MODELLING AND ANALYSIS OF PERMANENT MAGNET SYNCHRONOUS GENERATOR FOR STAND ALONE RENEWABLE ENERGY GENERATION

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Abstract – *Different types of permanent magnet generator for wind power application have been subjected to research during last two decades. In recent years Permanent Magnet Synchronous Machine are increasingly applied in several areas such as Generation, traction, robotics, aerospace technology. This thesis describes a permanent magnet synchronous generator that was designed, built, and tested to serve a low speed wind turbine. This generator was built to operate without a speed increaser, implying very low speeds. A FEA and performance result from the simulation is done in ANSYS software is presented. The hardware test results demonstrate that the generator performs satisfactorily while reducing while reducing the cogging torque to the greatest possible extent.*

Key Words: Permanent Magnet Synchronous machine (PMSG), FEA, low speed.

1. INTRODUCTION

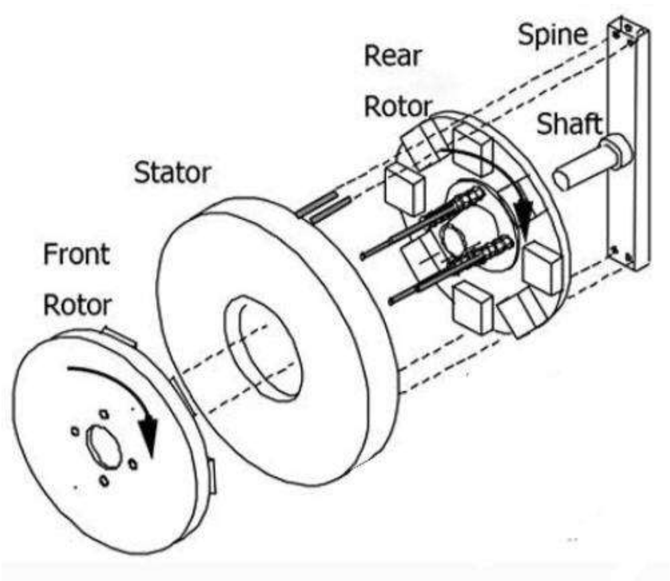
Wind energy is one of the best technologies available today to provide a sustainable supply to the world development. In terms of the generators for wind-power application, there are different types of wind turbine are there, fixed-speed wind turbines and variable speed wind turbine.

In fixed speed wind turbine, induction generators are used (application in wind farms). But the main disadvantages of using such generators are low efficiency and poor power quality. In variable speed wind turbine, doubly fed induction generators and permanent magnetic synchronous generators are used.

1.1. The Working of the project

As we all know synchronous generator are generator in which f, frequency of the induced voltage in the stator is directly proportional to RPM, the rotation rate of the rotor. Each passing of north and south pole corresponds to a complete cycle of the magnetic field oscillation. Therefore, the constant of proportionality is P/120 and the factor of 120 comes from 60 seconds per minute and the two poles in the single magnet. f(hz) = RPM *P/120.

1.2. Cross-sectional view of PMSG



In a permanent magnet generator, the magnetic field of the rotor is produced by permanent magnets. Other types of generator use electromagnets to produce a magnetic field in a rotor.

Permanent magnet generators (PMGs) or alternators (PMAs) do not require a DC supply for the excitation circuit, nor do they have slip rings and contact brushes. In this permanent magnet alternators, the speed is directly proportional to the output voltage of the alternator.

2. LITERATURE SURVEY

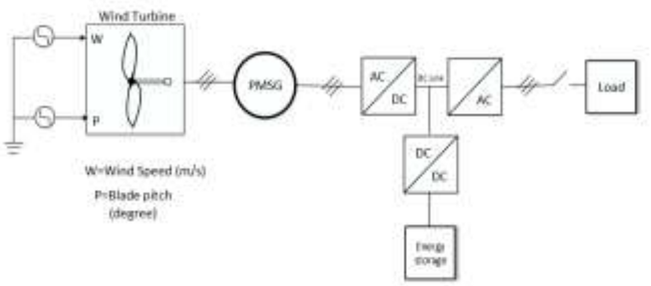
2.1. Existing System

The Existing system uses a gearbox coupled with the wind turbine. But this can only be used for high capacity wind turbine. For small scale wind turbines, the manufacturers prefer direct driven generators which eliminates the use of gearbox.

2.2. Proposed system

The aim of this work is design and analysis of permanent magnet synchronous generator using ANSYS Maxwell software. We can see that the no. of magnetic poles is greater in PMSG and it can operate at low speed to match the speed of the wind and to generate power within the permissible frequency range(50hz-60hz). the higher the frequency, the smaller is the matching transformer. As there is no need for gearbox since PMSGs are direct driven type generator, it can be easily installed over the top of the tower.

2.3. Proposed block diagram



3. WIND TURBINE AERODYNAMICS

The amount of kinetic energy in the air can be evaluated based on the size of wind turbine and the wind speed. The momentum theory gives the detailed explanation about the energy conversion in ideal circumstances. The amount of the kinetic energy of a fluid mass m with a mass density ρ, moving at a velocity v through the area A is

$$E = m. \vartheta^3 \quad .... (1)$$

And the mass flow is

$$m = A.\rho. \vartheta \quad ...... (2)$$

The power available in the wind is equal to the amount of energy yield passing per second.

$$P_{wind} = E. m = \rho.A. \vartheta 3 \quad ...... (3)$$

The power coefficient Cp is the function of tip speed ratio λ and the blade pitch angle β.

$$P_{mech} = C_p.P_{wind} = \rho \cdot A \cdot C_p (\lambda, \beta) \cdot \vartheta 3 \quad ..... (4)$$

Where,

$$\lambda = \frac{r.\ \omega}{\vartheta} \quad ....(5)$$

ω is the rotor tip angular speed and r is the rotor plane radius.

4. Finite Element Modelling of PMSG

A numerical technique for solving engineering field problems, which involves differential equations applied over regions, constrained by boundary conditions is known as finite element method (FEM). The purpose of using FEM is to make the overall structure discrete by using limited units to represent complex objects. The units are connected with a finite number of nodes. By choosing suitable boundary conditions of the model, a better solution of the model can be obtained. FEM have been used to solve engineering problems due to its great reliability and accurate results. And in recent times, it has been widely recognized as a general method for the design and analysis of different type of permanent magnet machines.

