Preliminary Evaluation of Wind Energy Utilization on Margarita Island, Venezuela

F. Gonzalez-Longatt, *Member, IEEE*, J. Mendez, R. Villasana, C. Peraza

Abstract— **Recently the Venezuelan government has begun a more aggressive policies and incentives on renewable energy resources. In this paper a preliminary evaluation of wind energy resource on Margarita Island was developed. Results of this evaluation, La Vecindad area was diagnostic with sufficient potential from several points of view for utility wind farm developing. Considering maximizing of land use of La Vecindad, technical economic evaluation exhibit feasibility of built a wind farm with eleven Enercon E-20 wind turbines to provide 22 MW to Margarita Island electric utility on Los Mijanes substation at 115 kV. A final evaluation of wind energy resource is recommended for this location, and take account the no-sale fuel produced for wind farm, to make more attractive the final project.**

Index Terms—**Renewable energy, wind energy resource, wind farm.**

I. Introduction

VENEZUELA is a country on the northern tropical Caribbean coast of South America. Venezuela borders Brazil to the south, Guyana to the east, and Colombia to the west. North of the Venezuelan coast lie the islands of Aruba, the Netherlands Antilles, and Trinidad and Tobago. With 916.050 km^2, Venezuela is home to a wide variety of landscapes, such as the north-easternmost extensions of the Andes Mountains in the northwest and along the northern Caribbean coast, of which the highest point is the Pico Bolívar at 4,981 m. The center of the country is characterized by extensive plains known as the llanos, and the south are found the dissected Guayana Highlands.

Recently the Venezuelan government has begun a more aggressive policies and incentives on renewable energy resources. An important fact is the Venezuela incorporation on Kyoto Protocol and his ratification on December 7 of 2004. Over last two years, special concern on wind energy has been important by the Venezuelan Government. The Business Planning 2005-2012 of the most important Venezuelan petroleum company, *Petróleos de Venezuela S.A.* (PDVSA), include several energetic projects with wind resources, solar energy and fuel cell on transport application. Projects to installation of five wind farms in the archipelagoes Los Roques and Los Monjes and in the islands La Tortuga, La Ochila and La Blanquilla [1]. This wind farms, will be added to two project of wind farms to be developed on La Guajira and La Peninsula de Paraguaná [2]. Some preliminary studies indicate the possibility of installations of some wind farm up to 100 MW on La Peninsula de Paraguaná [3].

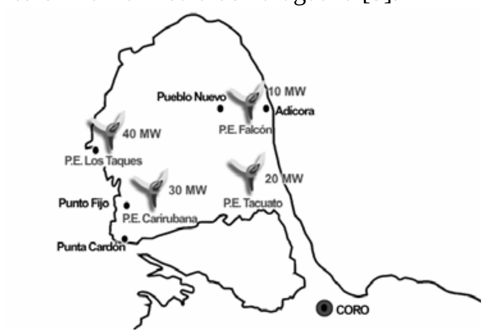

Fig. 1. Wind Farm to be installed on La Península de Paraguaná [3].

In this paper a preliminary evaluation of the wind energy resource is developed on Margarita Island, Venezuela. Results of the evaluations La Vecindad wind farm preliminary project is proposed; and this results are shown in this paper.

II. Evaluation

A. Margarita Island Situation

Margarita belongs to the collar of islands that form the Minor Antilles and located about 25 km north-East of the mainland and only 12 degrees north of the equator. The territorial extension is about 934 km^2.

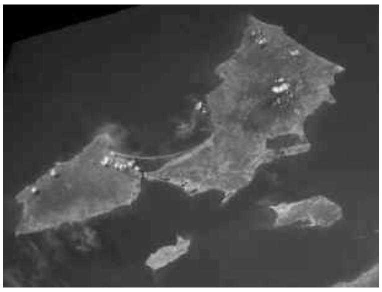

Fig. 2. Satellite view of Margarita Island, Venezuela [4]

Its longer part, from the east to west, reaches about 62 km and its biggest width is 32 km (Figure 2). The narrow isthmus joining the eastern and western sides of Margarita is the national park La Restringa.

