RESEARCH ARTICLE OPEN ACCESS

The Contribution of Wind Power Generation in Kuwait's Grid.

Adel Abdulazziz Alnassar*
**Faculty Member, Electrical Engineering Tech. Department, Industrial Training Institute – Shuwaikh, PAAET, Kuwait*

ABSTRACT: For the past decade The Electrical Power Generation sector is carrying out globally a huge Plan to Adopt Widely the Renewable Energy Resources with its all types, And most of all the PV Solar Power, which is prevailing rapidly in the World and mainly in the Middle east due to its versatility, affordability and relative efficiency, locally Kuwait government has set up a strategically target by the year 2030 to utilize the Renewable Energy by 15% of its total Power generation capacity, respectively a 70 MW pilot project has been launched comprising a three types of renewable power: PV, Wind turbine generators and CSP in order to assess and evaluate the performance and efficiency of each type before proceeding with gigantic plant ,Hence my aim of this paper is to discuss the contribution of the existing WTG in supporting Kuwait's grid peak demand.
Keywords: Wind Turbine Generators, Al-Shagaya Complex of Renewable Power, DFIG, Net Load, Peak Demand, Kuwait Power Grid

Date of Submission: 03-03-2020 Date Of Acceptance: 22-03-2020

I. INTRODUCTION

Kuwait Institute of scientific Research (KSIR) has commissioned at the end of 2018 Al-Shagaya complex for Renewable power, That comprise a 5 NOS. of wind Turbine each of it produces 2 MW (At the optimal operational condition), the complex is also comprising a 50MW CSP (parabolic Troughs) & 10 MW P.V Farm, the complex is connected to the grid by a Tie-in 11/132 kV substation (Fig. 1).

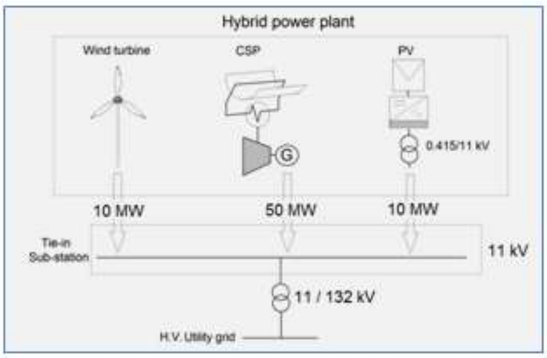


Fig. 1 Al-shagaya hybrid power station grid tie-in

The Average Capacity Factor of wind Generation is 39% annually which makes it the best Alternative; My Aim from this paper is to discuss the feasibility of the wind turbine Generators in terms of net-load sharing of Kuwait's peak demand.

Table. 1 Al-Sahagaya complex basic data

Energy type	Name-plate power [MW]	Energy storage	Capacity factor [%]	Maximum Design [MWh-year]
CSP	50	TES (10 hrs@73%)	41 (with TES)	179,580
PV solar	10	Nil	22	19,272
Wind power	10	Nil	40	35,040
Total	70			233,892

The Shagaya area, west of Kuwait, was selected due to that the fact that it is 280m above sea level, thus causing the air stream passing over the location to be compressed. Hence, the site is subjected year-round to higher wind velocities than the urban areas of Kuwait.

II. METHODOLOGY:

The methodology of this paper is about analyzing the output of the wind turbine cluster of Al-Shagaya by its monthly capacity factor, and match it with Kuwait grid peak demand, therefore this section provide the details of Al-Shagaya Project windmills and technical data about the turbines, but before proceeding further we shall provide the data summary of Al-Shagaya complex (Table.1).

2.1. Analyzing the consumption of Electrical Energy in Kuwait:

The robust urban in Kuwait and expand of the industrial Areas which was the normal need for the expansion of residential Areas, All of that led to high demand in power. The demand was increased rabidly (Table.2), we can see that the demand was doubled in 20 years from 6450 MW in 2000 to 13910 MW in 2019.The peak demand season in Kuwait is the summer season from May to October and the least month is February (Table.3).

