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Increase The Life Time And Efficiency Of A Wind Mill Using Re Engineering

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Abstract

The Renewable energy sources of a windmill have many operation and maintenance to be needed. The maintenance after the wind mill life can extended some years. The windmill overall life was initially designed and manufacturing for twenty years. At the end of year dismantling process takes place for analyzing the strength of the wind mill. From this the life time of component should be calculated.

But we are calculating the life of the windmill at the parts of tower, wind blade, rotor, and gearbox on theoretical and experimental(NDT) basis to avoid the dismantling of AMTL- 250KW wind turbine to replace the minimum and maximum size of the component. The applying re engineering and analyzing the life time of various parts of the wind mill work the life time will be increasing to give more production and profit. This paper describes the procedure to calculate the theoretical and Non Destructive Tests(experimental) solution and creating a design using CREO Parametric software for rectifying the AMTL wind mill yaw drive problems for offshore wind turbine.

Key words: old windmill (AMTL), analysis, NDT, CREO Parametric.

1. Introduction

1.1 Wind

Wind is simply air in motion. It derives energy from solar radiation. It is caused by the uneven heating of the Earth's surface by radiant energy from the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's energy at different rates

1.2 Wind Power

Wind turbines are systems that harness the kinetic energy of the wind for useful power. Wind flows over the rotor of a wind turbine, causing it to rotate on a shaft. The resulting shaft power can be used for mechanical work, like pumping water, or to turn a generator to produce electrical power. Wind turbines span a wide range of sizes, from small roof top turbines generating less than 100 kilowatts up to large commercial wind turbines in the megawatt power range, many of which operate in large clusters called wind farms.

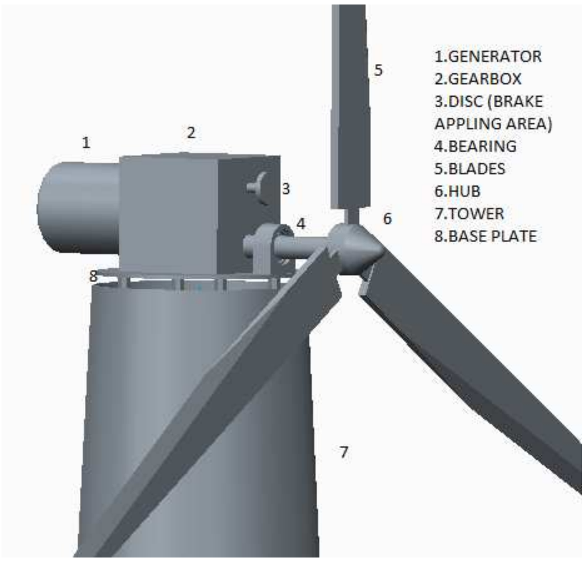
1.3 Betz Law

According to Betz's law, no turbine can capture more than 59.3 percent of the kinetic energy in wind. The factor (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit. The theoretical maximum efficiency of a wind turbine is given by the Betz Limit, and is around 59 percent. Practically, wind turbines operate below the Betz Limit.

1.4 Introduction of AMTL Wind mill

The windmill has several models .We select the AMTL 250kw model. The windmill has basic simply configurations. It has tubular tower and also lattice. The parts are high speed generator, three stage gearbox, rotor and three blades. The generation start wind velocity at 8m/s, the wind velocity has only above 8m/s, the speed reduces the generation stopped.

The top of the tower has the gearbox is fitted. The two sides of gearbox are one side is blade and other end has generator. The direction of wind flow has turned nacelle setup by the yaw drive system. The wind velocity measurement, brake system and hydraulic unit are controlled by the electronic control unit. The yaw drive system is placed in that the vertically downward to the gearbox base plate.



"AMTL Model Wind Mill"

1.5 Wind Mill Parts

1.5.1 Blades

The rotor blades capture the wind's energy and convert it to rotational energy of shaft. The rotor blades are usually two or more in number and are made of Glass-fibre reinforced plastic or Epoxy resin laminated wood. It

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also includes structures of AluminumCopper for lightning protection and steel for the connection to the hub. The hub in turn transfers the energy to the low speed shaft. Blade designs operate on either the principle of drag or lift.