F. González-Longatt, J. Mendez, R. Villasana and C. Peraza are with Department of Electrical Engineering, Universidad Nacional Experimental Politecnica de la Fuerza Armada, Maracay, Aragua 2122, Venezuela (e-mail: fglongatt@ieee.org, juane2586@yahoo.com ravillasana@yahoo.com cperazam@cantv.net).

F. Gonzalez-Longatt is PhD student, Universidad Central de Venezuela, Caracas, 1011 Venezuela (e-mail: flongatt@elecrisc.ing.ucv.ve).

B. Weather Evaluation

For this preliminary evaluation of the wind energy resource on Margarita Island, NASA Earth Science Surface meteorology and Solar Energy (SSE) [4] data set and data from some weather stations on airports was used. Margarita Island territories were divided on four zones (North-East, North-West, South-East, South-West, considering the resolution of the SSE information and the regional politic divisions); on Table I show average wind speed over ten year measured at 50 m, the northeast zones exhibit a better wind condition than southeast regions.

TABLE I
MONTHLY AVERAGE WIND SPEED OVER A TEN YEARS PERIOD AT 50 M [4]

Zone	*South-West*	*North-East*	*North-West*	*Sorth-East*
January	5.00	7.31	7.13	5.60
February	5.36	7.45	7.45	5.74
March	5.49	7.59	7.65	5.82
April	5.26	7.29	7.24	5.59
May	4.74	6.53	6.41	5.11
June	4.34	6.52	6.32	4.84
July	4.13	6.20	6.04	4.57
August	3.80	5.37	5.30	4.03
September	3.65	4.83	4.76	3.75
October	3.63	4.80	4.71	3.74
November	3.84	5.33	5.22	4.05
December	4.50	6.58	6.40	4.93
Mothly Av. (m/s)	4.47	6.31	6.22	4.81

A complete weather evaluation was developed, considering ambient temperature, atmospheric pressure, rain precipitation, and other climatic variables; a monthly, hourly measure was studied and max, min and average values was calculated. On Figure 3, show the most suitable regions based on weather diagnostic for wind farm location on Margarita Island.

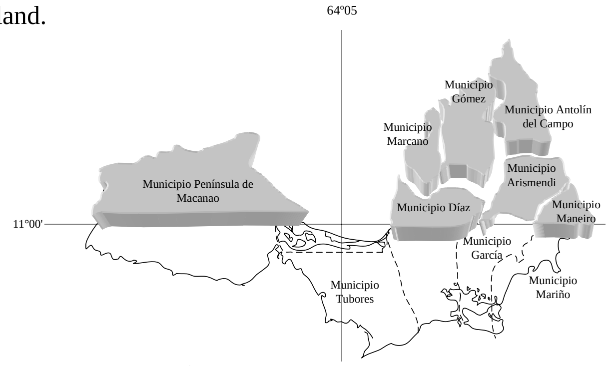

Fig. 3. Suitable Regions for Wind Farm location on Margarita Island based on Weather Diagnostic

Detailed wind resource information is compiled and shown on Figure 4. Wind rose, Weibull distribution and Reylaigh distribution for each zone was developed.

C. Environment Constraint

Land final use, land owned and environmental constraints are special issued to consider on location selection for wind farm on Margarita Island. Venezuelan laws establishes a basic rules for basic land use and ownership. Specifically, on territories ordination plan of the Nueva Esparta State, law is clear on decelerate zones and uses of land: agriculture, industry, miner, rural, urban, fishing, special administration areas, etc. Considering this restrictions and other like environmental, a complete map was developed, just zones with potential wind resources are denoted as gray color on the map, Figure 5.