Table.2 Daily Max. Consumption of Electrical Energy in the State Of Kuwait During 2018(MWh)

Month	Max. Consumption
January	110784
February	117488
March	173600
April	182197
May	249504
June	269312
July	271842
August	269911
September	264300
October	219536
November	139713
December	122932

Table.3 Development of Maximum Loads (MW) During 2000-2018

Period	Maximum Load
2000	6450
2001	6750
2002	7250
2003	7480
2004	7750
2005	8400
2006	8900
2007	9070
2008	9710
2009	9960
2010	10890
2011	11220
2012	11850
2013	12060
2014	12410
2015	12810
2016	13390
2017	13800
2018	13910

2.2. Wind turbine cluster details:

The Shagaya Project contains 5 Nos. of wind turbine that was installed at 30m height from the ground with 10m vent long. Each one of them generate 2MW (Table.4) at total the Wind turbines will generate 10MW in The Shagaya Project (Fig.2), The wind turbine consists of three main parts: Tower, Nacelle and Rotor that holds the Blades which is made from a Light Composite such as Carbon fiber. The wind speed and direction vary frequently which will affect the produce Electrical Voltage and current according to the speed and the torque of the wind turbine. There is three methods to control the speed of the turbine, first is to change fan angle Pitch Control system with which the fan response to air changes in speed and torque, Pitch Control accounted for 35% of all wind turbine control operations.

Second is Gear Box to change speed and torque converter, which the low speed shaft management column provides movement through the turbine fan, That act as a Prime Mover and whose speed is limited to avoid the occurrence of a rotating insufficient repellent Moment of Inertia that could leads to the extraction or damage in Fan blades or shear in other fixed bearing parts.

Third is Drive Yaw fan orientation change mechanism, which includes gears with horizontal wind movement driven by an electric Yaw Motor that rotates the Nacelle generator room for the purpose of orienting the fan to the Orientation wind to receive winds according to the signals sent by an electronic system specialized in wind vane direction and Anemometer Keep it away from facing air in unfavorable weather conditions, knowing that a loud sound occurs in the surrounding area when the Yawing turbine body wraps due to the receding and deflating of the air.

Table. 4 Al-Shagaya WTG datasheet

Manufacturer	Gamesa	
Type	G97	
Capacity	2000	kW
Rotor diameter	87	m
Power Production	6,828,719	kWh/year
Capacity Factor	39	%
Full load hours	3'412	hrs/year
Operating hours	7'348	hrs/year

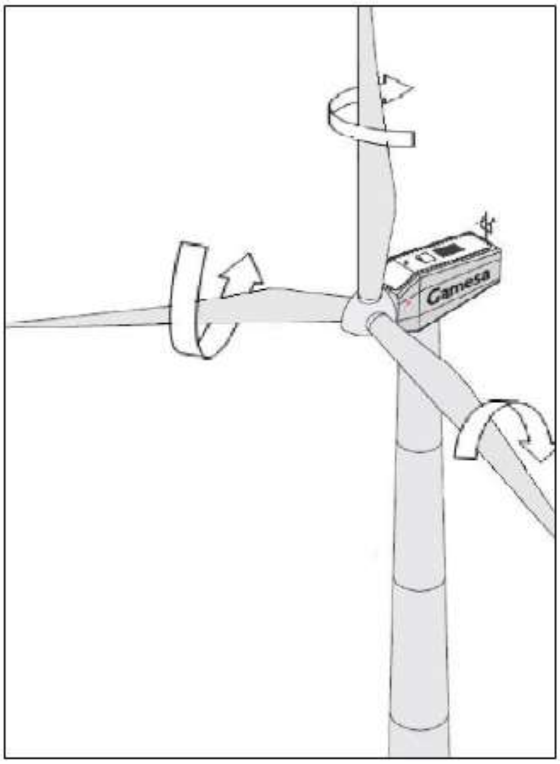


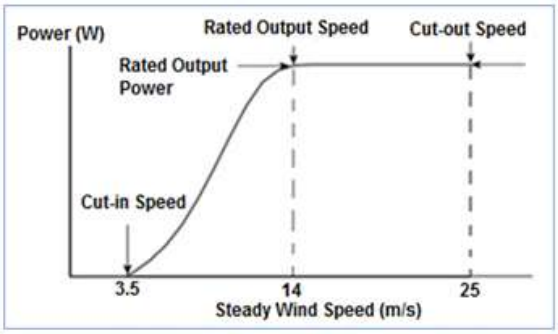
Fig. 2 WTG diagram similar to the installed units at Al-Shagaya

As known the horse power generated depends on torque & revolution according to the following formula:

$hp = T. S / 5252.1$ (1)

, Where T is Torque (lb-ft), S is rotational speed (rpm).