1.5.2 Rotor

Fiberglass rotor blades represent the most vulnerable components of a wind turbine. Lightning, Vibrations or contact with the tower can result in major damage to the blades. Design errors and manufacturing defects can also cause problems in the rotor blades during its operation. For example, blades can develop cracks at the edges, near the hub or at the tips. The possibility of the bolts breaking due to overload also cannot be ruled out. Studies show that about 20% of the total damage due to lightning has occur red to the windmill blades.

1.5.3 Brakes

Brakes are used to stop the rotation of rotor shaft in case of power overload or system failure. The High speed shaft is equipped with an emergency mechanical disc brake, which is used in case of failure of the aerodynamic brake, or when the turbine is being serviced.

1.5.4 Power Transmission System

The low speed shaft of the wind turbine connects the rotor hub to the gearbox. The low speed shaft rotates at relatively slow speed of about 19 to 40 revolutions per minute and transfers the rotational energy from the hub to the gear box. The shaft contains pipes for the hydraulics system to enable the aerodynamic brakes to operate. The power transmission system increases the speed and transfers the rotation energy to the high speed shaft, which rotates about 50 times faster than the low-speed shaft.

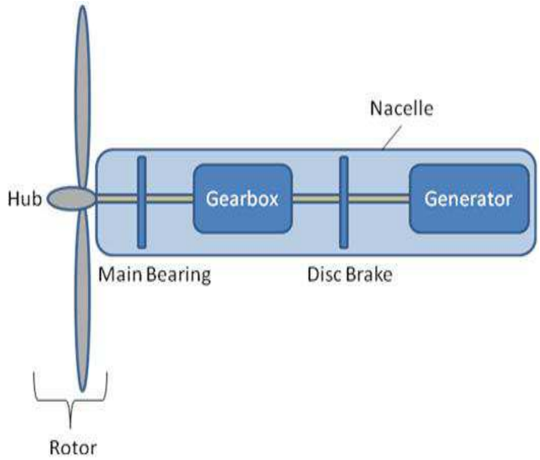
1.5.5 Generator

The generator converts the turning motion of wind turbines blades into electricity at medium voltage (hundreds of volts) by the principle of Electro magnetism. Inside this component, coils of wire are rotated in a magnetic field to produce electricity. The generator's rating, or size, is dependent on the length of the wind turbines blades because more energy is captured by longer blades. The most commonly used generator in wind turbines are induction generators or asynchronous generators.

1.5.6 Tower

Modern wind turbine generators are installed on tubular towers.large turbines use tubular tower. The tower thickness is 12mm plate. It has made up of cast iron high grade.

1.6 Wind Turbine Operation



“wind turbine operation”

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A wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Wind turbines, like windmills, are usually mounted on a tower to capture the most energy. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.

1.7 VERIFICATION OF AMTL 250KW BY USING BET'Z LAW

Our selected wind power mill is 250kw

- 250 Kw
- 250 Units Per Hour
- 6,000 Units Per Day
- 21,90,000 Units Per Year

1.7.1 ACCORDING TO BET'Z LAW

Theoretical value of power= 2190000 x 59.3/100 = 1298670 units per year

But,

Actual value of power = 605763units per year

Efficiency = Actual Value / Theoretical Value=1097737/2190000x100 =22.66 %

The initial efficiency can satisfy 27.66%

1.7.2 CURRENT EFFICIENCY

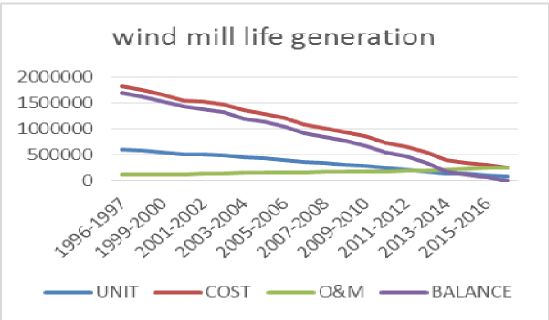
Theoretical value of power= 2190000 x 59.3/100 = 1298670 units per year

But,

Actual value of power = 132000units per year(2014)