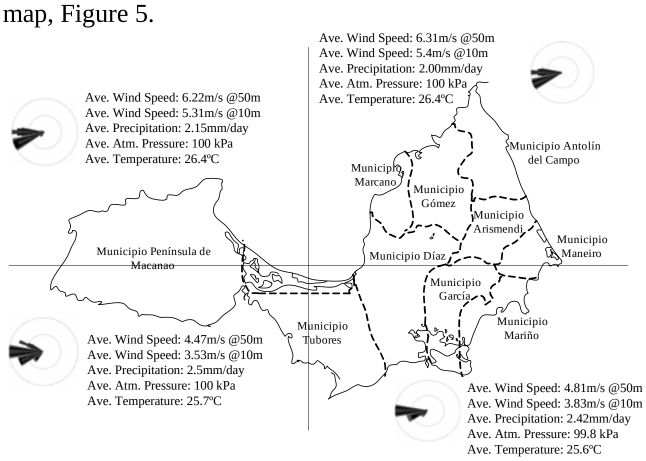

Fig. 4. Weather Variables Resume on Margarita Island

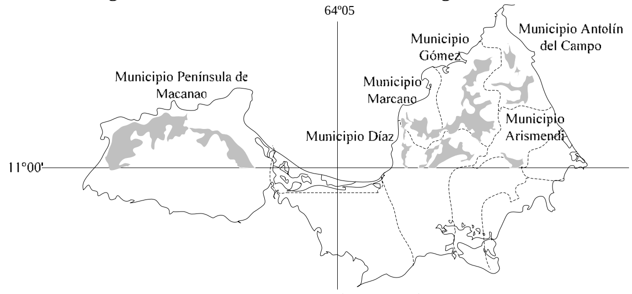

Fig. 5. Available and Appropriates lands for wind farm locations, considering environmental, land use, land owned and tourist restrictions on Margarita Island

D. Communication and Electrical Access

Communication access to wind farm location is important to provide a way to carry all equipment and facilities. On Figure 6, a complete highway and road map on Margarita Island is shown.

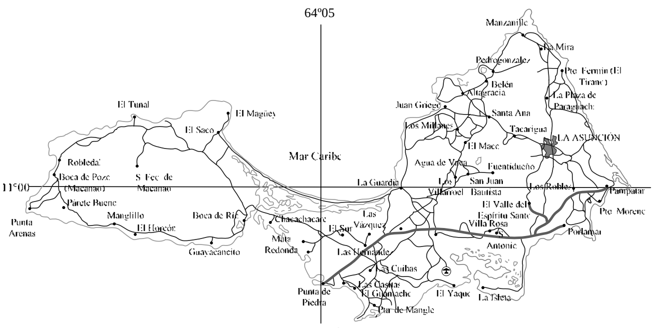

Fig. 6. Road Map of Margarita Island

E. Electrical Service

Sistema Electrico de Nueva Esparta C. A, SENECA, is the power utility for the Margarita Island; this is a connection with the Venezuelan power pool by a 115 kV submarine power cable, connecting the on shore electrical power system between Chacopata I substation and Luisa Cáreces de Arismendi substation. This power cable is rating for 100 MW, and was installed on 1976; today available transfer capacity is only limited to 40 or 50 MW, because several failures have deteriorated the thermal capacity of this cable. On Margarita Island, SENECA operate only a generation plant named Luisa Cáceres de Aristendi, with nine thermal dual fuel machines:

232.21 MW, 13.8 kV. Main characteristic of this generation units are shown on Table II.

TABLE II
MAIN CHARACTERISTIC OF GENERATION UNITS INSTALLED ON LUISA CÁCERES DE ARISMENDI POWER PLANT [5]

Unit	*Manufacturer*	*Voltage (kV)*	*Power (MW)*	*Power Factor*
3-4	AEG-KANIS	13.8	21.7	0.8
5-6-7	HITACHI	13.8	20	0.8
8-9	General Electric	13.8	20	0.8
10	General Electric	13.8	40	0.85
11	General Electric	13.8	37	0.85

Online diagram representative of the Luisa Cáceres de Arismendi Power Plants y la de la Luisa Cáceres substation is show on Figure 7. On February 2006 this power plant generated 94.1 GWh, and 19.2 GWh was imported from continental Venezuelan power pool by the submarine power cable.

