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Experimental Study of Wind Turbine blade consists of Airfoils (NACA 63.XXX+FFA-W3)

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***Abstract*—Wind turbines have been shown to be one of the most viable sources of renewable energy. With new technology, the low cost of wind energy is competitive with more conventional sources of energy such as coal. Most blades available for commercial grade wind turbines incorporate a straight span-wise profile and airfoil shaped cross sections. In this paper studies of NACA 63.XXX+FFA-W3 airfoils blade at zafarana wind farm, Egypt. The Wind turbine's structure, parameters, electrical control system and low voltage installation are introduced; there are two projects at Zafarana site are focused. The first is named as zafarana No. (7) Consists of 142 turbines as shown figure (1-a) and the other is named as zafarana No. (8) Consists of 142 turbines as shown figure. (1-b), the distance between them is about 12 kilometers. This paper studies the effect of wind speed, landscape, alarms and spare parts on the power production and availability**

Keywords—: wind turbine, power generation, availability, wind speed

Fig. 1-a

I. INTRODUCTION

Wind turbines interact with the wind, capturing part of its kinetic energy and converting it into usable energy. Historic designs, typically large, heavy and inefficient, were replaced in the 19th century by fossil fuel engines and the implementation of a nationally distributed power network. A greater understanding of aerodynamics and advances in materials, particularly polymers, has led to the return of wind energy extraction in the latter half of the 20th century. Wind power devices are now used to produce electricity, and commonly termed wind turbines. This paper mainly introduces studying two projects in zafarana site and the affection of climate, landscape, human factors, mitigations loads "depend on national network of electricity " and spare parts.

Fig. 1-b

Fig. 1-a, 1-b the landscape zafarana NO. (8) is flatter than zafarana NO.(7)

II. WINDTURBINE DESCRIPTION

The Gamesa G52- 850 kW is a three bladed, upwind, pitch regulated and active yaw upwind-turbines as shown figure 2-a It has a rotor diameter of 52 m as shown figure 2-b and uses the Ingecon-W control system concept that enables the wind-turbine to operate in a broad range of variation of rotor speed [1]. The rotor pitch is variable and equipped with Optitip system. This feature provides fine adjustment of the blade-operating angle at all times with respect to power production and noise emission.

The main shaft transmits the power to the generator through the gearbox. The gearbox is a 3 stages Combined planetary and helical parallel shafts gearbox. From it the power is transmitted via a flexible coupling to the generator.
The generator is a high efficiency 4 – pole doubly fed generator with wound rotor and slip rings.
The wind-turbine primary brake is given by full feathering the blades. The redundant brake is an emergency disc brake system hydraulically activated and mounted on the gearbox high-speed shaft.

Vane)

All functions of the wind turbine are monitored and controlled by several microprocessor based control units. The controller system is placed in the nacelle. Blade pitch angle variation is regulated by a hydraulic system actuator which enables the blade to rotate from –5° to 88°. This system also supplies pressure to the brake system.
The yaw system consists of two gears electrically operated and controlled by the wind turbine controller based on information received from the wind vane mounted on top of the nacelle. The yaw gears rotate the yaw pinions, which mesh with a large toothed yaw ring mounted on the top of the tower. The yaw bearing is a plain bearing system with built-in friction.

A- INGECON-W SYSTEM

The Ingecon–W system consists of an effective asynchronous generator with wound rotor, slip rings, and two 4-quadrant converters with IGBT switches, contactors and protection [2]