Efficiency = Actual Value / Theoretical Value =132000/2190000x100 =6.02 %

1.8 WINDMILL LIFE POWER GENERATION



"Graph for the generation power"

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2. PROBLEM IDENTIFICATION AND METHODS

2.1.1 Yaw Drive

The AMTL wind mill design and construction was very different to other windmill for example NEPC, SUZLON, ENERCON. But AMTL wind mill has not like that nacelle part all component should be fixed at bottom position. gearbox was balancing with generator and rotor in static and dynamic position. but vibration occur at certain situation of wind mill, that time can majorly damaged with the yaw system. The yaw drive as connected with nacelle part. When the yaw pinion gear as connected with the yaw motor, then other gear of slew ring has fixed with tower. So vibration occurring time the yaw setup has oscillating it. The yaw system components or fasteners suddenly damaged the drive has falling down.

“Problem in yaw drive system”

“Problem in yaw drive system”

"Yaw drive Hydraulic brake"

2.2 ANALYSING METHOD

2.2.1. VISUAL INSPECTION

Visual testing is probably the most important of all non-destructive tests. It can often provide valuable information to the well trained eye. Visual features may be related to workmanship, structural serviceability, and material deterioration and it is particularly important that the engineer is able to differentiate between the various signs of distress which may be encountered. These include for instance, cracks, pop-outs, spalling, disintegration, colour change, weathering, staining, surface blemishes and lack of uniformity.

2.2.2 REBOUND HAMMER TEST

Fundamental Principle

The Schmidt rebound hammer is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges.

Equipment For Schmidt/Rebound Hammer Test

The Schmidt rebound hammer is shown in Fig. The hammer weighs about 1.8 kg and is suitable for use both in a laboratory and in the field. The main components include the outer body, the plunger, the hammer mass, and the main spring. Other features include a latching mechanism that locks the hammer mass to the plunger rod and a sliding rider to measure the rebound of the hammer mass

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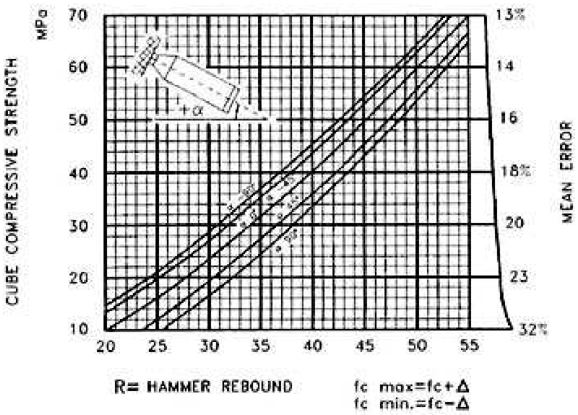


“Compressive strength vs rebound hammer chart”

2.2.3 ULTRASONIC TESTING (PULSE VELOCITY TEST)

Fundamental principle

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete.

Longitudinal pulse velocity (in km/s or m/s) is given by:

V=L/Twhere

v is the longitudinal pulse velocity,

L is the path length,

T is the time taken by the pulse to traverse that length.

3. WORKING METROLOGY

The major component for analysis components

1.Generator

2.Foundation

3.Tower

4.Blade

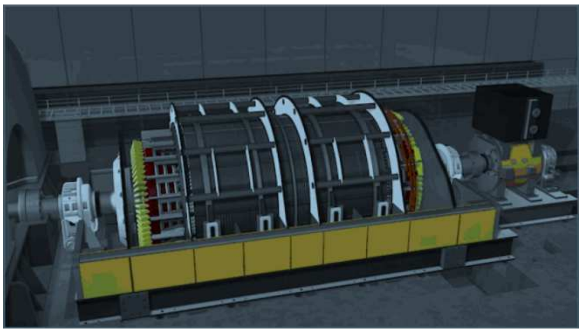
5.Gear Box

3.1 Generator

The manufacture of this windmill generator as Siemens. They can be used in a power plant for several decades, but aging increases the technical risk of their operation. To be able to reduce the risk and to operate the plant according to the valid requirements, a modernization of the generators might become necessary.

The modernization can be done by different approaches. Major solutions that can be performed are the modernization of the limiting components of the replacement of the entire generator. The best approach for the limiting component can be replaced.

