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STUDY THE VALIDITY OF USING THE WIND MILL DOUBLY FED INDUCTION GENERATOR SYSTEM FOR ELECTRICITY GENERATING IN IRAQ

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Abstract:

This study aims to investigate the complete technology cycle of windmill, the work consists of two parts, the first is mechanical part and the other is electrical part. The first part includes air attacking with the windmill blades and transfers the dynamic energy to the mechanical energy using triple or octal blades mill. The resulted velocity will increase with a certain magnitude by using a suitable gearbox. The final power and velocity resulted from this part used as an input to the electrical part. **EXCEL** program used to obtain the optimal specifications for number of blades, blade diameter, the tower height and wind velocity. The windmill doubly fed induction generator **WMDFIG** system consists of the windmill, the doubly fed induction generator, current, and torque control circuits. The (A.C / D.C) and (D.C / A.C) converter circuits are divided into two components; which are rotor side converter (**Crotor**) and the national grid side converter **Cgrid,** also an inductor is used to connect grid converter **Cgrid** to the electrical national grid.. The model of electrical part was programmed by **MATLAB** package Vol.7.0 using the inputs mentioned above and the output electrical power produced is controlled by a certain controller circuit and feedback speed meter. This study proves that power produced from available winds energy in Iraq is acceptable, which gives 15. 213 kW for eight blades model and 3.983 kW for three blades.

KEYWORDS: Renewable Energy; Wind Velocity; Specification (height; and blades), Slip-Ring Induction Generator; Rotor and Grid Converters;

خلاصة البحث:

يدرس هذا البحث الدورة التقنية الكاملة لطاحونة الهواء والتي يتكون عملها من مرحلتين الأولى ميكانيكية والثانية كهربائية. تتضمن المرحلة الميكانيكية اصطدام الهواء بريشة الطاحونة وتحويل الطاقة الحركية إلى طاقة ميكانيكية باستخدام ريش ثلاثية وأخرى ثمانية. يتم زيادة السرعة الناتجة من هذا الجزء عن طريق جهاز نقل الحركة, وتستعمل القدرة والسرعة النهائية من هذه المرحلة كمدخلات للجزء الكهربائي. للوصول إلى أفضل المواصفات لعدد الريش, قطر الريشة, طول البرج وسرعة الريح واتجاهها وذلك باستخدام برنامج (أكسل). تتكون منظومة WMDFIG من طاحونة هواء ومولد حثي ثنائي التغذية ودوائر السيطرة على التيار والسرعة والعزم مع دائرتي تحويل الفولتية من متناوبة إلى مستمرة ثم من مستمرة الى متناوبة والتي تسمى الأولى محول الجانب الدوار والثانية محول جانب الشبكة الوطنية وكذلك محاثة تستخدم لربط دائرة محول جانب الشبكة مع الشبكة الوطنية الكهربائية. لقد تم برمجة الموديل الكهربائي باستخدام الحزمة البرمجية لمختبر المصفوفات الأصدار السابع باستخدام المدخلات المذكورة أعلاه ويتم السيطرة على القدرة الكهربائية الناتجة بدائرة سيطرة ومؤشر قياس السرعة. برهنت هذه الدراسة أن القدرة التي ستنتج من طاقة الرياح المتوفرة في العراق بكميات مقبولة, ستولد بمقدار 15.213 كيلو واط لموديل ثمانية الريش و3.983 كيلو واط لموديل ثلاثي الريش.

INTRODUCTION

The basic machinery that converts wind power to electricity is called wind turbine. In wind turbine design computational fluid dynamics (CFD) is often used such that the blade velocity, velocity distribution and pressure distribution around the blades can be obtained. The wind spins blades that are attached to a hub called the rotor; the turning rotor spins a generator producing electrical power. There is also a controller that starts and stops, the controller and other equipment are found inside a covered housing directly behind the turbine blades. Outside an anemometer measures wind speed and feeds this information to the controller [1]. Wind turbine begins to run with wind speeds between (15 – 23) Km / hr and it automatically shut off at 100 Km / hr. This work is considered as comprehensive study of wind generator design by using suitable generator for proposing turbine to obtain accepted practical design. The technical advancement in power electronics is playing an important part in the development of wind power technology. The contribution of power electronics to the control of fixed speed wind turbines and interfacing to the grid is of extreme importance. The horizontal-axis turbine which is the commonest used. A large number of designs are commercially available, ranging from (50 W to 1.8 MW). The best compromise for electricity generation, where high rotational speed allows use of a smaller and cheaper electric generator is two or three blades [2]. The Slip – ring induction generators are widely used with variable – speed wind turbines, which is a special application of three – phase induction machines. In some applications, wound rotor induction generators have also been used with adequate control schemes for regulating speed by external rotor resistance, this allows the shape of the torque- slip curve to be controlled to improve the dynamics of the drive train [3]. The stator is directly connected to the main ring through a Y/ Δ connection of power transformer and the rotor to a D.C- link connects the main – side inverter to the rotor- side one. The slip – ring rotor type contains windings similar to the stator windings. The three phase windings are connected in "Y" with the loose ends coupled to their slip – rings. Using slip – rings has two advantages: firstly the electrical characteristics of the rotor can be modified (for example additional resistances may be introduced in the rotor circuit, allowing to enhance the starting properties of the machine), and secondly having direct access to the rotor windings better possibilities to control torque. An (L – C) passive filter is used to damp the high frequency harmonics generated by the switching of the insulated gate bipolar transistor IGBT. This latter also has the function of furnishing reactive power to enable power factor correction on the net within a desired range. Such a configuration maintains either the speed or the torque control within a range suitable for wind power generation. Furthermore, it splits the reactive power in both the rotor and net sides with a view to control the power factor and minimized losses. Advantages of wind energy are: it is one of the renewable energy; non – polluting, so it has no adverse influence on the environment, avoid fuel provision and transport, and for small scale, up to a 30 kW systems is less costly. Costs can be competitive with conventional electricity. The disadvantages of wind energy are: fluctuating in nature, unlike water energy, it needs storage capacity because of its irregularity, wind energy systems are noisy in operation: a large unit can heard many kilometers away, relatively high overall weight because they involve the construction of a high tower and include a gearbox. An alternate energy interface control for implementation with utility derived power sources and alternate power sources such as are provided by solar panels and with systems utilizing storage batteries. The system monitors the current level of photovoltaic solar panels within intervals during such panels are connected with the battery storage source and further monitors the voltage levels developed by such panels during normal open circuit conditions. Three and eight blades are chosen according to the previous studies which proved that these types are suitable for Iraq environments [4].

1- THEORETICAL STUDY

The theoretical study consists of two parts, the mechanical part and electrical part.