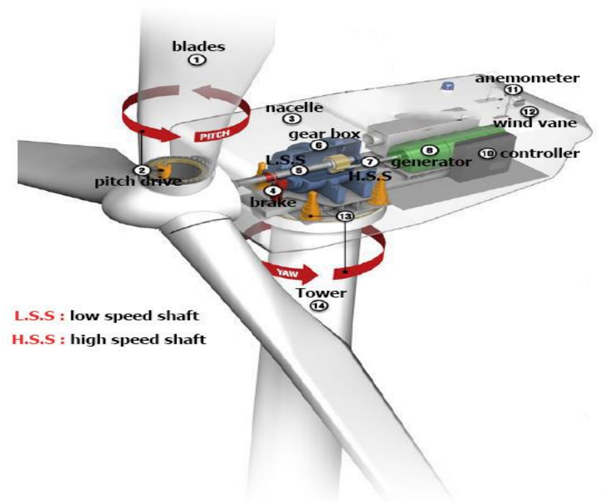


Fig. 2-a

B- MEASURING THE WIND

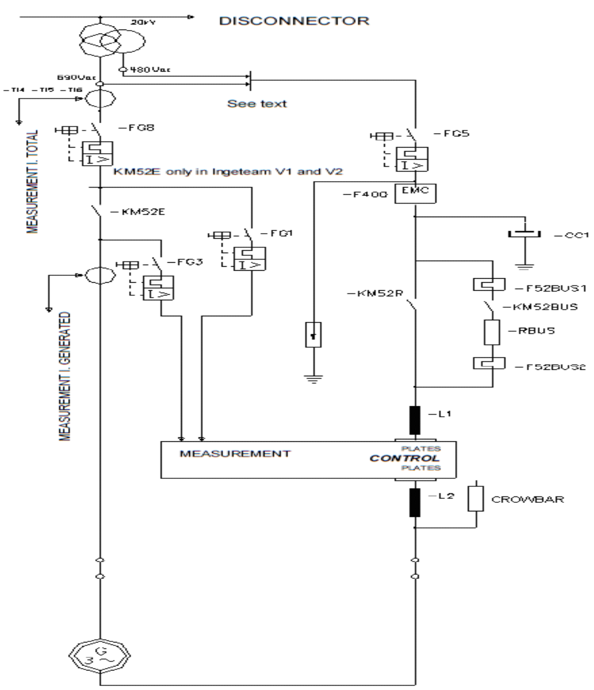
Outside the nacelle, in the rear part, a vertical mast supports the wind-measuring sensors (anemometer and wind-vane).

F. 2-b

C- DESCRIPTION OF THE DOUBLE FED SYSTEM

The double fed machine (DFM) is the equipment that regulates and protects electrical energy production from the wind turbine. The double fed machine consists of a double fed asynchronous generator with access to the rotor winding via slip rings. The stator (in delta) is connected directly to the grid and the rotor is connected to a frequency converter[3]. In addition, the converter is connected to the grid. This layout ensures that, for electrical distribution grid, the wind turbine behaves as a synchronous generator. Which serves to stabilize the grid, enabling the connection of several wind turbines, and eliminates the need for capacitor banks to compensate reactive power and resonance problems, The converter control unit (CCU) controls the active and reactive power with the frequency converter connected to the generator rotor, this is, and it allows the user to select the desired power factor.

The single row-diagram the double fed machine is as following



The main characteristics of the LV installation are listed below.

- **Rated voltage 690 V**
- **Frequency 50/60HZ**
- **Rated power 850KW**
- **Rated current a t690V 800 A**
- **Maximum short- circuit current in LV (MV grid+generator) 16 A**
- **Rated current provided by a wind turbine at 20KV 27.6 A**
- **Rated current provided by a wind turbine at 30KV 18.4 A**

Generator data

- **Voltage per phase 690 V**
- **Resistance of stator"R1" 0.0159(115 C)**
- **Reactance of stator"X1" 0.0755Ω**
- **Resistance of the rotor referred to stator "R2" 0.011Ω**
- **Reactance of the rotor referred to stator "X2" 0.105Ω**

Tables 1. Parameters of the design of G52 - 850 KW wind-turbines [4]

Concept	Value	Units	Remarks
IEC class	S	-	IEC 61400-Ed.2
Annual mean wind speed	7.5	m/s	Referred to hub height
Weibull shape parameter ,K	2	-	
Turbulence intensity at 15m/s,I_{16}	16	%	
Reference wind 10min. averaged	43	m/s	50 years recurrence time
Reference wind 3 sec. averaged	52.5	m/s	50 years recurrence time
Stop / restart wind speed	21/18	m/s	100 sec filtere

NOCE CONE

DEMENSIONS	Length 2.70 m; root Diameter 2.20m
MATERIAL	Glass reinforced polyester coated with gel- coat
WEIGHTS	220Kg

