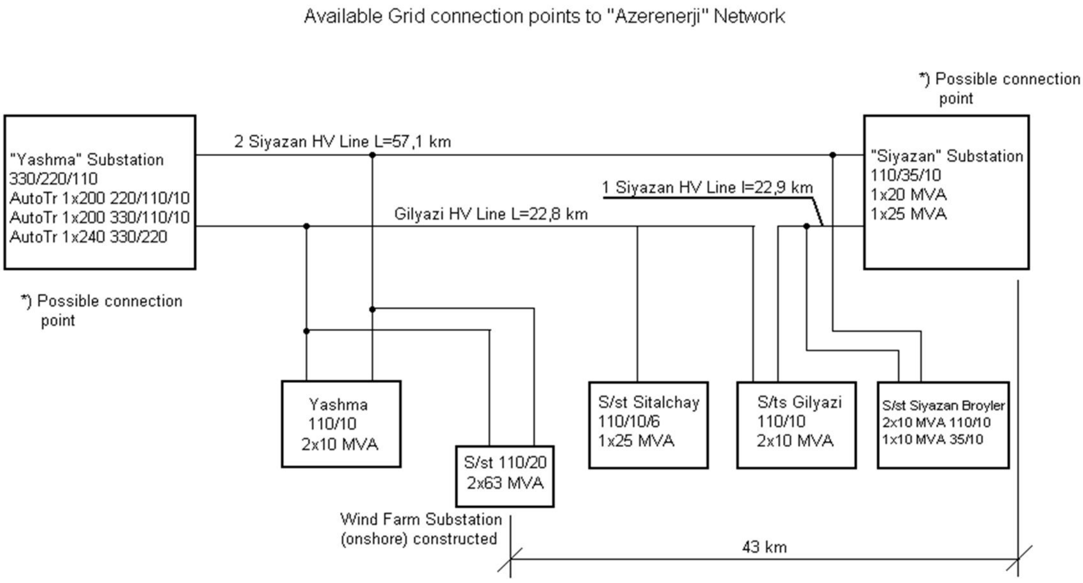

Figure 8. The Diagram of power substations of "Azerenerji" Grid at the north side of Apsheron peninsula