1-1: MECHANICAL PART

Using Excel program different windmills are tested with different specifications as shown in **TABLE (1)**. The governing equations used are as follow [5]:

$$V_2 = V_1 \left(\frac{h_2}{h_1} \right)^n \tag{1}$$

Where n = 0.4 for down town city terrain, $V_1 = 4.3$ is the velocity at height $h_1 = 15$ and V_2 is the velocity at height h_2, respectively. For the air density, the ideal gas law is:

$$\rho = \frac{P}{RT} \tag{2}$$

Where: P is the pressure in (Kg / m^2)
T is the temperature in (K)
R is the universal gas constant in (J / kg. K)
And ρ is the density of air in (Kg / m^3)

Also area and the mass moment of inertia can be calculated using the following formulas, respectively:

$$A = \pi L_{blade}^2 \tag{3}$$

$$I_{Shaft} = \frac{N_B \rho_B (L_B W_B t_B) L_B^2}{3} \tag{4}$$

Where I_{shaft} : the mass moment of inertia of the rotor about the rotating shaft (kg. m^2)
N_B : Number of blade, L_B : Length of blade, W_B : Width of blade, t_B : Thickness of blade,
ρ_B : Density of blade material.

The wind power is obtained from the following expression [6] :

$$\bar{w}^{o} = \frac{1}{2} \rho V^3 \eta_{wt} \tag{5}$$

Where: η_{wt} = the efficiency of wind turbine.

The tip speed ratio (TSR), which is shown in Fig. (1.a) is the ratio of the speed at the tip of the wind turbine blade to the wind speed and is given by [7]:

$$TSR = \frac{\varpi R_{rotor}}{V} \tag{6}$$

Where : V is wind speed in m / sec.

To calculate (η_{wt}) using the following equation [4]

$$\eta_{wt} = -0.39105.(TSR)^2 + 0.66586.(TSR) + 0.026583 \tag{7}$$

Assume: $C_1 = 0.39105, C_2 = 0.66586, and C_3 = 0.026583$.

To calculate the rotation speed ω, equate the mechanical power of the turbine due to the rotation with the wind power that is captured by the turbine:

$$\eta_{wt} \rho A V^3 = \frac{1}{2} I_{shaft} \omega^3 \tag{8}$$

To determine the efficiency the tip speed ratio TSR must be known. This requires knowing the rotational speed of turbine, which means solving the problem iteratively using equations (8, 6, and 7), with the following iterative loop:

1- Guess η_{wT}.
2- Calculate ω from equation (8).

3- Calculate TSR from equation (6).
4- Calculate η_{wT} from equation (7).
5- Check η_{wT} for convergence (less than 1% change).
6- Repeat steps 2-5 until convergence is achieved, using η_{wT} in step 5 for each iterative loop.

Before iteration, calculate some of the parameters that do not change during the iteration like $\rho, A,$ and I_{shaft}.

In case of that the wind speed value, which turns the wind turbine blade is more or less than the permissible velocity range used in this turbine type, the mechanical brake system must be operated to keep the speed within the range depending on the electrical signal comes from anemometer system, which is used originally to measure the wind speed in m/sec. The signal is sending by tacho- meter, which converts the rotational speed to voltage value.

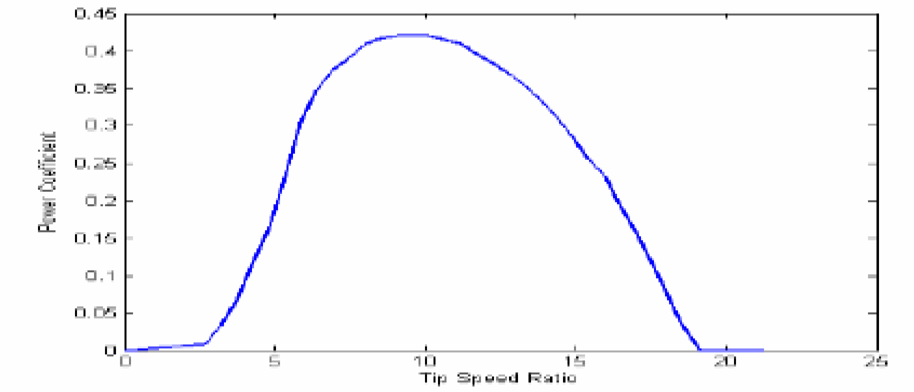

Fig. (1-b): Power Coefficient Verses Tip Speed Ratio.

GEAR BOX SYSTEM

The wind turbine rotation is quite slowly due to the a available current wind velocity and to make this system operate in the required velocity range it is useful to suggest a suitable gear box to increases the number of revolutions from the shaft to the desired number of

Revolutions of the generator. Fig. (1- b), represents gear system used for increasing generator rotation speed [8]. The number of the teeth on each gear is direct proportional to the radius of the gear and inversely proportional to the angular velocity $\frac{\omega_2}{\omega_1} = \frac{N_1}{N_2}$ and mass moment of inertia in second gear is $J_2 = J_1.(\frac{N_2}{N_1})^2$ .The gearbox specifications are as follows: Gear 1: Number of teeth =14, Diameter =14. 28 cm, Gear 2: Number of teeth = 98, Diameter = 84 cm.

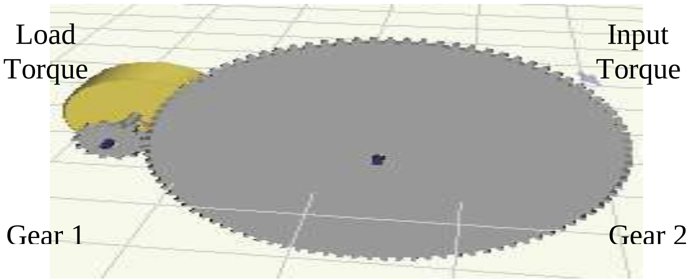

Fig. (1-b): Gear System Used for Increasing Generator Rotation Speed.

1 – 2: ELECTRICAL PART

When the induction machine is receiving the mechanical power in form of rotating torque on its rotating axial that is the sign of internal mechanical power is negative and when this machine supply the electrical power to the main feeding system so the internal power for its also is negative thus this machine say operating as induction generator. The flow chart for power flow to a three phase induction generators is shown in Fig. (2), since the total interred wind mechanical power in form of rotating torque ($P_{2\ wind}$) covered first the friction windage (P_{fw}) and additional looses (P_{add}), result the useful mechanical power (P_M) and this in turn covered a part of electrical looses in rotor (P_{cu2}) and the remainder giving to air gap as electromagnetic power (P_{em}). The air gap power is covering the iron (P_{Fe}) and electrical copper losses (P_{cu1}) in stator and the remainder (P1) is giving for the main feeding system as useful electrical power. The induction generator takes the magnetizing current (10 - 30) % from main source feeding, continuously during operation at the same time it supplies load current for the main feeding system. It must be independent source as terminal in exchanging operation that is the induction generators can be operated in parallel with other A.C generators in national super grid and this method called external excitation or using self excitation by connecting a group of capacitors star connected for stator terminal, if wind mill in rural locations [9].