BLADE

Principle	Shells bonded to supporting beam
Material	Glass fibre reinforced epoxy
Blade connection	Steel root inserts
Airfoils	NACA 63.XXX+FFA-W3
Length	25.3m
Chord(root/tip)	2.32m/0.3m
Max. Twist	16.4^0
Weight	Approx.2550 Kg/piece

ROTOR

Diameter	52m
Swept Area	2010.9 m^2
Rotational Speed Operation Interval	14.6 : 30.8 rpm (T55, T65m) 16.2 : 30.8 rpm (T44m)
Sense of Rotation	Clockwise (front view)
Rotor Orientation	Upwind
Tilt angle	6^0
Blade coning	3^0
Number of blades	3
Aero-dynamic brake	Full feathering

NACELLE COVER

6590×2240×2850mm^3	Dimensions
Glass fibre and polyester resin	Material
1600 Kg	Weight

ROTOR HUP

Spherical	Type
Nodular Cast Iron	Material
EN-GJS-400-18U-LT per EN 1563	Material specification

MAIN SHAFT SUPPORT

Type	Cast iron support
Material	Nodular cast iron
Material speciation	EN-GJS-400-18U-LT Per EN 1563

MAIN SHAFT BEARING

Type	Spherical Bearings
Blade bearing	
Type	4- Point ball bearing. Double row

MAIN SHAFT

Type	Forged shaft
material	Quenched and tempered steel
Material speciation	34CrNiMo6 per EN 10083-1

YAW GEARS

Type	3planetary stages
	1 worm gear non- locking Stage (maximum ratio 1:10)
motor	2.2 kW .6 pole Asynchronous motor with brake

MAIN FRAME

Type	Combination of welded steel plates

YAW SYSTEM

Type	Plain bearing system with brakes and spring Loaded pads
material	
Yaw ring	
Base	EN-GJS-400-18U-LT ass.to EN 1563
Teeth inserts	42 CrMo4 per EN 10083
Plain bearing	PETP
Yaw speed	0.4^0/s :1 turn each 15 min

TOWER SECTION CHARACTERISTIC

	Length [mm]	Outer Ø at Bottom[mm]	Outer Ø at top [mm]	Weight [Kg]
Tower44				
Bottom	17688	3018	2440	22000
Top	24448	2440	2170	18100
Tower 55m				
Bottom	9610	3320	3026	16200
Top	19185	3026	2440	22500
intermediate	24448	2440	2170	18100

I
II

III .Case study of wind turbine blade consists of profiles (NACA63.xxx+FFA-W3), model G5٢

Table 2. Comparison between two project at Zafarana wind farm, Egypt through years 2017, 2018, 2019

name	Zafarana No.(8)	Zafarana No.(7)
No. of turbines	142	142
Turbine model	G52	G52
Rated power(per a turbine)	850 KW	850 KW
Manufacturer	Gamesa	Gamesa
Total power	120 MW	120 MW
Blade airfoils	NACA 63.XXX+FFA-W3	NACA 63.XXX+FFA-W3

The affection of the wind and landscape on power production and availability through years 2017, 2018, 2019 as shown at the following figures and tables.

Some notes:-

A- The distance between the two projects is about 12 kilometers

B- The landscape of project Zafarana No.(7) is worse than the landscape of project Zafarana No.(8) as shown figure(1-a), (1-b)

IV .RESULTS AND DISCUSSION

Figures[3,4,5] show power generation distribution of project Zafarana NO.(8) and project Zafarana No.(7) through years 2017, 2018, 2019 respectively where year 2019 is from (Jan to Sep), and show the effect of wind speed, landscape and availability on the power generated from the two projects. as shown the power increases with the wind speed

Generally, the power generated from Zafarana No. (8) is larger than from Zafarana No. (7) Because of :

1- The wind speed in Zafarana No. (8) Is higher than in Zafarana No. (7)

2- The landscape of Zafarana No. (8) Is flatter than Zafarana No. (7)

3- Efficient manpower plays main role in the power generation

Figures [6], [7] show the power distribution of the two projects in June and December. At Year 2017 the maximum power was occurred in June and the minimum power was occurred in December at the two projects.