With the increasing demand for higher efficiency and output, increased requirements are being put on base load power plants. With intermediate and peak load operation, plants have more start/stop cycles than they do in base load. Increased start/stop cycles and operation on turning gear can put additional stresses on generator components, potentially reducing their service life.



“figure 6. Generator”

3.1.1 Generator calculation

(Theoretical)

P=250KW

I=414 A

V=415 V

Output Power By A Generator P=VI×103 KW

Pout =171.81 KW

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$\%\eta$ =[Pout / Pin] × 100

=[171.81/ 250] × 100

$\%\eta$ =68.6% [initially]

Now

Units as 132000 per year

Pout = 15.068 KW

$\%\eta$ =[Pout / Pin] × 100

$\%\eta$ = [15.068/ 250]× 100

= 6%

current is below 500A, so lap winding will be choosing

THEN LAP WINDING

P=A

Now Taken As Conductor Aproximately 600

ϕ =V/(Z×Ns)

N=N/60

=16.83

N=120F/P

P=120×50/1010

P=5.9≠ 6 pole

ϕ =415/[600×16.83]

ϕ=0.0037wb

E=PϕNη/60A

A=P for lap winding

E=PϕNη/60P

So, p to p neglect

=0.037×1010×600/60

=373.7V

NOW CONSIDER

small size of machine

ELECTRIC LOADING (Ac) =15000 [amp.cond/m]

Magnetic loading (Bav) =0.55

Pa=P/η for generator

Pa=367kw

Pa – Armature power

Pa =Co ×D×D×L×Ns

Co=π^2Bav×Ac×〖10〗^(-3)

=π^2×15000×0.5×〖10〗^(-3)

Co=74.022 - output co efficient

For DC machine

Pitch arc/pitch pole [L/τ] =L/(πD/P)

=0.7

L/D=0.7×η/P

L/D=0.366

L=0.366D

P=CoD^2LNs

367=74.02×D^2L×16.83

D^2L=367/74.02×16.83

D^2(0.3666D) =0.2946

D^3 =0.8049

D =0.9m

L=0.39m

These are the initial design of the generator

If some years working after

ϕ=V/(Z×N/60)

=415/(450×16.83)

ϕ =0.054wb

E=P ϕNZ/(60A)

(A=P) for lap winding

=ϕNZ/60

=0.054×1010×450/60

E/P=409.05

In old machine (generator) air gap length will decrease,

If flux will reduce and emfa generation was reduce

According to the armature reaction efficiency will reduce

3.1.2 Generator replacement

- The damaged and repair is impossible.
- Modifying main generator components does not provide the necessary power output after turbine refurbishment.
- The generator lifetime shall be extended to 20 years and more.
- The spare parts are no longer available.

3.1.3 Solution

The generator are controlled in control panel system do not cross limit of peak load. So the generator winding has no affection takes place, but winding insulation coating can be melted. If the Winding (copper or aluminum), Brush, Insulated coating (York) should be need for the generator.

3.1.4 Generator result

The windmill generator after re engineering, working in minimum two years and maximum at five years.

3.2 FOUNDATION

The foundation strength (compressive strength) of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. In those cases where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties.

Compressive strength is also used as a qualitative measure for other properties of hardened concrete. No exact quantitative relationship between compressive strength and flexural strength, tensile strength, modulus of elasticity, wear resistance, fire resistance have been established nor are they likely to be.

The compressive strength of concrete is generally determined by testing cubes or cylinders made in laboratory or field or cores drilled from hardened concrete at site or from the non- destructive testing of the specimen or actual structures. The testing of hardened concrete is discussed in the subsequent.

3.2.1 Rebound Hammer Test

The tested reading as following that

Rebound hammer foundation

S.No	Rebound number	Direction	Compressive strength(MPa)
1	50	Vertical downward	59
2	48	Vertical downward	57
3	30	Horizontal	27
4	44	Horizontal	52
5	47	Vertical downward	56

The calculations to be followed by rebound number vs compressive strength in concrete technology. the foundation compressive strength as below the 5MPa-8MPa the foundation should be weaked. the calculation of foundation should be safe.