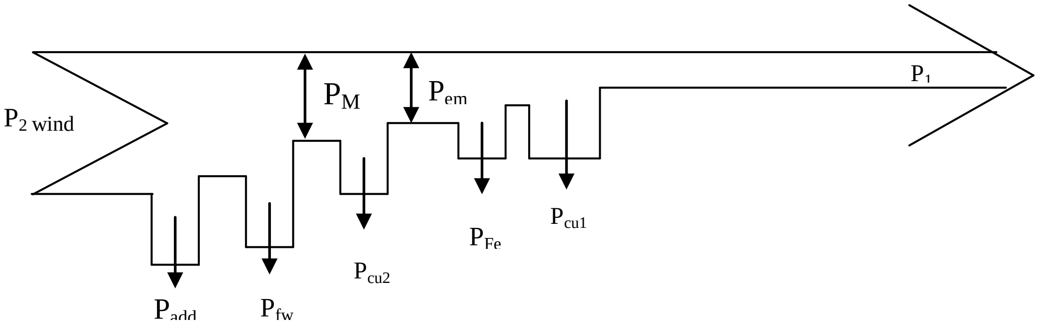

Fig. (2): Flow chart For Power Flow in Three Phase Induction Generators.

The mechanical and the stator electrical output power are computed from the following equations:

$$3 * P_{Mechanical} = T_m * \omega_r \quad , P_{Stator} = T_{em} * \omega_s \tag{9}$$

Where: Tem: electromagnetic torque and T_m : mechanical torque in N. m

ω_r : rotated speed in rad. / sec and ω_s : synchronous speed in rad. / sec.

In condition of steady - state and for doubly fed induction generator the electromagnetic generated torque equation is:

$$T_{em} = T_m - T_{Loss} \text{ and } P_e = P_s + P_r - P_{Total\ electrical\ losses} \tag{10.a}$$

Where: $P_{Total\ electrical\ losses}$ are copper and iron losses in rotor and stator in watt.

The electrical output efficiency for the windmill doubly fed induction generator WMDFIG is:

$$\eta_{Electrical} = \frac{P_{Electrical}}{P_{Mechanical}} \tag{10.b}$$

$$Tem = \frac{3 * Pem}{\omega s} \qquad \text{Or, } Tem = \frac{3 * V_s^2}{\omega_s} * \frac{\bar{R}_2 / s + R_{External}}{[(R_1 + \bar{R}_2 / s + R_{ext})^2 + (X_1 + \bar{X}_2)^2]} \quad \text{N. m} \tag{10.c}$$

Where: R_1, $\bar{R}_2 / s$: phase stator resistance and phase rotor resistance referred to stator ,respectively.

$$s = \frac{\omega_s - \omega_r}{\omega_s} = \frac{-\Delta\omega}{\omega_s} \quad \text{(Super synchronous, dimensionless factor)} \qquad -1 < s < 0$$

The motor operating stability system and its operation occurs when balance the electromagnetic torque with the summation of applied torque on rotor, which are starting torque, dynamic torque and losses: so the following balanced equation for a slip-ring induction generator is [10]:

$$T_{em} = T_{starting} - J.\frac{d\omega_r}{dt} - \omega.\frac{dJ}{dt} - T_{Loss} \tag{11}$$

Where: J is combined rotor and wind turbine mass moment of inertia in kg . m^2 and in this study however, will consider J as constant.

And $\frac{d\omega_r}{dt}$ is the rotor acceleration in m^2 /sec.

Where: s is defined as slip value of the slip - ring induction generator which has a negative value.
The rotor current referred to stator windings in induction generator is:

$$\frac{E_r^-}{Z_r^-} = \frac{E_r^-}{R_r^- / -s + jX_r^-} = \frac{E_r^-}{(\frac{R_r^-}{-s})^2 + X_r^{2-}}(\frac{R_r^-}{-s} - jX_r^-) = \frac{E_r^- * R_r^-}{-s[(\frac{R_r^-}{s})^2 + X_r^{2-}]} - j(\frac{E_r^- * X_r^-}{(\frac{R_r^-}{-s})^2 + X_r^{2-}}) \tag{12}$$

$$\frac{E_r^-}{Z_r^-} = -I_{r\ active}^- + jI_{r\ reactive}^- \qquad \text{Amp.}$$

Where: $I_{r\ reactive}^-$ is an A.C reactive component for rotor current referred to stator in induction generator.

And $I_{r\ active}^-$ is an A.C active component for rotor current referred to stator in induction generator, which has a negative value in amper.

3 – MATHEMATICAL CALCULATIONS AND RESUILTS

For triggering delay angle at angle 10 degree, the drop voltage for each switch device is (0. 7) V and the maximum line voltage is (0.4) kV at (50) HZ, the output direct current voltage from rotary converter is [11]:

$$E_{(D.C)} = \frac{1}{2\pi/6}\int_{\pi/6+\alpha}^{\pi/6+\alpha+\pi l3} \sqrt{3} * V_m \sin(\omega i + \pi/6)d\omega/ = \frac{3\sqrt{3} * V_m}{\pi}\cos\alpha - 2 * V_{Trans.} = 374.76997\ V \tag{13.a}$$

When the inverter operates in the 120 degree conduction mode, the three phase load at any time is connected through one insulated gate bipolar transistor **IGBT** on one side and through another one IGBT side on the other side The current rating of a single IGBT can be operated up to 400 A, 1200 V and the switching frequency can be up to 20 kHz, also it combines the advantages of bipolar junction transistor **BJT** and metallic oxide silicon field effect transistor switch **MOSFETS**, has high input impedance and low on state conduction losses, so for a negative phase sequence the r.m.s phase voltage is:

$$V_{An}(r.m.s) = [\frac{1}{T l2}\int_0^{2T/3}(E_{D.C}/2)^2 dt]^{1/2} - 2 * V_T = \frac{E_{D.C}}{\sqrt{3}} - 2 * V_{Trans.} = V_{Bn(r.m.s)} \angle 120^0\ V = V_{Cn}(r.m.s) \angle 240^0\ V$$

$$V_{An}(r.m.s) = 215.229 \ \angle 0\ V \tag{13-b}$$

In Table (1), as shown below, items (5 and 6) are selected according to many considerations, which are: low cost, suitable for Iraqi environments, relatively high efficiency and high power.