Figures [8,9] show the power distribution of the two projects in September and November.

At Year 2018 the maximum power was occurred in September and minimum power was occurred in November at the two projects.

As the years pass, the wind speed decreases gradually where the average wind speed at 2019 was smaller than at 2018, and the average wind speed at 2018 was smaller than at 2017 in zafarana site.

Table 3. annual power distribution of the two projects in 2017

months	Zafarana NO.(8)			Zafarana NO.(7)		
	Power(MWh)	Wind(m/s)	availability	Power(MWh)	Wind(m/s)	availability
Jan	19407	6.7	89.8%	18846	5.8	73.4%
Feb	19042	5.6	93.3%	16219	6	76.1%
mar	21190	6.8	93%	17161	6.1	74.8%
apr	21784	6.9	84%	20956	6.2	73.6%
may	17022	6.8	76.9%	15789	6.5	76.6%
Jun	25995	7.4	68.1%	20882	6.4	57.3%
jul	21212	7.3	68%	17714	6.6	60.1%
Aug	21399	7.5	67.6%	16517	6.5	63.5%
sep	16799	8.5	64.7%	18186	8.2	55.1%
oct	17615	7.2	73%	13325	6.5	55.6%
nov	15303	4.9	81.3%	13839	6.1	62.9%
Dec	9790	5.6	81.7%	9499	5.5	66.4%