3.2.2 Ultrasonic test for foundation

S.No	Length(m)	Time ($\mu\ sec$)	Pulse velocity(m/s)	General Condition
1	0.3	93	3225.80	medium
2	1.5	354	4237.28	excellent
3	1.0	264	3787.87	good
4	0.8	229	3503.44	good
5	0.2	40.9	4889.97	excellent

3.3 Tower

The tower is large part of the windmill. tower with stand the nacelle load .the tower has 12mm plate thickness, height 30m..the brake will be applied the entire tower vibration will acted.

3.3.1 Rebound hammer tower

S. No	Rebound number	Direction	Compressive strength

			(MPa)
1	28	horizontal	20
2	27	horizontal	18
3	26	horizontal	17
4	32	horizontal	26
5	29	horizontal	22

3.3.2 Ultrasonic testing

S.No	Length(m)	Time (μ sec)	Pulse velocity(m/s)	Sound velocity of steel(km/s)	Condition
1	0.012	2.14	5600	5.85	satisfy
2	0.32	58	5517	5.85	Satisfy
3	0.15	26	5769	5.85	Satisfy
4	1.5	252	5952	5.85	Satisfy
5	0.5	86	5813	5.85	satisfy

3.3.3 Theoretical calculation

Tower has static load acted.the fluctuating load will be negleated at the height of tower.

Load $P = 136849.5\, N$

Length of tower $l = 3\, m$

Ultimate stress =350 MPa

$$pressure\ p = \frac{P}{A}$$

$$A = \frac{\pi}{4} d^2$$

$$Factor\ of\ safety = \frac{ultimate\ stress}{working\ stress}$$

$$\sigma = \frac{p\, D}{2t}$$

Inner Diameter $D = 2.1\, m$

Outer Diameter $d = 2.112\, m$

Inner Area $A = 3.46\ m^2$

Outer Area $a = 3.503 m^2$

Cross section Area (A~a) $= 0.0433\ m^2$

Pressure $p = 3160496\ \ N/mm^2$

Working stress $\sigma = 276\ MPa$

Factor of safety =1.3

Design is safe.

"Windmill AMTL-250KW"

3.4 ROTOR

3.4.1 Rebound hammer rotor

S.No	Rebound number	Direction	Compressive strength(MPa)
1	40	Vertical downward	44
2	44	Vertical downward	50
3	42	Horizontal	48
4	40	Horizontal	44

3.5 BLADE

3.5.1 Ultrasonic test for blades

s.no	locations	Blade1	Blade 2	Blade 3
1	tip	4444	4379.55	4477
2	Upper surface	4589	4476	4610
3	Lower surface	4523	Small crack formed	4643
4	Cylindrical root	3888	3684.2	4000

The small cracks formed by the blade 2.the strength will be reduced.the neglate the the cracks to use apprasive bond coating.other wise replace the blade 2.the other blade ha no cracks formation.the life extended.

3.5.2 Rebound hammer for blade joints

S.No	Rebound number	Direction	Compressive strength(MPa)
1	42	Horizontal	48
2	40	Horizontal	44
3	40	Vertical download	44
4	444	Horizontal	52

3.6 GEAR BOX

3.6.1 GEAR BOX CALCULATION:

The gearbox is made by the C_{45} material.

Number of teeth gear Z_1=36;

Number of teeth gear Z_2=102;

Pinion speed n_1= 1010 rpm;

Rated Power =250KW;

Gear ratio i =$\frac{Z_2}{Z_1}$

Gear ratio i = 2.83 ~ 3

From psg data book refer

C_{45} gear material

Tensile strength σ_y = 710 N/mm^2

Yield stress σ_u= 360 N/mm^2

Design surface stress σ_c= 500 N/mm^2

Design of bending stress σ_b= 140 N/mm^2

Young's modulus E = 2.05*10^5 N/mm^2

BHN =229

For designing the helical gear of centre distance

$$a \geq (i \pm 1)\sqrt[3]{\left(\frac{0.7}{[\sigma_b]}\right)^2 * \frac{E\,[M_t]}{i\,\varphi}}$$

$$[M_t] = M_t . k_d . k$$

$$M_t = \frac{60p * 10^6}{2\pi n_1}$$

$$\{\varphi = 0.5; k_d . k = 1.3;\}$$

$$a = 374\ mm$$

For checking the helical gear of centre distance

$$a = \frac{m_n}{\cos\beta}\left(\frac{z_1 + z_2}{2}\right)$$

$$m_n \geq 1.15\cos\beta\sqrt[3]{\frac{[M_t]}{y_v[\sigma_b]\varphi_m z_1}}$$

$$\{\varphi_m = 10; \beta = 20^\circ;\}$$

$$a = 440\ mm$$

Design is safe.