Also, to increase the input rotating speed to six times by a desired gearbox system.

Fig. (3): illustrates the schematic of windmill model: A: for eight blades B: For three blades

Fig. (4) shows: A: system overview and power flow for active and reactive power. B: Flowchart of windmill power station, Fig. (5) shows the turbine power characteristics and Fig. (6), which represents an equivalent circuit per phase for slip - rings 12 poles induction generator for two models.

TABLE (1): Excel Optimization Results.

Items	$\eta_{\omega t}$	L m	Area m^2	High (h2) m	Speed (v2) m/sec	$v^3 \frac{m}{\sec}$. speed	Nb	Wb m	tb m	I_{shaft} $kg.m^2$	ω rad / sec	TSR	C1	C2	C3	New ηωt	Δ η	Mechanical Power W
1	0.31	5	78.57	20	5.93	209.35	8	0.30	0.03	3600	1.20	0.90	-0.31	0.60	0.02	0.30	0.008	3049.64
2	0.31	4	50.28	20	5.93	209.35	8	0.30	0.03	1843.2	1.29	0.96	-0.36	0.64	0.02	0.30	0.009	1924.50
3	0.31	4	50.28	20	5.93	209.35	8	0.30	0.03	1843.2	1.28	0.96	-0.36	0.64	0.02	0.30	0.007	1925.68
4	0.30	5	78.57	30	6.98	340.55	8	0.30	0.03	3600	1.39	1.04	-0.42	0.69	0.02	0.29	0.008	4740.02
5	**0.31**	**8**	**201.14**	**35**	**7.42**	**409.75**	**8**	**0.32**	**0.03**	**17626.56**	**1.21**	**0.90**	**-0.32**	**0.60**	**0.02**	**0.30**	**0.009**	**15265.63**
6	**0.30**	**7**	**153.99**	**20**	**5.93**	**209.35**	**3**	**0.36**	**0.02**	**4007.17**	**1.42**	**1.06**	**-0.44**	**0.71**	**0.02**	**0.29**	**0.008**	**5638.67**
7	0.30	7	153.99	20	5.93	209.35	3	0.37	0.02	4352.29	1.39	1.04	-0.42	0.69	0.02	0.29	0.008	5714.65
8	0.30	7	153.99	20	5.93	209.35	3	0.39	0.02	4711.33	1.36	1.02	-0.40	0.68	0.02	0.29	0.009	5777.38
9	0.30	4	50.28	10	4.50	91.12	3	0.40	0.02	614.40	1.39	1.04	-0.42	0.69	0.02	0.29	0.008	811.23
10	0.30	4	50.28	10	4.50	91.12	3	0.40	0.02	614.40	1.39	1.04	-0.42	0.69	0.02	0.29	0.008	811.23
11	0.30	4	50.28	10	4.50	91.12	3	0.40	0.02	614.40	1.39	1.04	-0.42	0.69	0.02	0.29	0.008	811.23

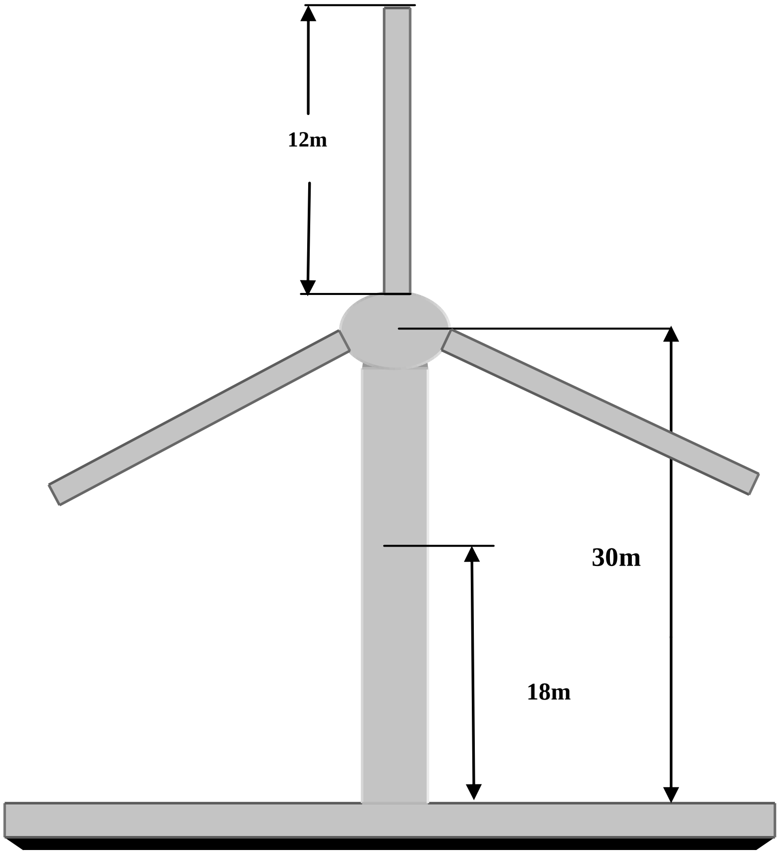

Fig (3.B): Illustrates the Schematic of Windmill Model (For Three Blades propeller)

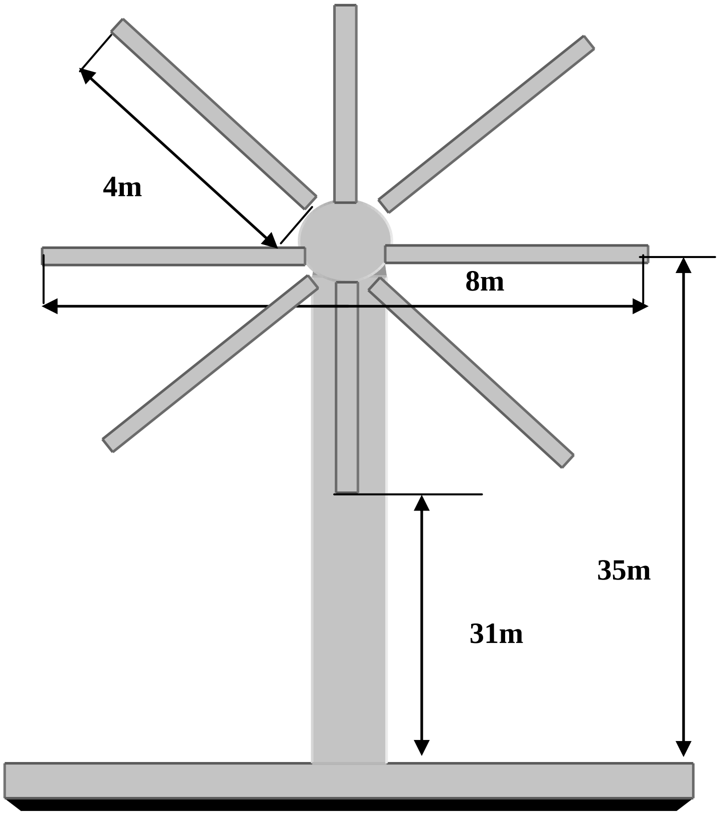

Fig (3.A): Illustrates the Schematic of Windmill Model (For Eight Blades propeller)