In this work, the ANSYS Maxwell software package was used for the finite element analysis (FEA) to solve magnetic and electric field problems. The FEM design of PMSG includes the structure type, selection of material and geometry of the model, i.e. outer and inner diameters of the stator and rotor, length-width-thickness of PMs, size of the slot, slew width, and data of winding.

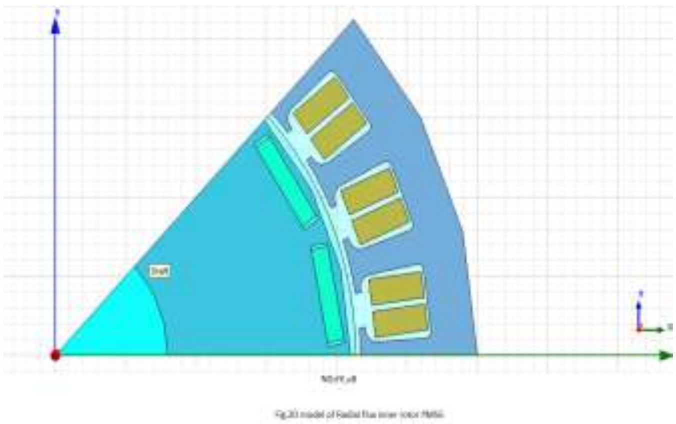
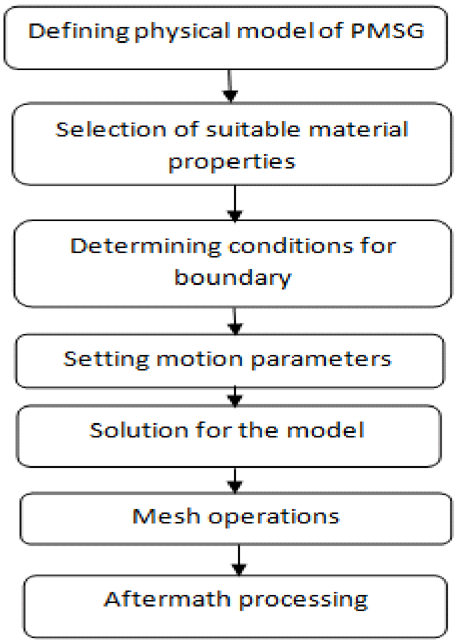


Fig.2D model of Radial flux inner rotor PMSG

Steps involved in FEA process are,



Geometric Dimensions Of PMSG

Parameters	Values	Unit
Rated Output Power	1	kW
Rated Voltage	24	V
Rated Speed	250	rpm
Number of Poles	16	--
Outer Diameter of Stator	300	mm
Inner Diameter of Stator	217	mm
Number of Stator Slots	24	--
Outer Diameter of rotor	210	mm
Inner Diameter of Rotor	80	mm
Length of Stator Core	125	mm
Stacking Factor	0.95	--
Conductor per slot	48	--
Stator slot fill	75.40 %	--
Operating Temperature	75	^{0}C

The ANSYS Maxwell 2D has many solvers namely, electrostatic, magnetostatic, transient among others. Electrostatic solver is used to understand a static electric field, magnetostatic solvers are used to observe static magnetic fields in the machine. Also, the ANSYS Maxwell 3D provides better view which can be used for detailed analysis of the PMSG. Transient solver allows the designer to observe and analyze the magnetic fields, energy, flux and many other parameters of the machine model at various time steps. The 2D and the 3D which are used in the analysis due to the symmetry of the structure of the model. It can be analyzed in 1/8 of the whole model to decrease the number of finite elements and save the simulation time. The process of analyzing the electromagnetic field is by solving the classical Maxwell's equation. The classical Maxwell's equations in differential form are written as follows:

$$\nabla \times E = -\delta B/\delta t \quad \dots (1)$$

$$\nabla \times H = J + \delta D/\delta t \quad \dots (2)$$

$$\nabla . D = \rho \quad \dots (3)$$

$$\nabla . B = 0 \quad \dots (4)$$

where,

E = Electric Field Intensity
D = Electric Flux Density
H = Magnetic Field Intensity
J = Electric Current Density
ρ= Electric Charge Density
B = Magnetic Field Density

The electric and magnetic field (E and H) and the corresponding flux density (D and B) quantities are not independent but are related by the equations as

$$D = \varepsilon E \quad \dots (5)$$

$$B = \mu H \quad \dots (6)$$

where ,
ε and μ are the permittivity and permeability respectively, of the material. In free space $\varepsilon=\varepsilon_0$ and $\mu=\mu_0$ which are related by ,

$$C_0^2 = 1/\mu_0\varepsilon_0 \quad \dots (7)$$

where,
C_0^2 is the speed of light in free space (8×10 ^{8} m/sec).

For a permanent magnet material, the expression becomes,

$$B/\mu_0 = \mu H + M_0 \quad \dots (8)$$

Where,
M_0 is the remanent intrinsic magnetization and the electric field strength is further related by ,

$$J = \sigma E \quad \dots (9)$$

Where,

σ is the conductivity.

5. RESULT AND DISCUSSION

In this thesis, we have chosen Permanent magnet synchronous generator on the application of Horizontal axis of wind turbine because of its high reliability and high efficiency. Analytical performance of PMSG, to design 2D and 3D model which is done based on Maxwell equation. Maxwell uses the accurate finite element method (FEM) to solve static, frequency-domain and time varying electromagnetic field and electric fields.