For checking the helical gear surface stress

$$\sigma_c = 0.7\frac{i \pm 1}{a}\sqrt[3]{\frac{i \pm 1}{ib}E[M_t]} \quad \leq [\sigma_c]$$

$$\{\varphi = \frac{b}{a}; b = 220mm;)$$

$$\sigma_c = 393.19\ N/mm^2 \leq 500\ N/mm^2$$

Design is safe.

Checking for helical gear bending stress

$$\sigma_b = 0.7\frac{(i \pm 1)}{abm_n y_v}[M^t] \leq [\sigma_b]$$

$$m_n = \frac{2a\cos\beta}{z_1 + z_2}$$

$$m_n = 6\ mm$$

$$\left\{a = 440mm; b = 220mm; i = 3; y_v for\ z_{v_1} = \frac{z_1}{\cos^3\beta}; y_v = 0.515;\right\}$$

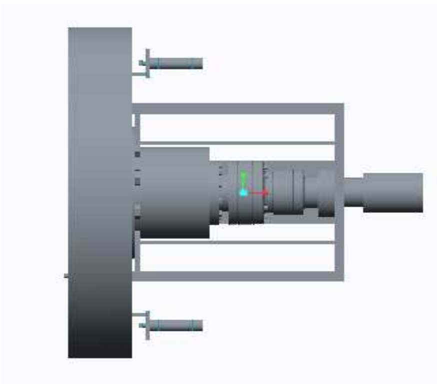
$$\sigma_b = 28.75\ N/mm^2 \leq 140\ N/mm^2$$

Design is safe.

3.7 Yaw Drive Solution (DESIGN)

The problem solution of falling down in yaw system and reducing with the yaw drive vibration (slew ring drag) as following that we can selecting the yaw drive falling problem to fixture to arrest with yaw drive system and yaw drive vibration as oscillation creating the yaw brake system to solve in already placed at hydraulic brake clamp parallel or 180 degree to set up a new hydraulic brake system that way to dragging yaw drive will be reduced and other 180 degree the mechanical clamp to be placed. That way to reducing the yaw drive problem.

“figure 8.view of yaw drive”

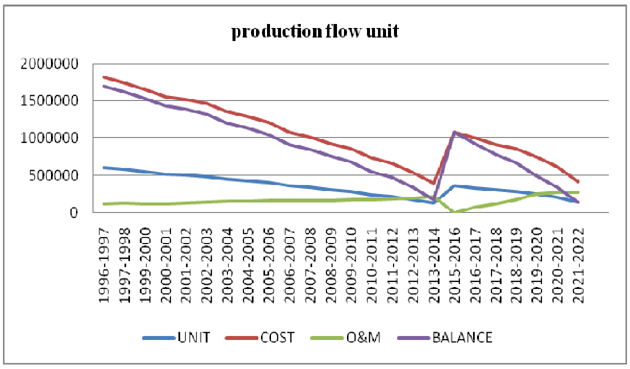


“figure 9. Side view of yaw drive”

4. CONCLUSION

The current urgent demand for efficiency and high production of power. the re engineering to life time of wind mill and power generation increased. The last two year profit of the windmill, of amount to use re engineering process. the increase the life time and efficiency. the following graph describe the flow of generation, list of components and cost. Changing parts list

S.No	Components	Changing parts	Cost
1	Foundation	-	-
2	Tower	Paint coating	25000
3	Gearbox	Gear oil change	15000
4	Blades	Blade 2 change	220000
5	Generator	Ordinary winding	150000
6	Minor parts	Bearing,fastners etc.	50000
Total			550000



“graph for production flow chart”

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