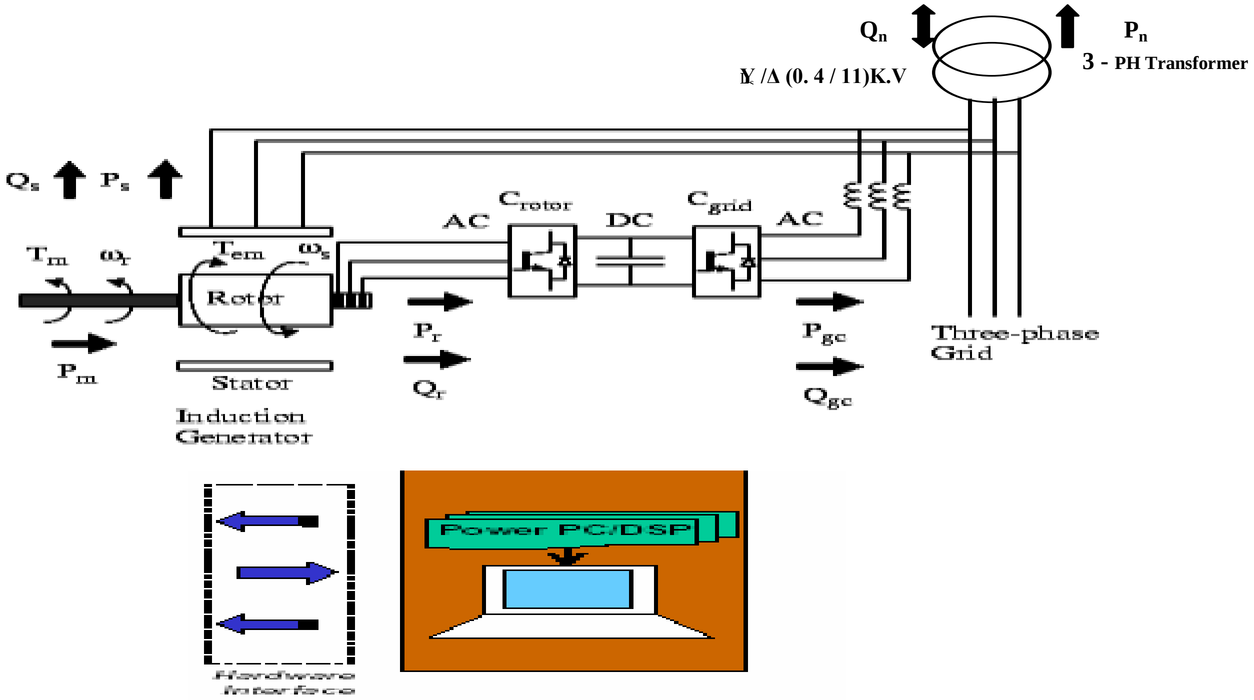

Fig. (4.A): System Overview and Power Flow for Active and Reactive Power [12]

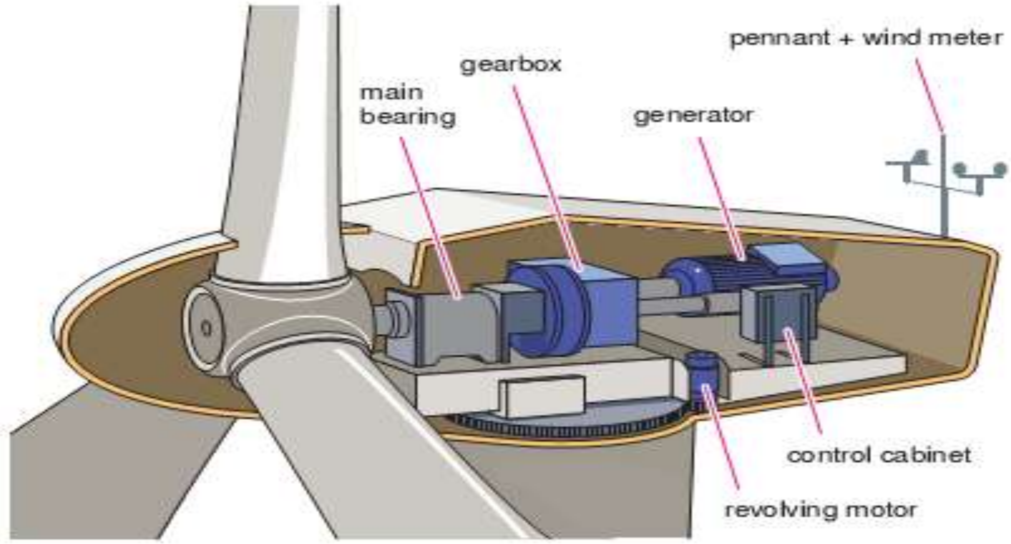

Fig. (4 - B): Cross-section of a Windmill Power Station.

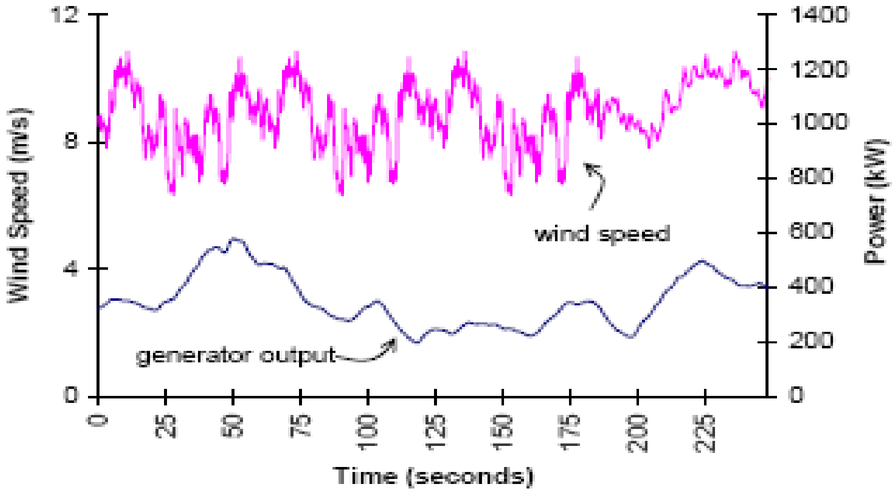

Fig. (5): The Turbine Power Characteristics [13].