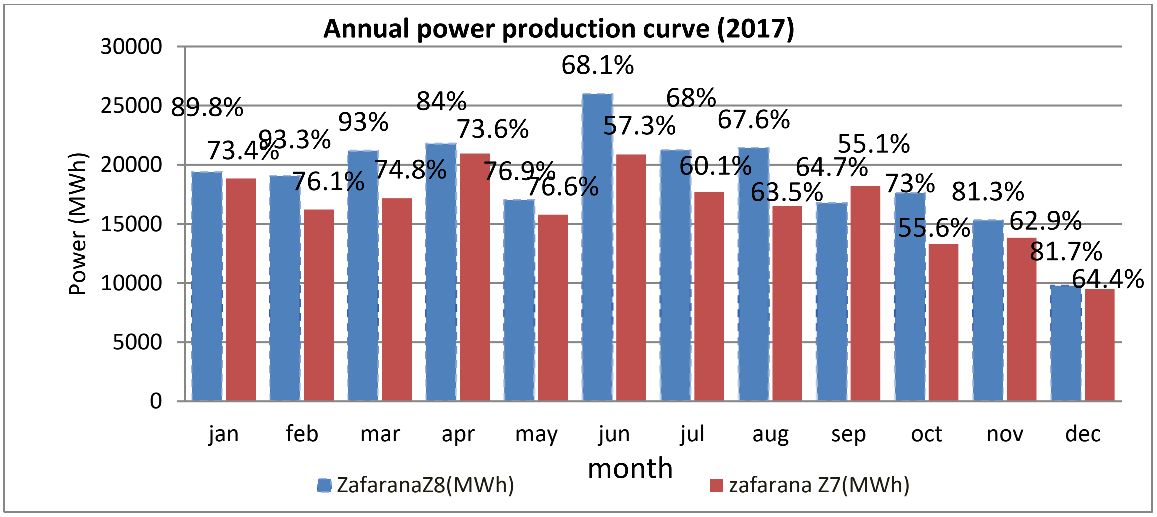


Fig. 3 Annual power distribution of the two projects in 2017

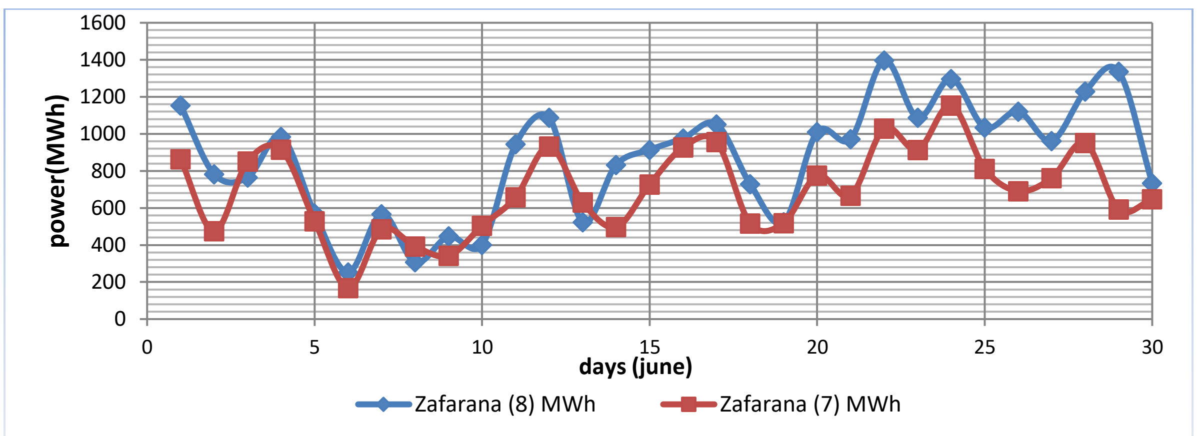


Fig. 6 Power distribution of the two projects in June (2017)

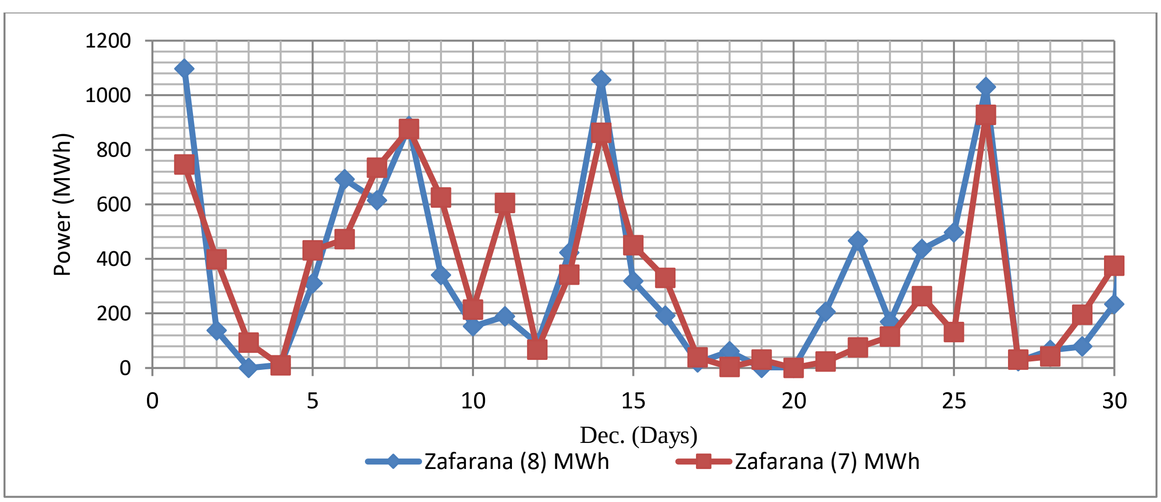


Fig. 7 Power distribution of the two projects in Dec. (2017)

Table 4. Annual power distribution of the two projects in 2018

months	Zafarana NO.(8)			Zafarana NO.(7)		
	Power(MWh)	Wind(m/s)	availability	Power(MWh)	Wind(m/s)	availability
Jan	17060	6.1	86.7%	13686	6.1	70.2
feb	12399	6.2	90.4%	11222	6	72.5%
mar	20834	6.5	90.8%	17909	6.1	76.9%
apr	24760	6.9	91.4%	22403	6.2	79%
may	25063	6.8	90.1%	22431	6.7	81.6%
Jun	28245	7.3	89.9%	22616	7	79.9%
jul	25947	7.2	89.8%	22085	7.2	81.7%
Aug	32312	6.9	91.1%	28297	6.5	81.1%
sep	33896	8.4	91%	30962	8.1	80.4%
oct	22716	6.5	89.9%	22004	6	80.4%
nov	8803	6.3	89.8%	9996	5.8	93.10%
Dec	14635	5.3	87.5%	12564	5.1	88.2%