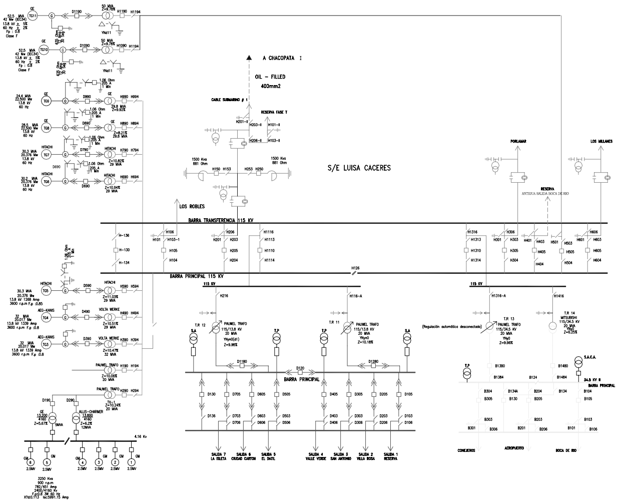

Fig. 7. On-line Diagram of Luisa Cacéres de Artismendi Power Plants and Substation [5]

SENECA transmission system have six step-down substation localized on Margarita Island. These substations are interconnected in ring scheme by more of 40 km of 115 kV overhead transmission lines, main characteristic of this are shown on Table III. Subtramission system is used by SENECA to interconnect main substation on 34.5 kV level; a representative parameter of this overhead sub transmission is shown on Table IV.

TABLE III
MAIN CHARACTERISTIC OF 115 KV OVERHEAD TRANSMISSION SYSTEM OF MARGARITA ISLAND [5]

Stations	*Long. (Km)*
Luisa Cáceres –Porlamar	9.96
Porlamar-Robles	3.37
Robles-Pampatar	6.87
Pampatar-Asunción	6.11
Asunción-Millares	12.2
Millares-Luisa Cáceres	18.55
Luisa Cáceres - Los Robles	10.03

On Margarita Island the distribution system is operated by SENECA using a 13.8 kV level, with more than 250 MVA of step-down transformation capacity; detailed characteristics of transformer per substation is shown in Table V.

TABLE IV
MAIN CHARACTERISTIC OF 34.5 KV OVERHEAD SUB-TRANSMISSION SYSTEM OF MARGARITA ISLAND [5]

Stations	*Long (km)*	*Wire Gauge*	*Conductor*
Luisa Cáceres -Boca de Río	37.57	350 MCM	ACAR
Luisa Cáceres- Las Hernández	22	4/0 AWG	Aluminum
Las Hernández- Boca de Río	20	2/0 AWG	Cooper
Luisa Cáceres- Aeropuerto	17.3	4/0 AWG	Aluminum
Las Hernández- Aeropuerto	10	4/0 AWG	Aluminum
Luisa Cáceres- Conejeros	4	4/0 AWG	Aluminum
Los Robles- Conejero	6.3	4/0 AWG	Aluminum
Los Robles-Morropo	6.4	4/0 AWG	Aluminum
Pampatar- Morropo	4.5	2/0 AWG	Cooper
Los Millanes- Aricagua	25	-	-

TABLE V
MAIN CHARACTERISTIC OF TRANSFORMER IN DISTRIBUTION STATION OF MARGARITA ISLAND [5]

Station	*Number of Transformers*	*Transformer Ratio*	*Capacity (MVA)*
Boca de Río	1	34.5/13.8	7.5
Las Hernández	1	34.5/13.8	10
Aeropuerto	1	34.5/13.8	7.5
	1	34.5/13.8	3.5
Conejeros	2	34.5/13.8	20
Morropo	2	34.5/13.8	20
Pampatar	1	115/34.5	20
	2	115/13.8	20
Los Robles	2	34.5/13.8	20
Porlamar	2	115/13.8	30
Luisa Cáceres	2	115/13.8	20
Los Millanes	2	115/13.8	20
	1	115/34.5	10
Acarigua	1	115/13.8	10
La Asunción	1	115/13.8	16
	1	115/13.8	30

A complete one-line diagram of Margarita Island transmission system is shown on Figure 8, and electrical-geographic map on Margarita Island is shown on Figure 9.

