VOL. 11, NO. 22, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FINITE ELEMENT MODELING OF A 1000 WATT WIND GENERATOR USING ANSYS MAXWELL

Zaiazmin Y. N., K. A. Ismail, M. S. Abdul Manan and Atikah Haji Awang
School of Manufacturing Engineering, Universiti Malaysia Perlis, Arau, Perlis, Malaysia
E-Mail: zaiazmin@unimap.edu.my

ABSTRACT

Harvesting the wind energy has existed since ancient civilization such as sailing ships. Nowadays, wind energy is harvested to generate an electrical energy using a wind generator. In order to ensure safety and durability of the wind generator, the performance and the characteristic of the generator needs to be investigated. Unfortunately, the purchased wind generator does not come with a detail drawing and electrical properties that are required for modeling purposes in the Finite Element Analysis (FEA) software. An image processing techniques is proposed to acquire the dimension of the generator internal parts. In order to generate a quality mesh, an adaptive meshing technique is used in the magnetostatic solver before it is imported into the transient solver in Ansys Maxwell. The proposed method to acquire the dimension produces error approximately 5 percent. Furthermore, using adaptive meshing technique proposed in this study, simulation results are in good agreement with experimental results with approximately 3 percent of error.

Keywords: wind generator, electromagnetic modeling, finite element analysis.

INTRODUCTION

Wind can be defined as a natural motion of an atmospheric air due to the temperature differences at the earth's surface. Wind is an abundant renewable energy. Harvesting the wind energy has existed since ancient civilization such as sailing ships. Nowadays, wind energy is harvest to generate an electrical energy using a wind generator. Electrical energy is used to power most of the electrical equipments and can be considered as the most important source of energy in the modern era.

Before installing a new wind generator, it is important to investigate the performance and the characteristic of the generator. This is to ensure the safety and the durability of the generator and able to design the support system for the generator such as a charging controller and the energy storage system efficiently.

Normally wind generator is bought without the detail drawing or its electrical schematic. So, modeling the generator in the Finite Element Analysis (FEA) is quite challenging without the accurate dimensioning. Another issue in the FEA modeling is the mesh quality. Few elements would produce inaccurate results on the other hand; too many elements required large computer memory and consumed a lot of computation time. Meshing quality does not always proportional to the meshing quantity. A good meshing technique is to create a smaller elements at the crucial area and bigger elements at less critical or crucial area.

Thus, this paper proposes a method to acquire an accurate dimensioning of the generator internal parts and to generate a quality mesh that produces a reliable simulation results.

MODELING METHODS

In general, analysis for a wind generator can be divided into two basic methods. The first method is the analytical lumped parameter technique and the other is the FEA via numerical methods. The analytical approach has an advantage for being the fastest method to characterize the generator. However, the method has the tendency to oversimplify the geometry in order to come out with an equivalent circuit (Lim *et al*., 2008).

Whereas the main strength of the second method that is the FEA, it can be used to model almost any geometry and able to predict the characteristic of a wind generator with high degree of accuracy. However, the FEA modeling method is very demanding in terms of model setup, computer memory and computational time (Connor, Pickering, Gerada, Eastwick, & Micallef, 2012).

Lumped parameter modeling method

In the lumped parameter modelling method, the generator is divided into a number of lumped components and each lumped component is represented by a collection of impedances and capacitances. Most of the structural parts in the generator namely the stator yoke, stator teeth, permanent magnets as well as rotor iron are presented by the simplified T-equivalent circuit and the equations used can be found in (Rostami, Feyzi, Pyrhonen, Parviainen, & Niemela, 2013) and (Nerg & Ruuskanen, 2013).

Finite element analysis (FEA)

In the FEA, the characteristic of the wind generator can be calculated by means of numerical methods. FEA is widely used in the industry to analyze mechanical, electrical and magnetic characteristic of electrical machinery especially in the final design stage. FEA allows the designer to predict the temperature distribution inside the generator, voltage and current output and also losses in details. Furthermore, it is paramount to validate the FEA models with the results obtained from the experiments to determine the compatibility of the mesh quality, solver equations, turbulence models and boundary conditions of the FEA models (Chin Hong, 2010).