The basic criteria for the description and operation of the wind turbine are the speed and density of the air exposed to it, the most important is determining the Critical - Effective Speeds to ensure the safety of the turbine and the surrounding and to ensure a good efficiency of the electric energy generated, where it needs a wind speed rate of 12 m/s to generate the required electric power, and this value may differ according to the product or design, and as shown in the properties of the wind turbine (Fig.3), operating speeds are divided into three main stages the first is Cut-in speed, which is the lowest running speed ,the second is Speed Rated output It is the ideal design speed for operation at which the turbine begins to generate the required electrical power, third is Cut-out speed, which is the speed at which the turbine stops preventively to avoid the growing force of the Moment of Inertia.



The installed turbine equipped with DFIG (Doubly Fed Induction Generator) which helps improving the energy efficiency by optimizing the power factor of the grid.

The output power of generator is fed to the grid through a built-in tertiary transformer (Fig.4).

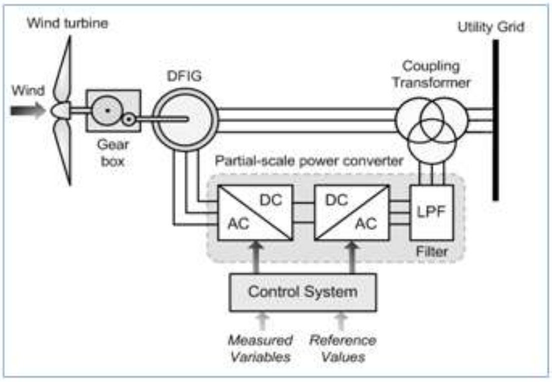


Fig. 4 DFIG basic diagram

In terms of mechanical design the mechanical capacity of the turbine rotation P by wind is calculated by the following preliminary equation:

$P = ½. ρ.A.v^3$ (2)

Where, ρ is air density (kg / m^3), A is the area of the fan blades, calculated for the so-called Swept area from the area equation of the circle as elaborated (Fig. 5) , Where the swept area A can be calculated as follow:

$A = r^2.π$ (3)

It is extracted from the general Kinetic Energy equation given that the air mass calculation equation is:

$m = ρ. A. v$ (3)

$K = ½. m.v2$ (4*)*

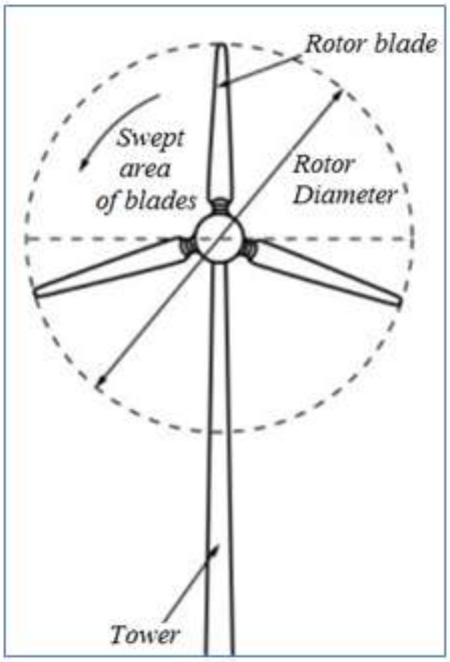


Fig. 5 WTG dynamic factors explanation

Where, K is Kinetic Energy (Joule), m is

$$Monthly\ C.F. = [\ \frac{Total\ MWh\text{-}month}{Nameplate\ power*30*24}\ ]\ *100$$

mass (kg), v is Velocity (m/s) , Noting that kinetic energy K is replaced by mechanical power P, given that the air velocity is m / s, and that design factor is added to this equation.