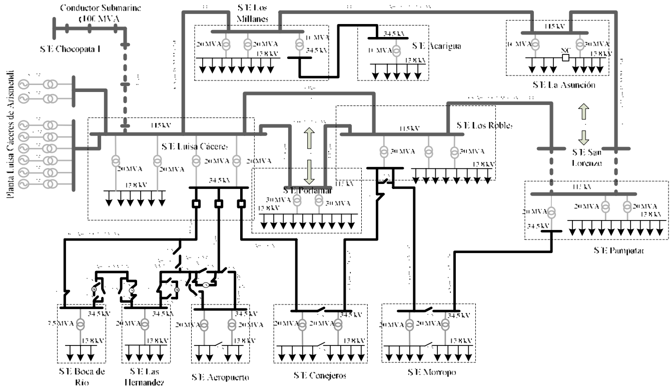

Fig. 8. One-line Diagram of Transmission System on Margarita Islands [5]

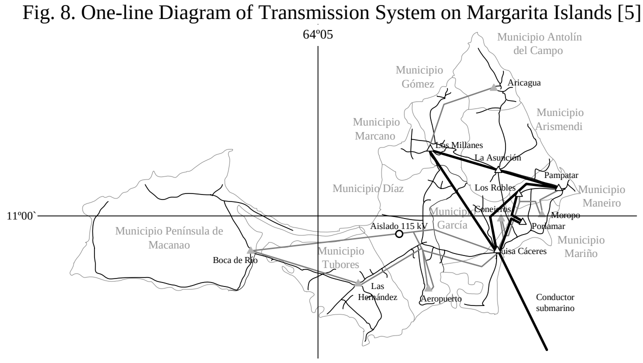

Fig. 9. Electrical-Geographic Map of Margarita Island

Electrical power consumption has been growing in last seven years on SENECA utility system, and the demand exhibit a characteristic cycle over year, in August to

September typically primary peak on electric power consumption is due high tourist season. Detailed curves of power demand are shown in Fig. 10.

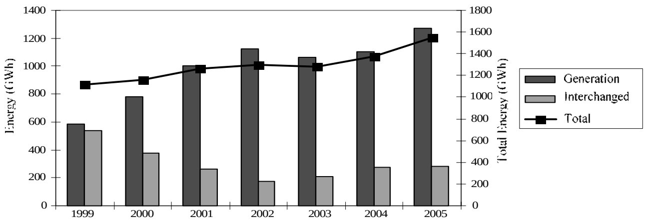

Fig. 10. Power demand behavior on Margarita Island 1999-2005

III. Wind Farm Design

A. Location

Considering preliminary diagnostic developed on last section. The location that accomplish with all restrictions is a land called La Vecindad, on Municipio Gómez at 1 km of Santa Ana; capital city of Municipio Goméz. This zone is a flat land with small vegetation and without threes.


Fig. 11. Photo of Candidate for Wind Farm developing at La Vecindad

La Vecindad provide a adequate wind energy resource, way access, and near to power grid, least 8 km of Los Millanes substation at 115 kV. A resume of wind energy resource and weather information is shown in Figure 12.