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Discretization methods

In the FEA, there are several discretization methods used to divide the geometry into cells and nodes. These cells and nodes form a grid used by the FEA software to generate a set of algebraic equations. There are various well established discretization methods used in FEA such as Finite Difference Method (FDM), Finite Element Method (FEM) and Finite Volume Method (FVM). Apparently papers that discussing on the mesh quality used in the Ansys Maxwell software until now is not available in the literature.

EXPERIMENT APARATUS

For this study, a 3-phase 1kW synchronous permanent magnet wind generator with a 48V/50Hz output voltage was used. This wind generator was chosen because of its weight that is 30 percent less compared to those conventional wind generators with the same power rating. The weight of this wind generator is estimated around 16 kg. Figure-1 below shows the wind generator used in this study.

Figure-1. 1kW permanent magnet wind generator.

Unfortunately, the purchased wind generator does not come with a detail drawing and electrical properties that required for modeling process in the FEA software. From the complexity and the compactness of the wind generator, it is very hard to conduct a precise measuring for all the components used. Measuring tools cannot be placed inside the wind generator due to small gaps thus unable to get an accurate dimension. It requires that the generator to be dismantled in order to measure the dimensions of the components. Dismantle and reassemble are quite a challenge and problematic process that may cause a short circuit in returned.

In order to solve the dimensioning issue, this paper proposes a technique to obtain the dimension without dismantling the wind generator. First, a high resolution photo of the internal wind generator is captured. Then, the captured picture is imported into CAD software. For this study Catia CAD software was used. Figure-2 shows the imported picture inside the Catia sketch environment.

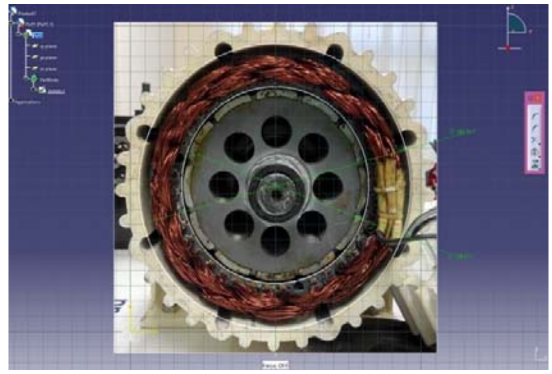

Figure-2. Wind generator picture in Catia environment.

The next step is to trace the edges of all the components using drawing tools such as line, circle and rectangle. Once the tracing process is completed, the dimension such as diameter is compared to the actual diameter measured by a digital vernier caliper in order to calculate the ratio between both measurements. Table-1 shows the comparison between two points of measurements using CAD and the actual dimension.

Table-1. Comparison between CAD and actual dimension.

Component	Stator diameter	Casing thickness
CAD (Catia)	153.838 mm	7.815 mm
Actual	163.7 mm	8.2 mm
Ratio	0.93976	0.95305

Then, the average ratio of 0.94641 is calculated and the value is used to scale the drawing in the Catia. The scale value is calculated by inverting the value of the ratio since the CAD dimension is less than the actual value. The scale used is 1.05662 for this study. For validation, a hole at rotor is measured using digital vernier caliper and compared to the CAD that has been scaled. Table-2 below shows the compared results and the percentage of error.

Table-2. Validation of the method.

Component	Rotor hole
CAD (Catia)	18.55 mm
Actual	19.6 mm
% Error	5.36 %

SIMULATION IN ANSYS MAXWELL

All dimensions that have been acquired were input into Ansys Maxwell. Table-3 shows the dimension used to model the rotor and the magnets.

VOL. 11, NO. 22, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-3. Rotor / magnet dimension (PM core).