Cp is Performance Coefficient; it is calculated from the following relative formula:

$Cp = v_{\circ} / v$ (5)

Where,v is Upstream Wind fan speed (m / s), $v_{\circ}$is Downstream wind speed (m/s) Optimum Cp value is 0.59 in optimum mode.

Table. 5 Average monthly wind speed; monthly (gross) production in Al-Shagaya wind farm during the first year of operation.

Month-year	Avg. wind speed (m/s)	Production (kWh)
Aug-17	8.0	4,179,365
Sep-17	6.9	3,822,571
Oct-17	7.2	3,174,254
Nov-17	6.7	2,770,897
Dec-17	7.8	3,948,152
Jan-18	7.3	3,330,362
Feb-18	7.0	2,876,305
Mar-18	7.3	2,692,287
Apr-18	7.2	2,624,838
May-18	6.3	2,506,604
Jun-18	10.2	5,192,837
Jul-18	11.1	5,471,524

2.3. Contribution of Wind power generation in Kuwait Grid

The Shagaya wind farm in Kuwait After operation for a one whole year shows that wind energy in that specified location, south western of Kuwait, records energy production numbers that far exceed the industry average. This was clearly associated with the high capacity factors throughout the year (Table.5), The Shagaya was selected as the southern parts is heavily occupied by the oil industry and is generally restricted. Also, the selection was based on the meteorological mast installed in Shagaya Wind Farm, average wind speed is around 7.8 m/s.

The capacity factor of WTG was found to be 39-40 %, the current Al-Shagaya wind farm powers 370 houses, at the current annual household consumption of 94,500 kW/h/yr.

III. RESULTS AND DISCUSSION:

Reference to all above figures and data we can elaborate the functionality of Al-Shagaya WTG cluster by the characteristic curves (Fig.6) and (Fig.7), where the net load can be determined by matching the highest grid demand values which occurs in the period between May and September, compared with WTG actual highest energy productivity that can be signified in the period between end of May and beginning of September, which of course referred to the increment in wind speed that is respectively reflected positively on the WTG monthly capacity factor that can be computed by equation-6, in order to indicate the occurrence of grid's highest consumption months and hence, the required peak shaving areas can be matched accurately.

$$Monthly\ C.F. = [\ \frac{Total\ MWh\text{-}month}{Nameplate\ power*30*24}\ ]\ *100 \qquad (6)$$

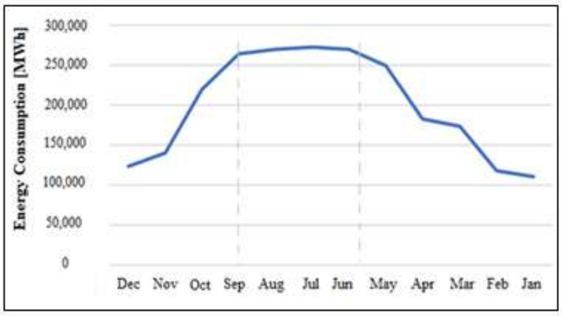


Fig.6 Monthly Consumption of Electrical Energy in the State of Kuwait during 2018 (MWh)

Our comparison based on per unit (or percentage) matching considering the magnitude difference between grid's capacity and WTG capacity.

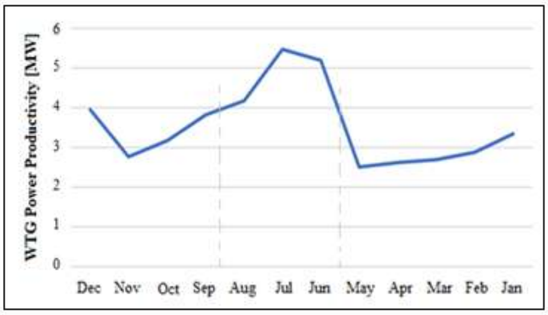


Fig.7 Monthly production in Al-Shagaya wind farm (kWh)

IV. CONCLUSION

Based on the extracted results, we can conclude this paper that the feasibility of wind turbines power generation system in Kuwait is significantly indicated in terms of electrical energy abundance in fulfilling the grid with semi-shortage periods in energy during highest demand months of the year.

Meanwhile there are also other economical aspects should be considered when evaluating WTG such as durability, maintenance cost and frequency.

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