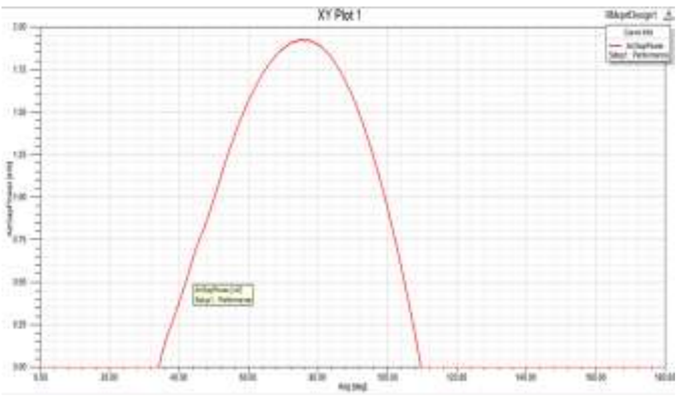


Fig5.1 Airgap power (KW)

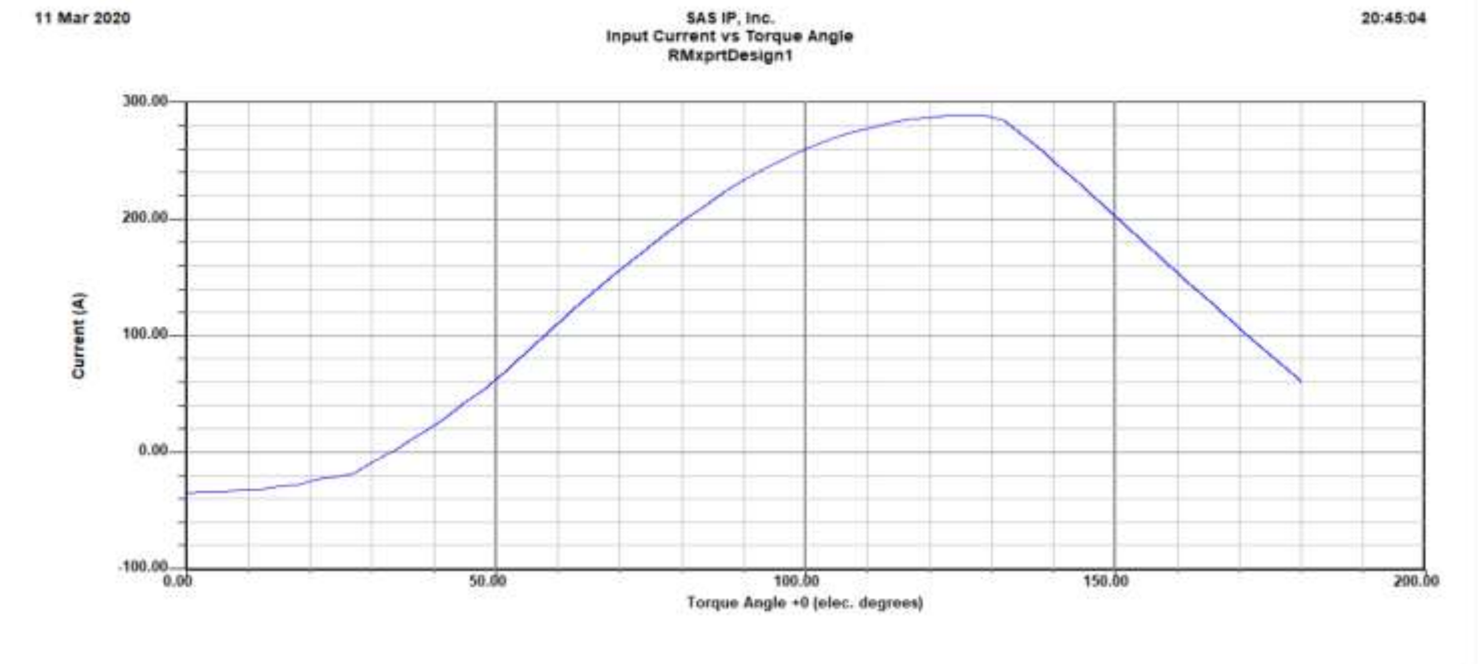


Figure 5.2: Input current vs Torque Angle

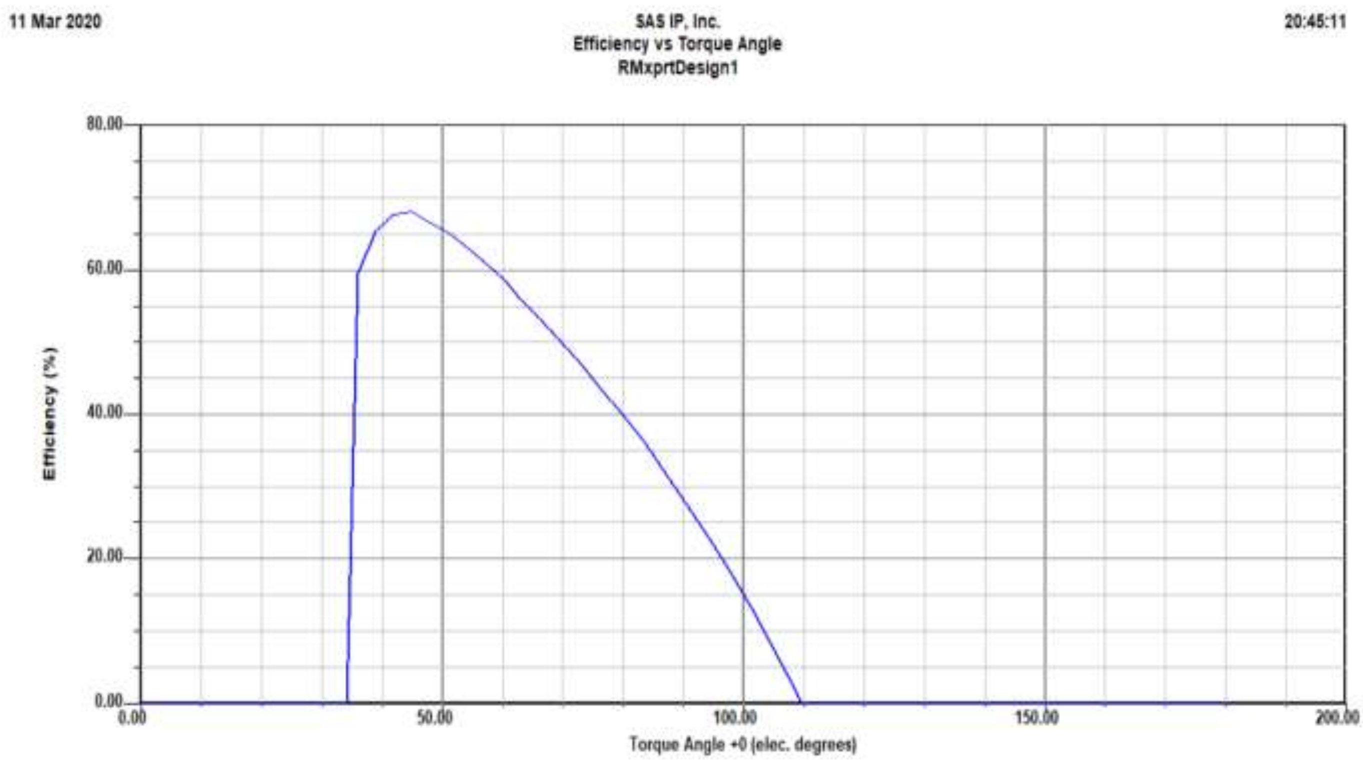


Figure 5.3: Efficiency vs Torque Angle

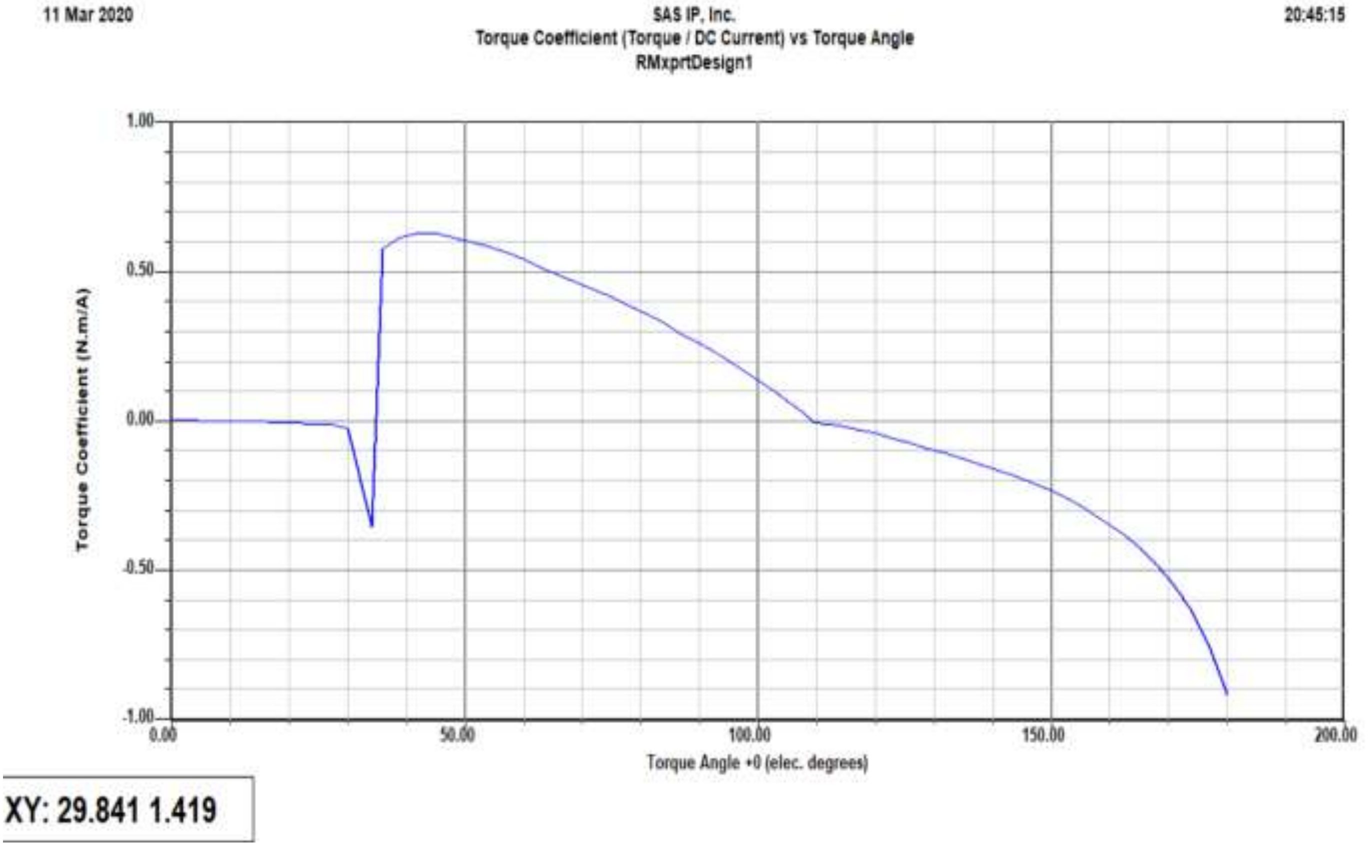