Name	Dimension (mm)
DiaGap	109.5
DiaYoke	33.8
Length	62.6
Poles	12
Pole Type	2
Embrace	0.835
ThickMag	4.1
WidthMag	45
Offset	20
Bridge	2
Rib	3
LenRegion	200
Info Core	0 (rotor) ,1 (magnet)

Table-4 shows the dimension used to model the stator whereas Table-5 shows the dimension used to model the coils respectively.

Table-4. Stator dimension (Slot core).

Name	Dimension (mm)
DiaGap	113
DiaYoke	163.7
Length	62.6
Skew	0
Slots	36
Slot Type	3
Hs0	0.41
Hs01	0
Hs1	1.373
Hs2	3.106
Bs0	2.051
Bs1	5.561
Bs2	5.561
Rs	1.3
Fillet Type	0
HalfSlot	0
SegAngle	15
LenRegion	200
InfoCore	0

Table-5. Coil dimension (Lap core).

Name	Dimension (mm)
Layers	2
Coil pitch	3
End ext	12.5
BendAngle	0
SegAngle	0
LenRegion	200
Info coil	0
No. of Conductors	23 turns

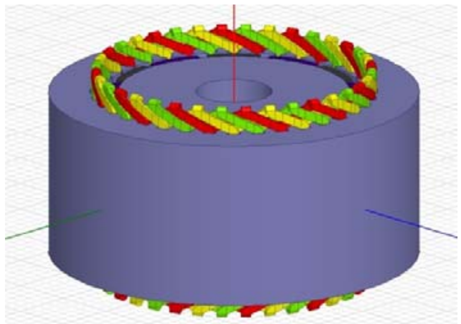

Figure-3. Wind generator model in maxwell.

Figure-3 shows the wind generator model in the Ansys Maxwell electromagnetic simulation software. Ansys Maxwell has several solvers used to solve transient, eddy current and magnetostatic problems. To characterize the wind generator over a time, the transient solver is chosen. Before starting the simulation, the geometry needs to be meshed. Transient solver has its own meshing engine that can automatically mesh the geometry once the simulation is started. It also has mesh refiner options built in to the transient solver.

In order to generate a quality mesh, the model needs to be meshed under the magnetostatic solver environment where it has the adaptive meshing capability. The adaptive meshing engine will calculate the energy error percentage and if the error is more than 1 percent, it will refine the mesh 30 percent more at the critical area automatically. Table-7 below shows the mesh quantity for automatic mesh in transient solver and adaptive mesh in the magnetostatic solver.

Table-6. Meshing.

	Auto	Pass #2	Pass #3	Pass #4
Elements	279659	363563	472639	614437
Time	2h50m	5h4m	8h14m	12h31m
Total Energy (J)	13.951	15.41	15.633	15.693
Energy Error %	7.5402	3.1629	1.581	0.95952

VOL. 11, NO. 22, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

From the table above, it is clear that once the number of elements increased, the time consumed to

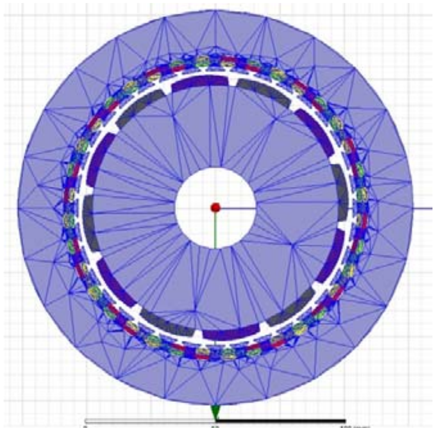

Figure-4. Automatic meshing.