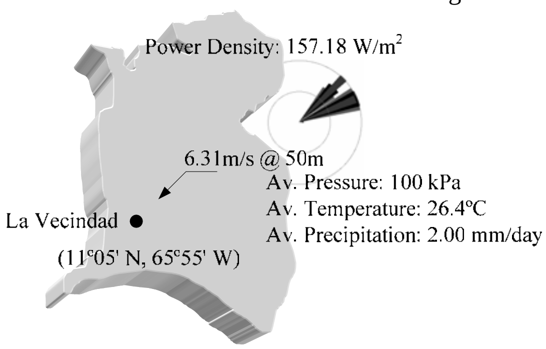

Fig. 12. Weather information at La Vecindad location

B. Sizing

Preliminary wind farm design is named La Vecindad. For technical and economical evaluation tree different wind turbines types was used: (WT-1) Enercon E-33, 330 kW [6], (WT-2) Gamesa G-58, 850 kW [7], (WT-3) Enercon E-70, 2000 kW [6].

Considering the 187.8 Ha available on La Vecindad zone and the main characteristic of wind turbines considered, Table VI show number for wind turbines to be installed (8.7 Ha was reserved for other wind farm facilities as transformers stations, control room, etc).

TABLE VI
MAIN CHARACTERISTIC OF WIND TURBINE AND NUMBER OF BE INSTALLED ON LA VECINDAD WIND FARM

Wind Turbine Model	*Power Capacity (kW)*	*Rotor Diameter (m)*	*Physical space (Ha)*	*Number of wind turbines*	*Wind Farm Power Installed (MW)*
WT-1	330	33,4	3.15	51	16.83
WT-2	850	58	9.51	17	14.45
WT-3	2000	71	14.24	11	22.0

To define the penetration level of the Vecindad wind farm, short circuit current of the nearest substation, Los Millanes at 115 kV was considered (Table VII); for all wind turbine models a low penetration level (>20) was obtained, and for final wind farm more detailed studies, i.e. short circuit, stability, etc would be conduced.

TABLE VII
PENETRATION LEVEL FOR SEVERAL WIND TURBINE MODEL OF LA VECINDAD WIND FARM

Wind Turbine Model	*Installed Capacity (MVA)*	*Penetration Level (Quantitative)*	*Penetration Level (Qualitative)*
WT-1	17.71	45.28	Low
WT-2	15.21	52.72	Low
WT-3	23.15	34.64	Low

Using a RETScreen® software and information of weather and wind turbine manufacturer, key technical and economics aspects was calculated and summarized on Table VIII.

TABLE VIII
TECHNICAL AND ECONOMIC INDICATOR FOR EVALUATION OF LA VECINDAD WIND FARM

Wind Turbine Model	*Energy Output MWh/year*	*Installed Power Cost (US$/kW)*	*Positive flow Cash (years)*
WT-1	37.465	1498.906	7.7
WT-2	34.091	1485.060	4.8
WT-3	44.062	1280.600	4.1

On Figure 13 cash flow over life time period of wind turbines model are shown. The WT-3 exhibit a short positive flow cash time with 4.1 years and minimum installed power cost.

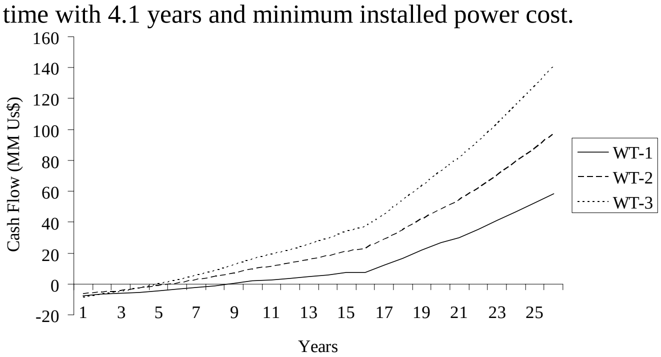

Fig. 13. Cash Flow over time for wind turbine types to be installed on La Vecindad wind farm

TABLE IX
RESUME OF FINANCIAL INDICATORS OF LA VECINDAD WIND FARM VIABILITY

Wind Turbine Model	*Inicial Cost (MM US$)*	*Net Present Value (MM US$)*	*Energy Production Cost (US$)*	*Return Over Invest index (%)*
WT-1	24.993	13.548	0.084	16.4
WT-2	21.659	12.749	0.0738	26.1
WT-3	28.173	20.287	0.0597	29.6

Financial report shown on Table IX indicate that WT-3 is most favorable alterative for the La Vecindad wind farm, although exhibit highest initial cost have shorter return over the invest.