Figure 5.4: Torque Coefficient vs Torque angle

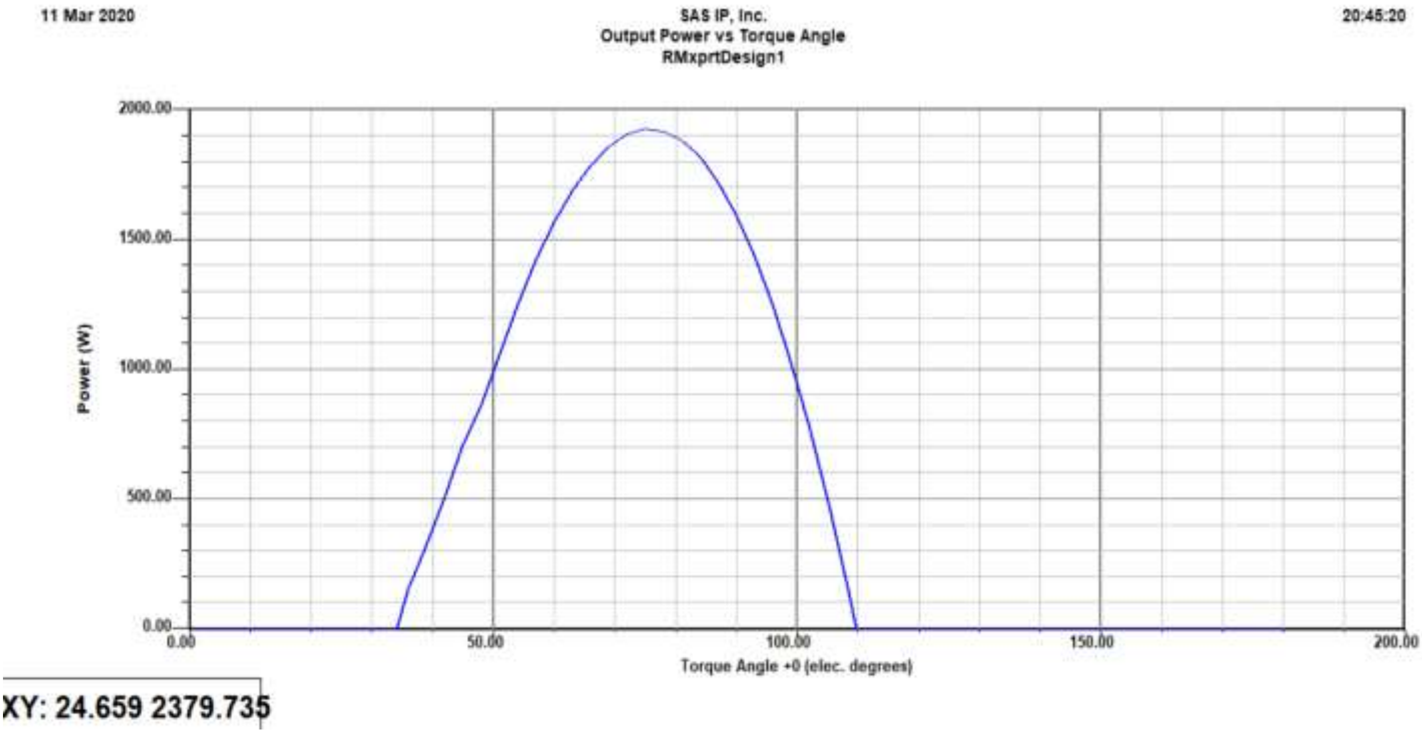


Figure 5.5: Output Power vs Torque Angle

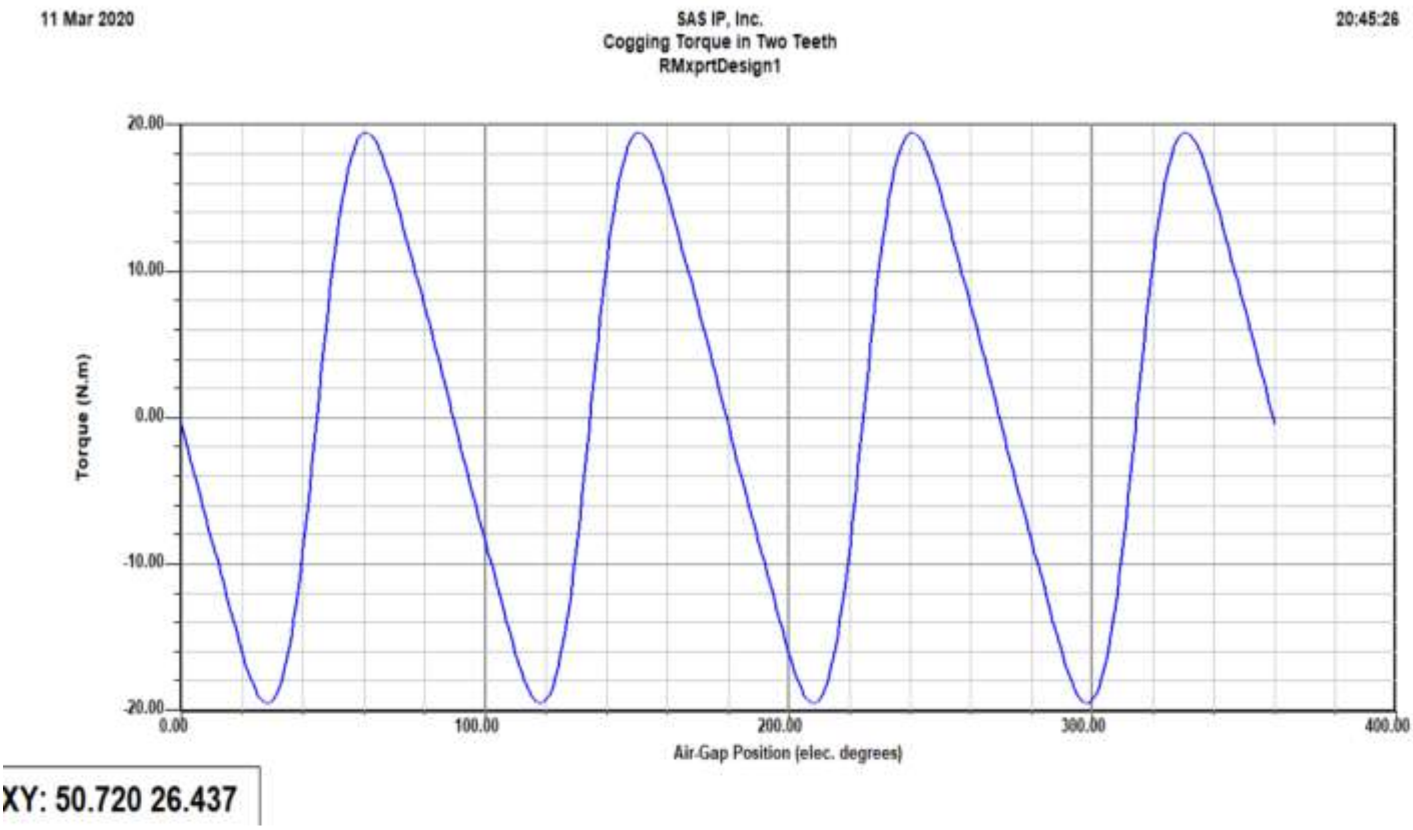


Figure 5.6: Cogging Torque in Two Teeth

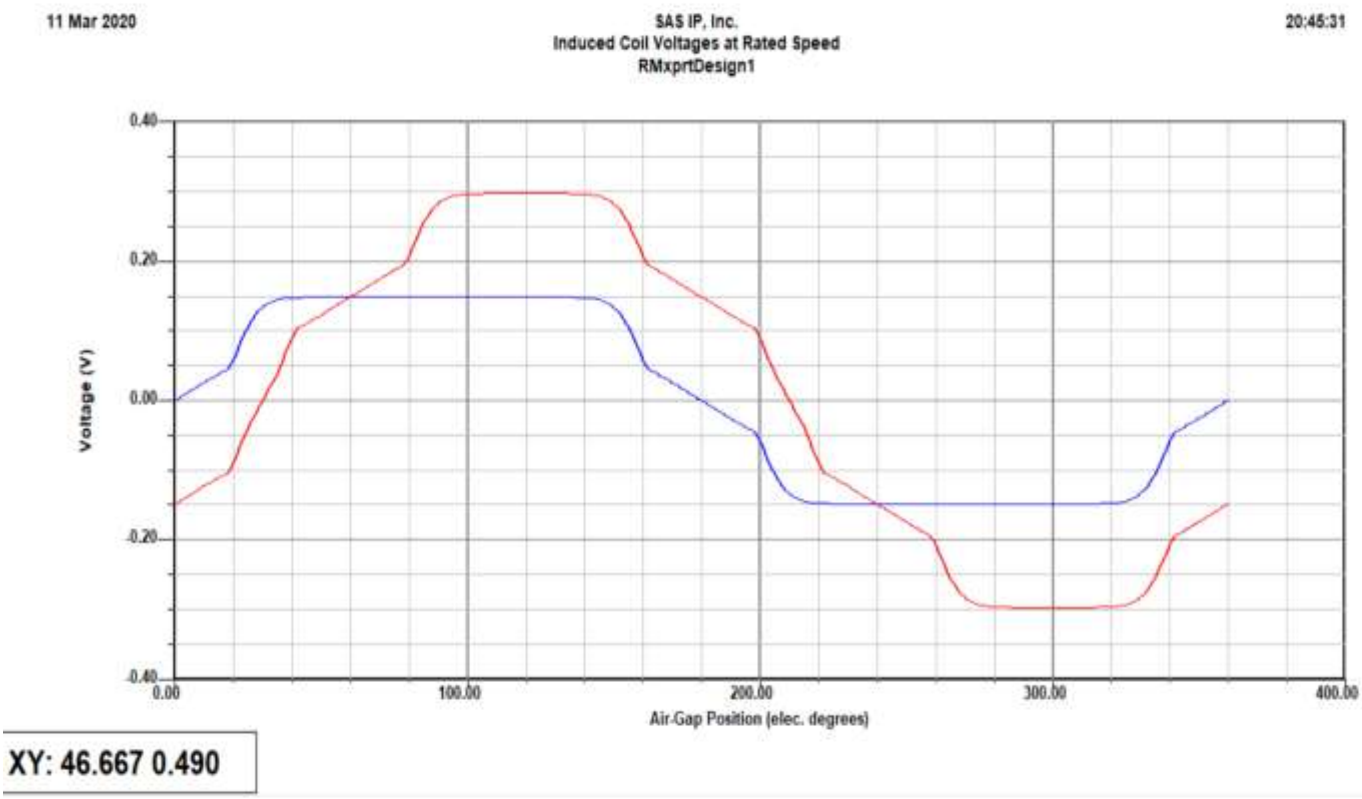