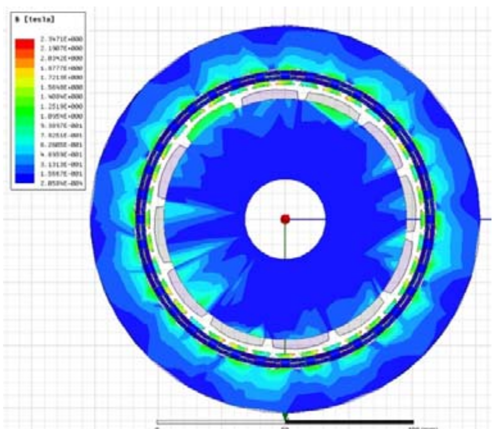

Figure-5. Magnetic flux for automatic meshing.

simulate a 300ms with a time step of 2ms increased drastically. Once the target energy error is achieved, the mesh generated in magnetostatic solver can be transferred to the transient solver for analysis. For the auto meshing method generated by the transient solver, it takes approximately 2 hours and 50 minutes to complete whereas using adaptive meshing pass #4, it took almost 12 hours and 30 minutes to complete. The simulation is run on a Z400 workstation with a memory of 24GB memory using a quad cores Xeon processor.

Figure-4 shows the mesh distribution for automatic meshing under the transient solver. It is very clear that the mesh is coarse at all parts of the geometry. There is no region where dense mesh is located. Figure-5 shows the magnetic flux distribution for automatic meshing under the transient solver. The value of maximum flux is 2.3471 tesla. The distribution of the magnetic flux is not even neither at rotor nor at stator. This may lead to inaccurate results.

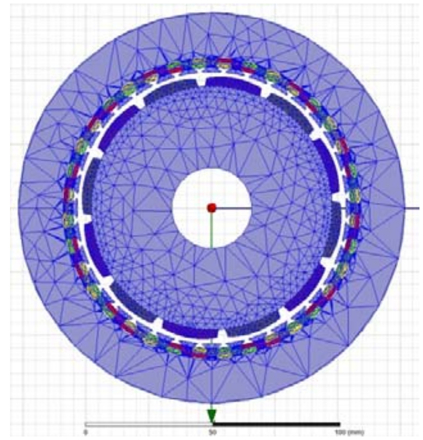

Figure-6. Adaptive meshing pass #4.

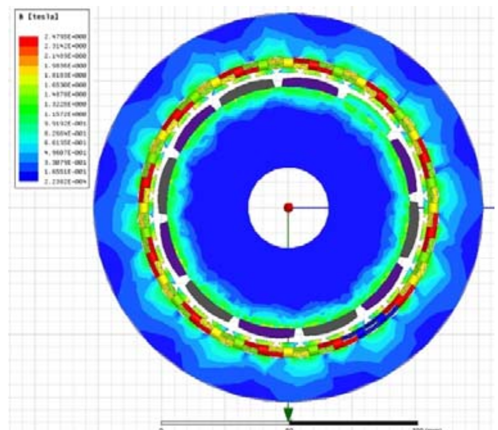

Figure-7. Magnetic flux for adaptive meshing pass #4.

Figure-6 shows the mesh distribution for adaptive meshing pass #4. Here, it is clear that the mesh is dense at the magnet, the coils and at the rotor compared to the automatic meshing. Figure-7 shows the magnetic flux distribution for the adaptive meshing pass #4. Here the magnetic field is better distributed around the magnet, the coils and the stator. The value of the maximum flux is 2.4795 tesla, which is 5.3 percent higher compared to the automatic meshing method.

EXPERIMENTAL RESULTS

To validate the simulation results, an experiment was conducted. The wind generator was set at 129 RPM rotation speed with the internal resistance was around 1 ohm. The wind generator was operating under load using 3.9 ohms resistive wire. A NI-USB DAQ card was used to capture the voltage profile.

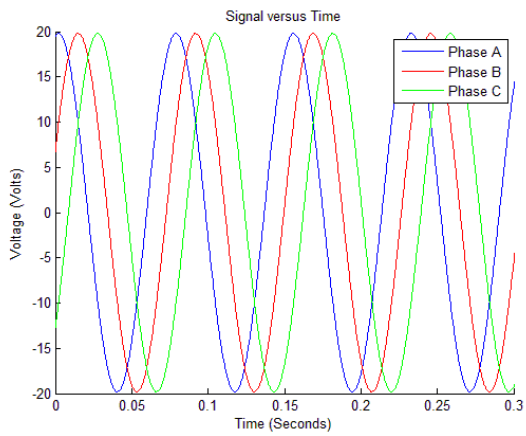

Figure-8. AC voltage wave form.