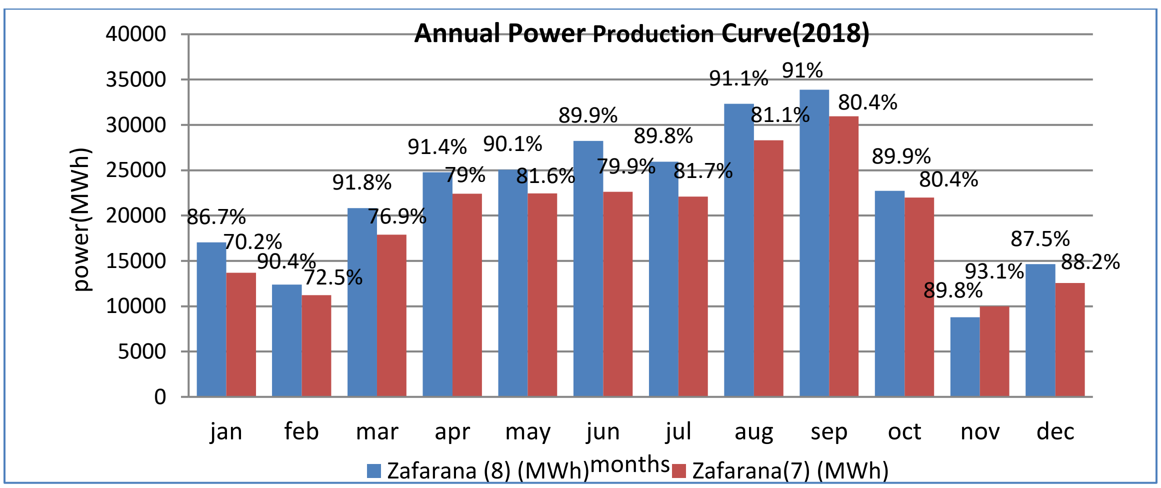


Fig. 4 Power distribution of the two projects in (2018)

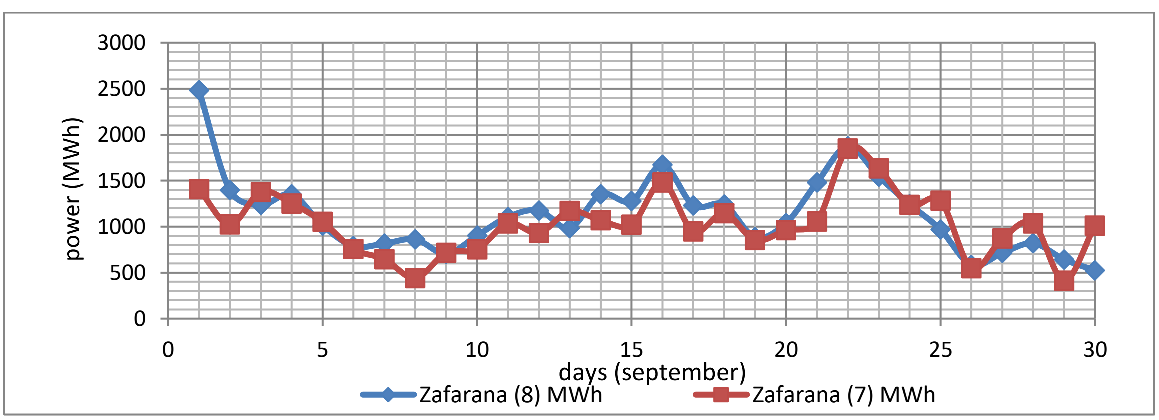


Fig. 8 Power distribution of the two projects in September (2018)