Figure 5.7: Induced Coil Voltages at Rated Speed

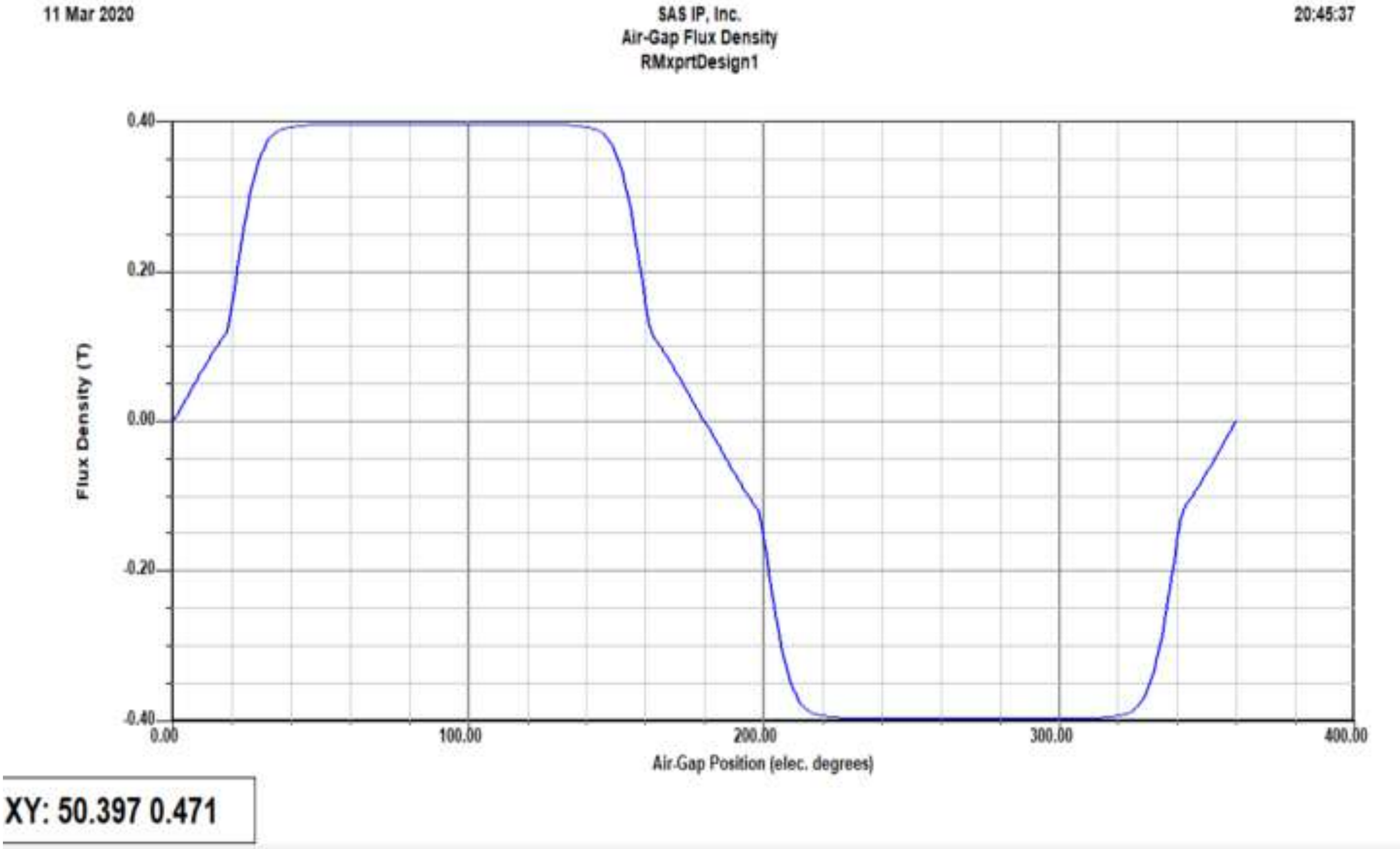


Figure 5.8: Air-Gap Flux Density

Figure 5.9: Induced winding voltages at Rated speed

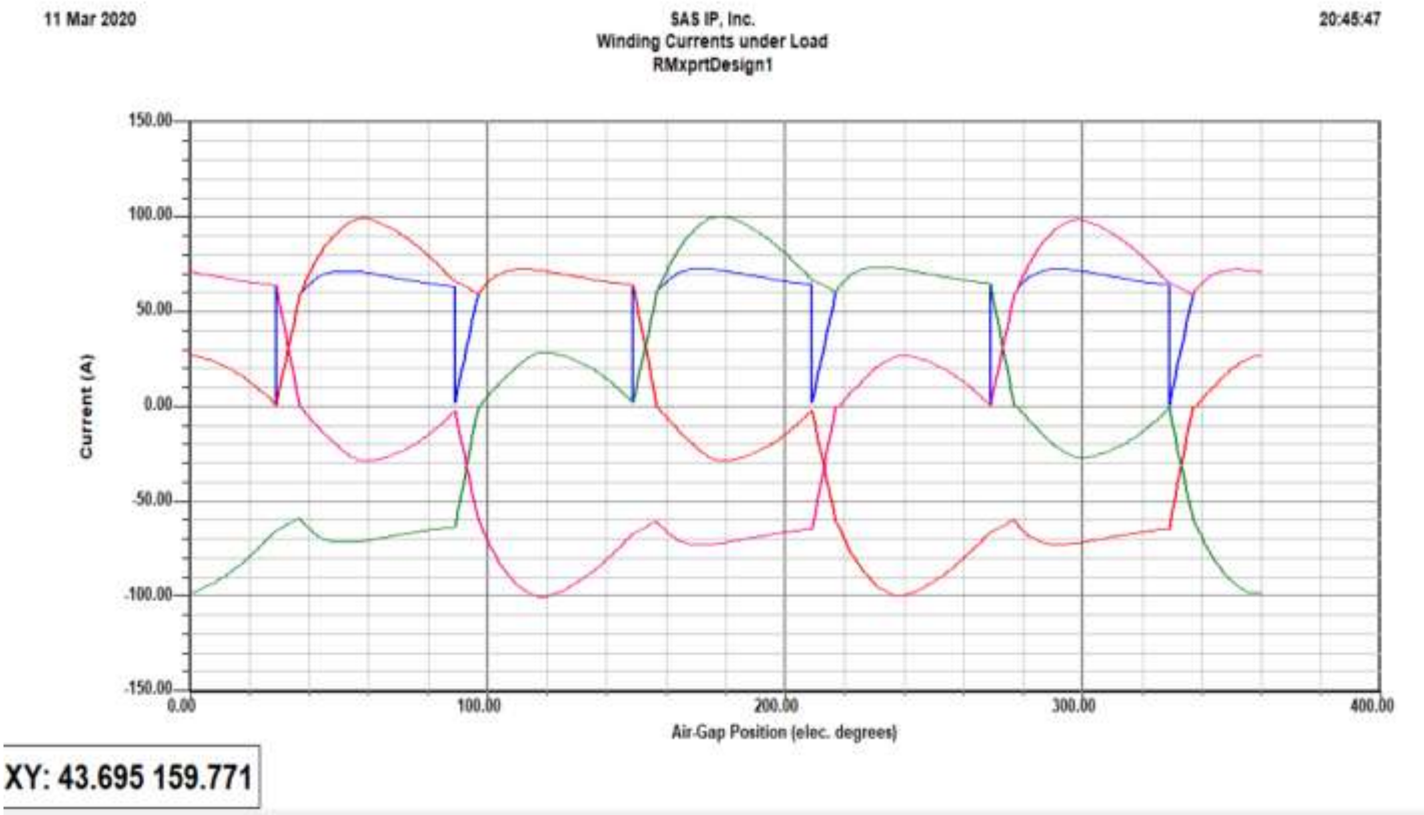