Figure-8 shows the AC voltage sine-wave that was captured by the NI-DAQ card. The raw data was filtered using low pass filter to remove the noise. Table-8 shows the experiment results extracted from Figure-8. Whereas Figure-9 shows the Induced AC voltage results from the Ansys Maxwell simulation.

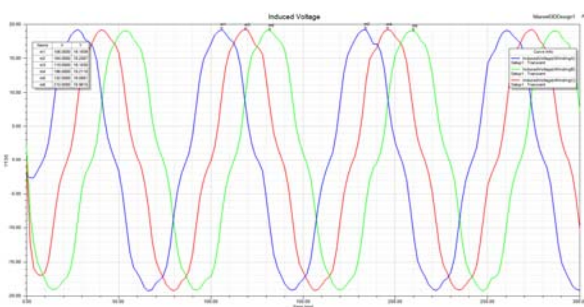

Figure-9. Induced voltage result from simulation.

Table-7. Experimental results at 129RPM.

Name	Unit
V_pAC	19.8 volt
Freq	13.0 Hz

Table-8. Validation.

	Auto	Pass #2	Pass #3	Pass #4
V_pAC	17.4	18.5	19.1	19.2
% Error	12.12	6.57	3.54	3.03

Table-9 shows the simulation voltage for automatic meshing and adaptive meshing. The percentage of error is calculated by comparing the experimental results and the simulation results. It is found that for the automatic meshing, the percentage of error is around 12 percent whereas by using the adaptive meshing, the percentage of error drops to around 3 percent.

CONCLUSIONS

From the results in this study, it shows that the image processing technique can be used to acquire dimension of wind generator parts with the percentage of error is approximately 5 percent. Furthermore, by using the adaptive meshing method in the magnetostatic solver, the transient results can be improved with the percentage of error is approximately 3 percent compared to the experimental values.

FUTURE WORKS

Once the simulation model is validated, then the data from the electromagnetic analysis can be transferred to Ansys Fluent for furthered study on the heat generation issue whether a cooling method is required to prevent an overheating that may lead to short-circuit.

ACKNOWLEDGEMENT

The authors would like to thank School of Electrical Engineering at UTHM for the Ansys Maxwell software for the execution of above work. Authors are also would like to thank the Ministry of Higher Education (MOHE) Malaysia for providing us a research grant for conducting this study. The grant number is MTUN-COE 9016-00011.

REFERENCES

Chin Hong, L. 2010. Thermal Modelling of the Ventilation and Cooling inside Axial Flux Permanent Magnet Generators. (Doctor of Philosophy), Durham University. Retrieved from http://etheses.dur.ac.uk/387/.

Connor, P. H., Pickering, S. J., Gerada, C., Eastwick, C. N., & Micallef, C. 2012, 27-29 March 2012. CFD modelling of an entire synchronous generator for improved thermal management. Paper presented at the Power Electronics, Machines and Drives (PEMD 2012), 6th IET International Conference on.

Lim, C. H., Bumby, J. R., Dominy, R. G., Ingram, G. I., Mahkamov, K., Brown, N. L., . . . Shanel, M. 2008, 6-9 Sept. 2008. 2-D lumped-parameter thermal modelling of axial flux permanent magnet generators. Paper presented at the Electrical Machines, 2008. ICEM 2008. 18th International Conference on.

Nerg, J. and Ruuskanen, V. 2013. Lumped-parameter-based thermal analysis of a doubly radial forced-air-cooled direct-driven permanent magnet wind generator. Mathematics and Computers in Simulation, 90(0), 218-229. doi: http://dx.doi.org/10.1016/j.matcom.2012.08.009.

Rostami, N., Feyzi, M. R., Pyrhonen, J., Parviainen, A., & Niemela, M. 2013. Lumped-Parameter Thermal Model for Axial Flux Permanent Magnet Machines. Magnetics, IEEE Transactions on, 49(3), 1178-1184. doi: 10.1109/TMAG.2012.2210051.