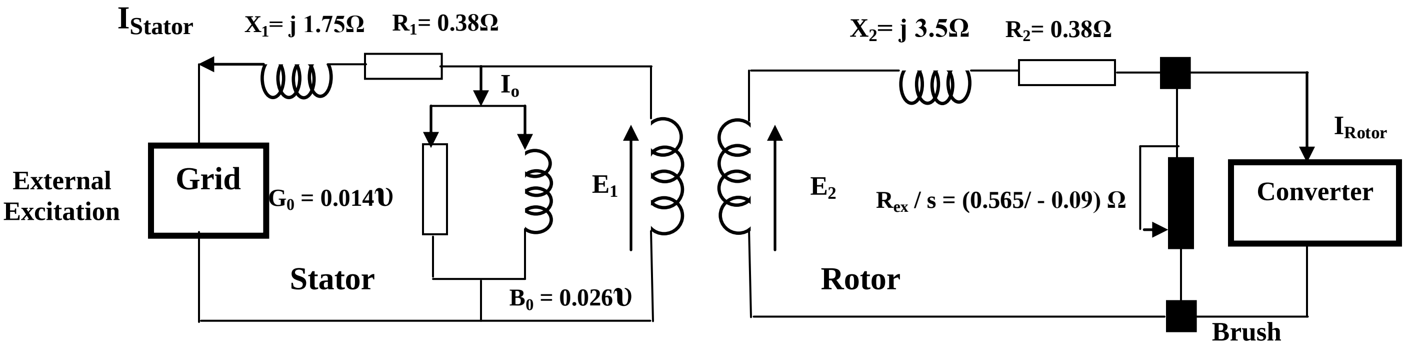

Fig. (6): Equivalent Circuit per Phase for Slip Ring Induction Generator at Full Load [13].

It can be deduced from **TABLE (1)** that the mechanical input power to DFIG for eight blades model is (15.266) kW at speed and the tower height are (1. 212) m / sec and (35) m, respectively, while for three blades model the mechanical input power is (3.999) kW at speed and the tower height are (1.421) m / sec and (30) m, respectively with gearbox operating according to the speed ratio of (1: 6) and the grid power factor is (0. 9) lagging. The electrical efficiency for **WTDFIG** is varied depending on wind speed and its direction. The specifications of three phase transformers in our study are covered by the British Standard system B.S. 171.From the equation (10.c) the electromagnetic torque for eight blades model is 821.111 N. m while for three blades model is 183. 36 N. m. Electrical output power results is shown in TABLE (2-A) From the equivalent circuit per phase for slip - ring induction generator at full load the copper and iron losses in stator and rotor for two modes (i.e, three and eight) of blades are shown in table (2-B).

TABLE (2-A): Electrical Output Active and Reactive Power Results.

Blades No.	**$P_{max.}$ Mechanical k.W**	**ω_S rad / sec.**	**ω_r rad / sec.**	**Full Load Slip p.u**	**P_{Stator} k.W**	**P_{Rotor} k.W**	**Q_{Total} Elect. kVAR**	**Trans. K.V.A**	**$P_{Elect.}$ Stator + Rotor k.W**	**Complex Current A**	**ηelrect. %**
8	15.266	50.992	55.582	- 9 %	14.098	1.2688	7. 847	17.000	15.213	24.427 - j11.83	99.653
3	3.999	59.786	65.167	- 9 %	3. 691	0. 332	2. 055	05.000	3.983	6.395 - j 3.097	99.599

TABLE (2-B): The Copper and Iron Losses in Stator and Rotor for Two Modes of Blades.

Blades No.	**Rotor copper Losses P_{CU2} k.W**	**Stator copper Losses P_{CU1} k.W**	**Total copper Losses P_{CUT} k.W**	**Iron Losses P_{Fe} k.W**	**Total Losses k.W**
8	$1.23 * 10^{-3}$	0.131	0.1322	0.0213	0.1535
3	$0.1585 * 10^{-3}$	0.0276	0.0277	0.0123	0.040

The energy stored in the capacitance (in joules) divided by the WTDFIG rating in V.A is time duration, which is usually a fraction of a cycle at nominal frequency so the time duration can be calculated as:

$$\tau = (\frac{1}{2} * C * V_{dc}^2) / V.A \qquad (14)$$

For 1000 μF capacitance or (51.320) magnetizing V.A.R and (374.769) volt D.C bus voltage at (17) K.V.A rating, the time duration required **(τ)** is (3. 179) m second. For a ripple factor (R F) of (5 %) the series inductance (L_s) for output current third harmonic smoothing can be calculates [11]:

$$R.F = \frac{V_{ac}}{V_{dc}} * 100\% = \frac{\pi}{(36\pi^2 f^2 L.C - 1) * 3.\sqrt{3}\ \cos\alpha} 100\% = 5\% \qquad (15)$$

After solving this equation the series inductance (Ls) is (14. 957) m Henry.

Results of these latter works are to be published and in order to make balance between the actual generation of (5,250) MW and the peak load demand in Iraq of (9,000) MW obtained from national control center NCC in year 2007 by using **WMDFIG** system for our case study and assume the agriculture areas, villages islanders have 10 % from the actual generation and peak load demand in Iraq so, Iraqi power system needs approximately (24,649) windmill units for (8) blades model and (94,150) windmill units for (3) blades model and the modern techniques in manufacturing will increase and modify the generation capacity for each unit and that is will decrease the number of required installed windmill units, drastically. **WMDFIG** system can be installed in our country from the known studying prediction in number of cities which is the speed of the wind is equal to (4.1– 6) m / sec. or (9. 2 – 13. 46) mil / hr for example: Al – Razzaza, Ruttba, Najaf, Haditha, Nassria, Sullaimania and the west areas due to available winds energy in acceptable quantities and good population density

4 - INDUCTION GENERATOR MODELLING

Some simulations were done using **MATLAB Vol. (7)** using the achieved values for the parameters, Fig. (7-a) and (7-b) shows the calculated electromagnetic torque versus speed and slip characteristics, respectively of the induction motor and generator, the crosses points are different measured operating points. A good correspondence is observed in the linear region. The value of the maximum electromagnetic torque in induction generators is greater than in induction machines by (30 – 50) % because of the e.m.f in induction generator ($E_{1)}$ is greater than main source voltage (Vs). The WMDFIG does not generate any zero-sequence current, but it can generate negative-sequence currents during unbalanced system operation.