Figure 5.10: Winding Currents under Load

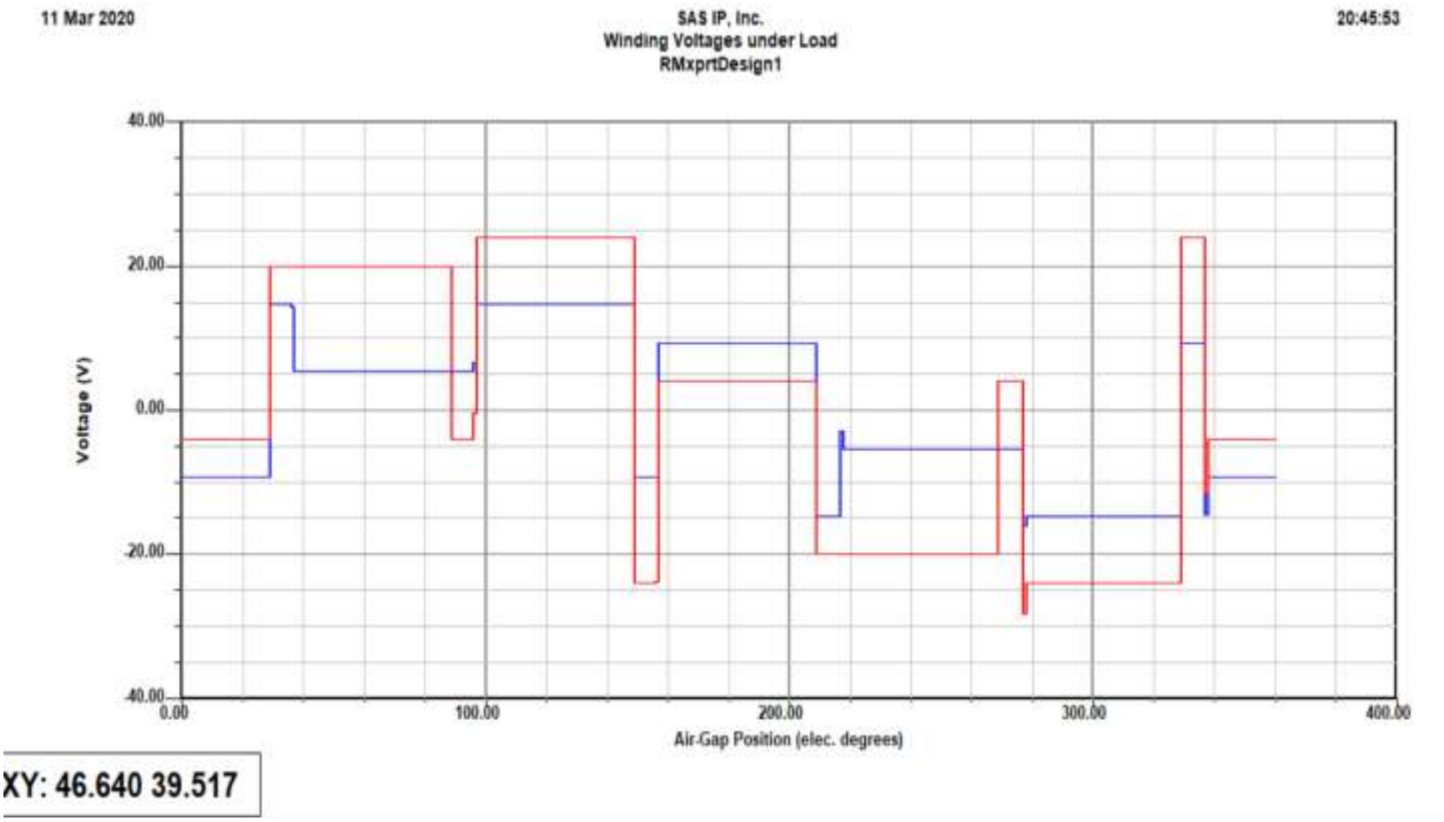


Figure 5.11: Windings Voltages under Load

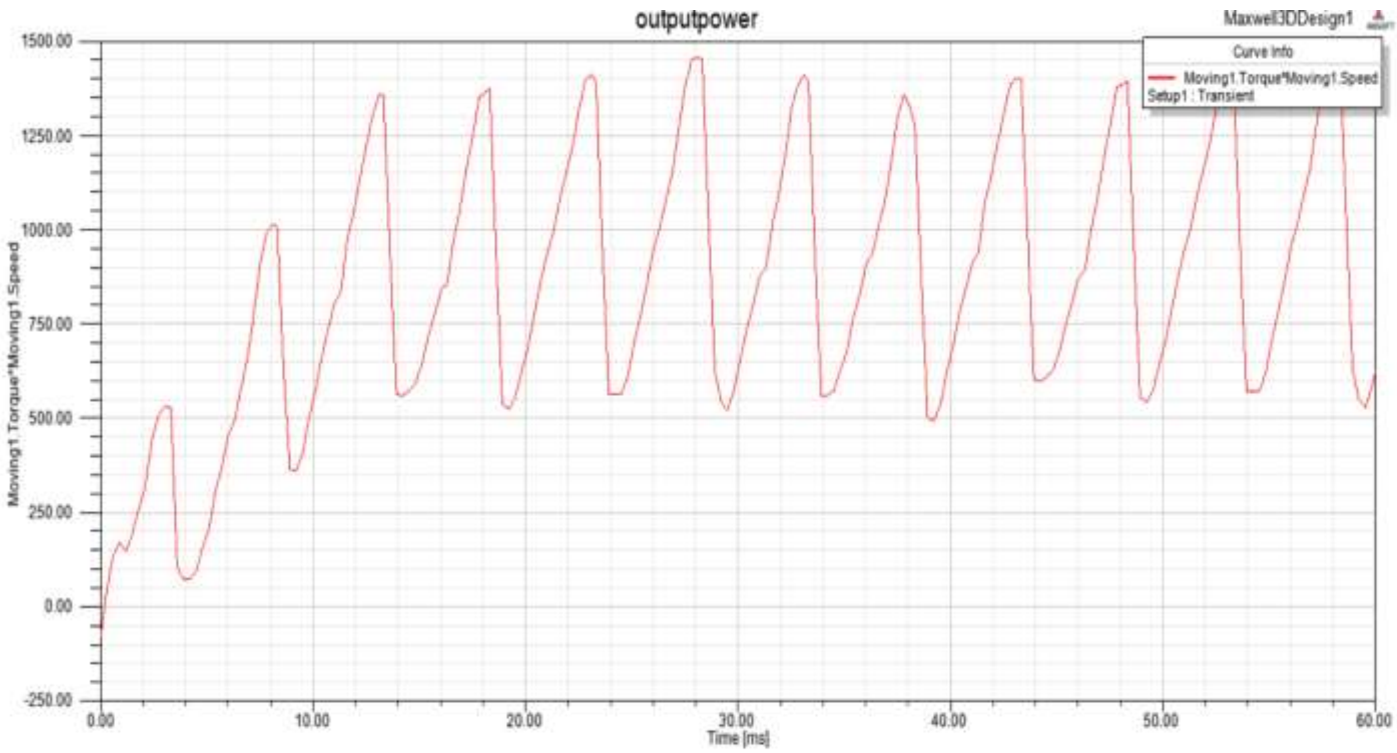


Figure 5.12: Output power of the PMSG

6. CONCLUSION

This paper completely describes about the energy generation and the analysis of Permanent magnet synchronous generator based on horizontal axis wind turbine. Design of permanent magnet synchronous generator and the analytical performance result has been validated using ANSYS MAXWELL software. We can conclude that the chosen PMSG has several advantages like low maintenance, high efficiency compared with any other type of generators.

7. REFERENCES

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8. BIOGRAPHIES

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