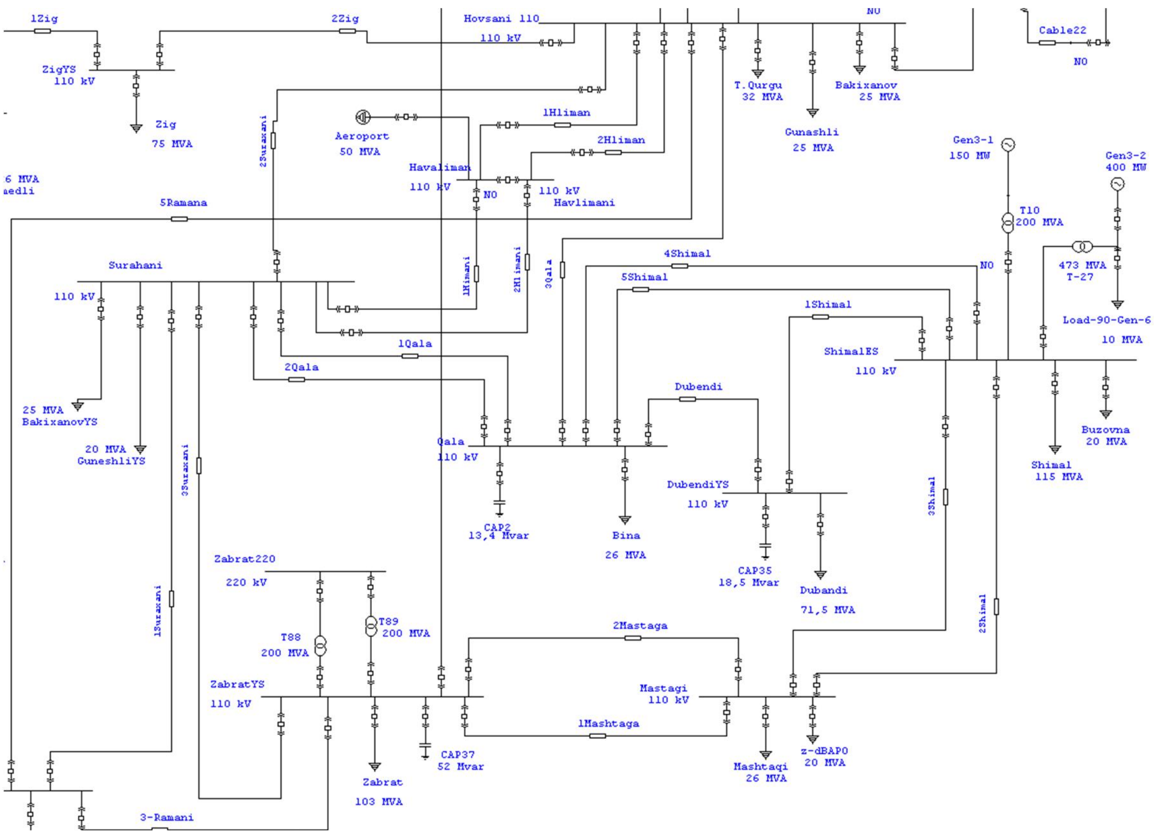

Figure 9. The Fragment of an "Azenerji" Grid on the northern coast of Apsheron, adjoining a zone of an arrangement of perspective wind farm

Figure 10. The map of location of Substations of "Azerenerji" Grid, adjoining a zone perspective for wind farm

IV. MODELING OF THE SEA WIND FARM OPERATION IN CONNECTION WITH GRID

The aspects of connection are with "Azerenerji" Grid. In Figure 8 the diagram of Grid substations located on the northern coast of Apsheron, and the nearest point for possible connection to a Grid is Substation "Siazan" of 110/35/10 kV at about 43 km from a possible wind farm substation. The 110/10 kV buses of the Substation "Siazan" was chosen to connect the wind farms to the Grid.

Results of modeling show that Grid operation stability is provided and it generally depends on a power production ratio between traditional sources and wind farm [9]. In Figure 10, geographical locations of the substations along the coast are shown.

V. CONCLUSIONS

A mapping of prospective wind farm location is carried out, based on the analysis of long-term monitoring and measurements of wind parameters for various regions of the Caspian Sea offshore zone and of parameters of Global Meteorological Model the choice.

- It was shown that measurement data corresponds to probabilistic estimates for power production from wind turbines.
- Among the chosen and mapped sites of an offshore zone the most suitable are allocated on economic indicators and convenience of an arrangement to connection to the grid.
- The most suitable for a choice of a connection point on the northern coast of Apsheron is defined with the help of the developed models.
- A comparison of the economy of various types of wind turbines is presented.

REFERENCES

[1] J. Klimstra, M. Hotakainen, "Smart Power Generation - The Future of Electricity Production", Avain Publishers, Helsinki, 2011.
[2] "Materials of the Workshop of a Legal Frame Work for the Promotion Renewable Energy Sources in Azerbaijan - Focus on Best International Practice and Technical Aspects", OSCE, Office in Baku, 21-23 June 2011.
[3] W. Durrschmidt, E. Hammer, "Renewable Energies - Innovations for a Sustainable Energy Future", Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), p. 11, 2009.
[4] N.R. Rahmanov, "The Electricity Grid and Administrative Procedures in Azerbaijan: Challenges Regarding the Integration of Renewable Electricity - Part 1", Baku, 2011.
[5] N.R. Rahmanov, R.N. Rahmanov, E. Pirverdiev, "The Wind Energy Potential and its Use of Wind Power Installations in the Caspian Sea", Baku, Azerbaijan, 2002.
[6] P. Gipe, "Wind Energy Basics", Vermont Chelsea Green, 1999.
[7] V.H. Alcalde, L.L. Freris, "Control Policies for Maximizing Energy Extraction from Wind Turbines", Proceedings of Fourth International Symposium on Wind Energy Systems, 1982.
[8] S.K. Kim, E.S. Kim, J.Y. Yoon, H.Y. Kim, "PSCAD/EMTDC Based Dynamic Modeling and Analysis of a Variable Speed Wind Turbine", IEEE, Vol. 2, pp. 1735-41, 2004.
[9] N.R. Rahmanov, A.M. Hashimov, R. Kerimov., "Effect of Combined Wind and Diesel Distributed Generation on Power System Operation", Renewable Energy World Conference and expo Europe, Fiera Milano City, Milan, Italy, 2011.

BIOGRAPHIES

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