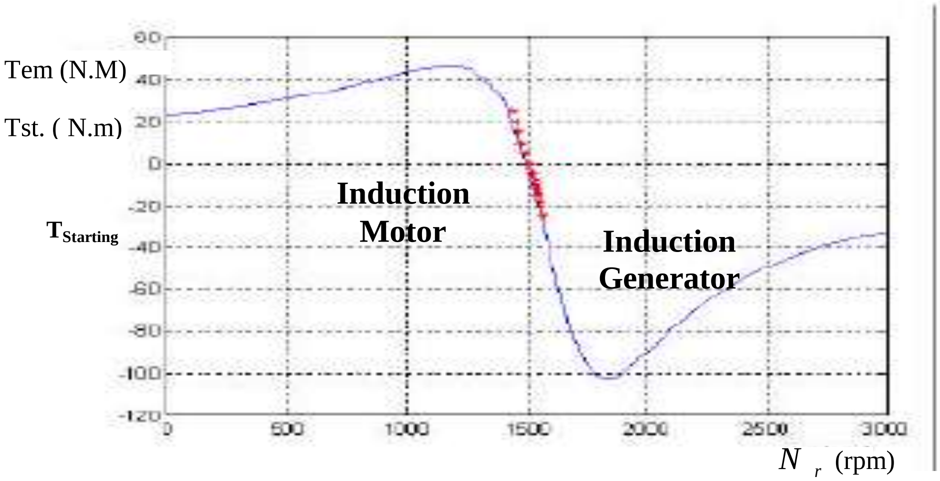

Fig. (7-a): Torque / Speed Characteristic for Motor and Generator.

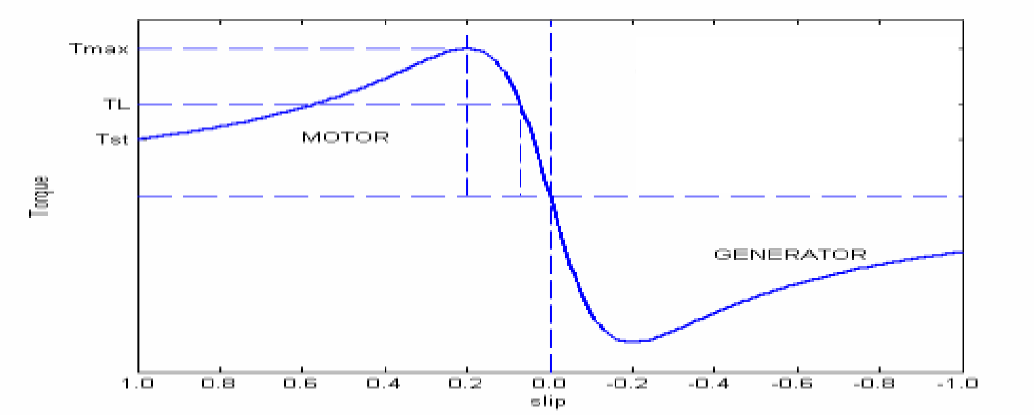

Fig. (7-b): Torque / Slip Characteristic for Motor and Generator.

5 - CONTROL STRUCTURE

The basic assumption for controlling that the inner current control loops in a cascaded structure would have to be fast enough to make the inverters behave like a current source for the outer control loops. The latter are responsible for regulating the active and reactive power flow. The control is performed in direct and quadrate - coordinates oriented to the mains voltage vector for the grid side inverter and to the slip for the rotor side inverter. Voltage is one of the input signals for the flux observer. It is therefore necessary to measure the voltage delivered by a converter. Since the converter output voltage contains a large amount of harmonics it is not possible to measure this voltage with common sampling methods as for example the A / D converter of a micro- processor.

The inverters were controlled by the space vector modulation technique in order to avoid low harmonics and to achieve a better modulation index (I < 1), especially in the case of the grid side inverter that has to impose higher voltage levels than the supply voltage magnitude in order to improve power factor. Measured values of current and voltages are conditioned at the interface and passed through analog to digital converters and then to the control routine. The coordinate transformations, controllers and further calculations are carried out and voltage reference values are given to the digital signal processors DSP’s and pulse width modulation PWM units. The switching signals are then passed to the hardware interface by the DSP’s I / O unit and finally to the Power modules where the gate pulses are generated and error signals are also passed to the hardware interface. The encoder signal is separately conditioned and passed to a special encoder input unit. Special routines give the reference values for the optimum power angles and torque in order to achieve minimum electrical losses and maximum wind power conversion. The control circuit for rotor inverter side circuit is shown in Fig. (8) [14].

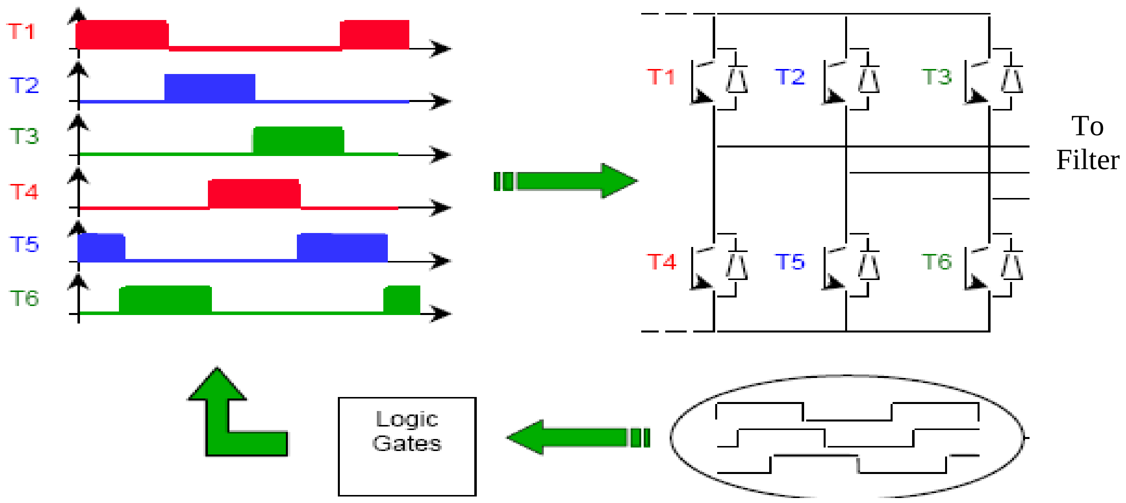

Fig. (8): The Control Circuit for Rotor Inverter Side Circuit.