La Vecindad wind farm will be exanimate more detailed in next study, a full evaluation study when wind speed resource will measure locally; but results of this preliminary evaluation a wind farm with eleven (11) wind turbine Enercon, Model E-70, 2000 kW, 22MW of installed capacity results feasibility on La Vecindad area, on Margarita Island, Venezuela.

IV. Conclusions

This preliminary evaluation of wind energy resource on Margarita Island indicates good possibilities of utility power production on northeast island regions. After considerations of weather, environmental restraints, land use, electric utility connections, and others, a place named La Vecindad was defined as favorable for wind farm localization.

Evaluation of several wind turbines types and technologies was developed. Economic and financial indicators reveal feasibility of develop La Vecindad wind farm to be composed of eleven wind turbines Enercon E-70, 2000 kW for a 22MW of capacity installed.

Although Venezuelan is one of most important oil producer, and power utilities exhibit low electric tariffs, wind farm feasibility result more attractive when cost of no-sale oil is calculated.

V. Acknowledgment

The authors gratefully acknowledge the contributions of Professor Celso Fortoul of Universidad Central de Venezuela, Professor Alberto Urdaneta and Professor Roberto Alves of Universidad Simon Bolivar for their work on the original version of this document.

VI. References

[1] "Energía alternativa viene en camino". Artículo de prensa. Diario El Universal, Domingo 30 de Octubre de 2005. Cuerpo 2: Disponible en : http://www.eluniversal.com/2005/10/30/eco_art_30201A.shtml

[2] Victor Castillejo. Ministerio de Energía y Minas, Dirección General Sectorial de Energía. Guía Práctica para el Cálculo de Aerogeneradores. Caracas. 1985.

[3] Fernández I. (2005). "Proyecto Jurijurebo. Península de Paraguana". Encuentro sobre Oportunidades de Negocios para Empresas Latinoamericanas de la Industria de la Construcción "Construir sin Fronteras". 20 y 21 de Abril de 2005, Caracas Venezuela.

[4] Surface Meteorology and Solar Energy [On-Line] Available at: http://eosweb.larc.nasa.gov/sse/

[5] Information obtained directly of SENECA Main Office, March 22 and 23, 2006, Headquarter on Calle Principal Sector San Lorenzo, Pampatar, Isla de Margarita, Venezuela.

[6] Technical Specification of Win turbine Enercon Model E33 and E70 [Electronic file]. Available at en: http://www.enercon.de [Consult: 2006, Mayo 23].

[7] Technical Specification of Win Gamesa Model G58. [Electronic file]. Available at: http://www.gamesa.es [Consult: 2006, Mayo 23].

VII. Biographies

Francisco M. González-Longatt (S' 1998, M'2005) was born in Cagua in Venezuela, on July 30, 1972. He graduated on Electrical Enginnering of Instituto Universitario Politécnico de la Fuerza Armada Nacional, Venezuela (1994), and Master of Business Administration of Universidad Bicentenaria de Aragua, Venezuela (1999). He is assistant professor on Electrical enginnerging Department of Universidad Nacional Politécnico de la Fuerza Armada Nacional, and PhD student on Universidad Central de Venezuela, reaching on alternative energy resources and power system stability with distributed generation.

Juan Mendéz is graduated of Universidad Experimental Politécnica de la Fuerza Armada Nacional, Venezuela (2006), and his main research interests are on renewable energy and wind power integration.

Rafael Villasana is graduated of Escuela de Formación de Oficiales de la Guardia Nacional, Venezuela (1989) as army oficial, and electrical engineer of Universidad Nacional Experimental Politécnica de la Fuerza Armada Nacional, Venezuela (2006). His main interest is economical issues of wind power integration.