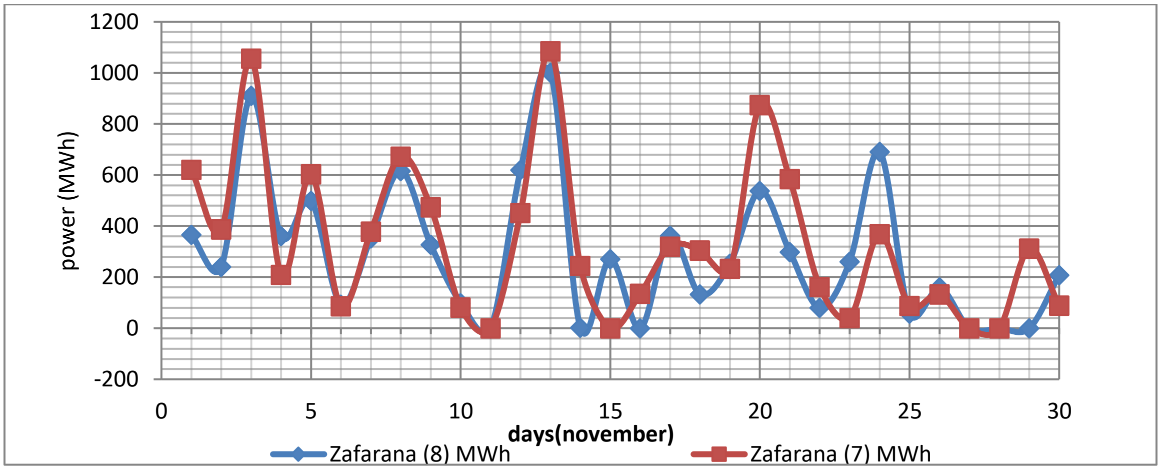


Fig. 9 Power distribution of the two projects in November (2018)

Table 5. Power distributions of the two projects in 2019

months	Zafarana(Z8) (MWh)	zafarana(Z7) (MWh)	availability (Z7) %	Availability . (Z8) %	Aver. Wind speed (m/s)	Aver. Wind speed (m/s)
jan	13840	15895	86.30	84.30	6.05	5.8
feb	12477	12608	90.1	89.50	5.7	6
mar	22408	17204	87.3	92.10	6.8	6.2
apr	19507	15176	88.60	91.70	6.64	6.4
may	27826	24142	90.0	90.27	7.3	7
jun	28511	24980	90.80	93.30	8.4	8.7
jul	26983	24608	89.80	89.70	8.57	8.67
aug	23137	21367	91.20	93.40	7.41	8.2

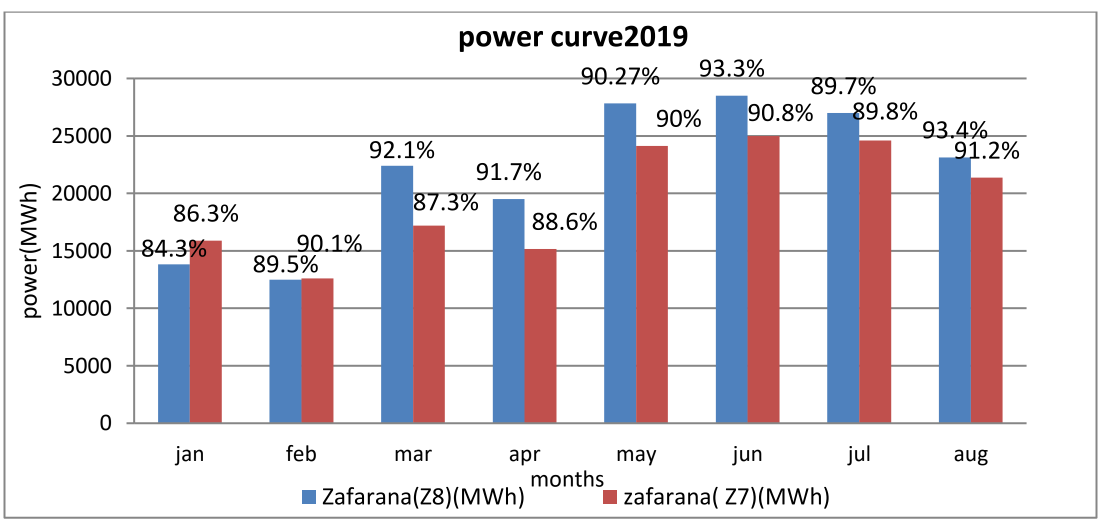


Fig. 5 Power distribution in 2019

VI. Conclusions

Based on the data obtained from SCADA Systems at Egypt, Zafarana Wind farm, it turns out the effect of the following conditions on the power
A-the climate (wind speed, landscape)
B-the human factor
C-Spare parts availability

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