6 - SPEED AND TORQUE CONTROL

For the outer speed and torque control loops the simplified current closed loop transfer function below was assumed under the condition that time T_Σ was small enough’ and this assumption simplifies the outer loops control design [15].

$$G_{i-c} = \frac{G_{i-0}}{1+G_{i-0}} = \frac{1}{s^2 2T_\Sigma^2 + s2T + 1} \approx \frac{1}{s2T_\Sigma + 1} \qquad (16)$$

The symmetrical optimum method fits quite well to the controller design for such a plant with a first order transfer function from the closed loop current control together with the pure integration from the mechanical system. For the torque control design and eventually for speed control when not using the simplified current control closed loop transfer function the optimal damping suits well for determining the controller parameters. The D.C - link voltage control design was carried out under the same assumption done above i.e., T_Σ was small enough, for the speed control. The D.C - link capacitor features a pure integrator and so the symmetrical optimum method is used. The power angles controllers must not work rapidly due to undesired fast power changes. Hence, the optimal magnitude criteria and optimal damping might be good choices. It should be commented that the outer control loop feed back values have to be filtered before compared with the reference values. When the speed velocity less then the acceptable reference value, the automatic transfer switch ATS must change the windmill option to other energy resources such as solar photo voltaic PV cells and liquid batteries automatically or manually as shown in Fig.(9)[16], which indicates a hybrid system for other energy resources in Iraq.

7- SIZE OF STATIONARY BATTERIES

To select the ampere – hour sizing battery of lead – acid cell type XT4LC-7 for single load profile using formula from IEEE standard 485 – 1997: and the results are shown in **TABLE (3)** for ten batteries, twelve cells per battery, (24) volt D.C minimum (i.e 2 V / cell) [17] **:**

$$\text{Uncorrected Cell Size (Amp-hr.)} = \max_{S=1}^{S=N} \sum_{P=1}^{P=S} [A_P - A_{(P-1)}] K_T \qquad (17)$$

Required Size (Amp-hr.) = (Uncorrected Cell Size) * (Temperature Correction Factor)*(Design Margin) * (Age Factor) (18)

Where: K_T is a capacity rating factor representing the ratio of rated ampere – hour capacity at standard time rate, at 25 C^0 and for T minutes.

S is section of load profile being analyzed.
N is number of periods in the load profile.
P is period being analyzed.
A_P is ampere required for period P.

TABLE (3): The Results for Required Size of Battery in Ampere – Hour of Lead – Acid Cell.

Blades No.	**Uncorrected Cell Size Amp – hr.**	**Period of Time hr.**	**Capacity Rating Factor K_T**	**Temperature Correction Factor**	**Design Margin**	**Age Factor**	**Required Size Amp – hr.**
8	27.27	1.5	1.01	1	10 %	25 %	40
3	7.07	3	1.01	1	10 %	25 %	10

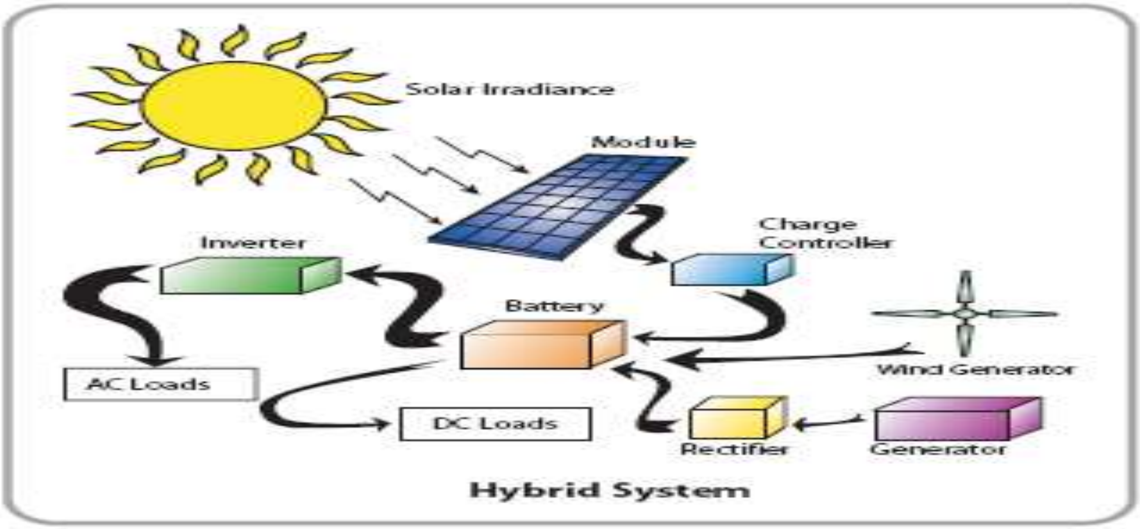

Fig. (9): Hybrid System for Other Energy Resources in Iraq.

8 – CONCLUSIONS AND RECOMMENDATIONS

Electrical power generation from wind energy is consider as a good solution for several cities in Iraq and the power quantity from this study indicates that the wind energy is promising future power source. The power produces from the wind turbine can be modified according to the dimensions and the specifications of the mechanical parts like number of blade, length of blade, material of blade, thickness of blade, angle of blade, and high of the tower

Results were shown and eventual problems were addressed. The space vector modulation routine can be still optimized. Slow oscillations of the network currents and D.C - link voltage as well as heating of the inductor filter were observed by some operating conditions. The oscillations were wiped out by reducing the switching frequency and using a proper sample time. Further tests and commissioning of the controllers are being carried out so as be the optimization procedure to happened. Results of the case studies are to be published and in order to make balance state between the actual electrical generation of (5,250) MW and the peak load demand in Iraq of (9,000) MW obtained from national control center NCC in year 2007 by using windmill doubly fed induction generator **WMDFIG** system for our case study and assume the agriculture areas, villages islanders have 10 % from the actual generation and peak load demand in Iraq so, Iraqi power system needs approximately (24,649) windmill units for (8) blades model and (94,150) windmill units for (3) blades model and the modern techniques in manufacturing will increase and modify the generation capacity for each unit and that will decrease the number of required installed windmill units, drastically. **WMDFIG** system can be installed in our country using prediction studies on number of cities at which the wind speed ranges from (4.1– 6) m / s or (9. 2 – 13. 46) mil / hr for example: Al – Razzaza, Ruttba, Najaf, Haditha, Nassria, Sullaimania and the west areas due to available winds energy is acceptable and good population density. When the wind is strong, the wind farm's turbines generate more electricity than the islanders need so the storage batteries are there to soak up the excess and pump it out again on days when the wind fades and the turbines' output falls. A ten batteries, twelve cells per battery, (24) volt D.C minimum (i.e 2 V / cell) with normal size battery typically rated from (10 - 40 Amp – hr. Series lead – acid storage batteries charging during periods of alternate power source availability is a pulsed technique to enhance battery lifespan. Although these batteries are capable of delivering large amount of energy.

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